Labor market informality, risk, and insurance*

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Abstract

In labor markets with substantial informality, distinct working arrangements offer different prospects for workers. Formal employment provides insurance programs requiring social security contributions and taxes. Informal and self-employment lack public insurance to mitigate risk but offer valuable routes out of unemployment. Workers face complex tradeoffs involving present and future risks, the ability to insure them, liquidity, and earnings. To investigate this question, I develop a life-cycle model of employment type and savings in a frictional search environment. I estimate the model using linked longitudinal survey and administrative Chilean data, exploiting policy reforms. The estimates suggest that formal sector insurance is valued; informal workers would be willing to forgo earnings to be formal employees. Informal opportunities also provide substantial insurance against unemployment risk. Exploring counterfactual policies, I show how the insurance values can be interpreted as summary measures of the attractiveness of these sectors given the policy and labor market environment.

Keywords: Labor market informality, unemployment insurance, social security

1 Introduction

The International Labor Organization estimates that around 58% of global employment is informal.[1] Informal workers do not comply with labor market regulations and do not directly contribute to social security. Consequently, they have limited access to several social insurance programs, including unemployment and pension benefits, leaving them considerably more vulnerable to risk than those formally employed.

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[1]ILO SDG indicator 8.3.1, estimates for 2023 for total employment worldwide.

However, if individuals can more easily find informal jobs or engage in informal activities, the need for formal insurance may be reduced (Gerard and Gonzaga, 2021). The relationship between informality, risk, and insurance is thus multifaceted and difficult to analyze.

This paper studies how labor market conditions, social insurance policies, and worker characteristics shape individual savings and employment decisions. I focus on how different contractual employment arrangements are connected with differential risk exposure and disparate access to insurance. This enables a deeper understanding of the distribution of risk and insurance and, importantly, the value that each employment type brings. For instance, it allows me to quantify how much individuals value the stability and insurance associated with formal employment and how valuable informal opportunities are.

These questions are fundamental to guide policy design regarding labor market and social insurance policies. Particularly, as the presence of a large informal sector not only alters but may also amplify tradeoffs in social insurance design. The option of working informally provides individuals with an additional margin of adjustment, potentially exacerbating the moral hazard associated with insurance mechanisms. For example, as the government cannot monitor the informal sector, individuals may receive benefits and informal earnings, prolonging their time away from formal employment (Gonzalez-Rozada and Ruffo, 2016, Gerard and Gonzaga, 2021). Similar tradeoffs are evident over a longer horizon as well. Generous pension systems may offer high benefits, even for individuals with few contributions. This provides insurance to those with weaker labor histories. At the same time, this may reduce the incentives for individuals to contribute to pensions. Therefore, designing a social insurance system that balances insurance and incentives in the presence of informality is particularly challenging.

To address these questions, I develop and estimate a life-cycle model where risk-averse agents decide on savings and employment in a frictional environment. Workers are exposed to unemployment risk and search frictions, leading to uncertainty regarding both the timing and wages of formal and informal job offers. Individuals can also engage in self-employment activities after making partly irreversible up-front investments. Self-employment offers amenities and more flexible hours but comes with riskier earnings. Longevity risk makes individuals uncertain about how long they will

need to finance consumption. These risks are quantitatively important and connected to their labor market choices.

Agents have two means of insuring against these shocks. First, they can accumulate savings and use it as a self-insuring mechanism. This is important as agents face borrowing constraints. Second, the government offers social insurance through welfare transfers, unemployment insurance, and pension benefits. Formal workers gain full access to these programs by paying social security contributions. Informal employees and self-employed individuals can not be monitored by the government. They do not pay taxes or contribute to pensions but have minimal access to social insurance through non-contributory minimum welfare transfers and minimum pension guarantees. Retirement is an endogenous choice, capturing all incentives from the pension design. All decisions (consumption, savings, sector of employment, and retirement) depend on individuals' current status, including age, unemployment insurance eligibility, and, importantly, savings.

The analysis is set around the experience of a Chilean worker. Chile provides an ideal setting for investigating these questions. First, as one of the most developed countries in Latin America, Chile features social insurance programs that co-exist with informality. Around one-third of the labor force is informal. Second, the government has experimented with social insurance programs in the last 20 years, with substantial reforms in unemployment insurance and pensions, providing useful policy variation. Third, rich microdata are available. I can link a longitudinal survey (*"Encuesta de Protección Social"*) with administrative data from the pension system (*"Historial Previsional de Afiliados"*) at the individual level. The merged data results in a long-term panel with demographics, labor market information, disaggregated wealth snapshots, and monthly administrative data on pension contributions and pension wealth. Such comprehensive data is rarely available.

Using these data, I derive empirical findings that guided the model design and estimation. I first show how three broad categories — formal employees, informal employees, and self-employed — have different characteristics, particularly in the age profile, working hours, and workplace. The longitudinal data also sheds light on the transitions to self-employment. The start of self-employment activity is associated with investments in physical capital and self-employed individuals predominantly report their own savings as their primary funding source. I also exploit a pension reform

implemented in 2004, which tightened the requirements for early retirement. To be eligible for early retirement, individuals need their pensions to be above a minimum threshold, which was raised by 40%. I exploit the discontinuous implementation of these changes across time and cohorts to estimate the causal effects of this reform. The reform reduced early retirement by 15 percentage points (pp), a sizable reduction from a baseline retirement probability of 25%. However, it only raised the probability of individuals contributing to pensions by 4–6pp. This discrepancy between individuals staying longer in the labor force but not necessarily contributing to pensions highlights the importance of analyzing informality.

I estimate the model primitives using the microdata and exploiting the pension reforms in a two-stage method of simulated moments. The model replicates key characteristics of the labor market and savings behavior. Particularly, it closely matches the labor market patterns over the life cycle: the hump-shaped profile for the formal sector, the declining participation of informal employees, and the increasing participation in self-employment. The model has novel mechanisms to account for these patterns. First, it allows the job search behavior to be contingent on savings levels. Agents with fewer assets are more likely to accept low-wage offers, particularly from the informal sector, where offer arrival rates are higher. Thus, the model also accounts for the observed cross-sectional correlation of wealth and informality, not exclusively through ex-post lower earnings in this sector. Other important mechanisms in the model are those related to self-employment. The irreversible up-front investments in the presence of borrowing constraints and the amenities offered by this sector are important in explaining the age profile of self-employment.

The richness of the model allows for a complete analysis regarding job search, savings, and insurance. The difference between reservation wages for those receiving or not unemployment insurance is larger as the individuals have fewer resources. This illustrates the insurance value of UI, enabling individuals to reject low-wage offers, even if they have fewer assets. Due to the inability of the government to monitor the informal sectors, individuals can accumulate UI benefits and informal earnings. Therefore, reservation wages are lower for informal opportunities when compared with the full-monitoring case. These results illustrate the insurance offered by UI, how it differs by wealth level, and the moral hazard forces.

Formal jobs are often assumed to be more valuable than informal jobs. They

are more stable and are associated with many benefits. However, it is often difficult to quantify this difference. Much of the existing literature relies solely on observed wage differentials, missing the utility gains and losses associated with differential risk exposure and insurance access. Moreover, it limits the discussion on the design of public policy, for instance, regarding the moral hazard components. I use the estimated model to compute the overall willingness to pay (WTP) for formalization that quantifies all such benefits. On average, an informal employee would forgo 18.7% of their earnings to have their job "formalized". This already takes into account that formal employees pay taxes and social security contributions and are subject to the minimum wage.[2] The framework is also useful in decomposing this WTP into a fraction attributable to the better stability and search prospects of formal jobs and access to all insurance programs associated with formal employment. The results indicate that around 62% is linked to higher stability and better job search prospects and the remaining 38% to the insurance package. The WTP is highly heterogeneous. It is notably higher for individuals with fewer assets for whom the benefits of a formal job are even more valuable. Self-employed individuals have similar WTP for the insurance component but lower overall WTP, partially attributable to the different characteristics of self-employment activity.

The estimated arrival rates confirm that informal opportunities arrive at faster rates. I use the model to compute how individuals value these opportunities by calculating the welfare losses associated with shutting down access to informal jobs. Losing access to informal employment is very costly. On average, welfare falls by 5.3%. This is much higher for individuals born with no assets and for young individuals, highlighting the insurance role of the informal sector. Informal opportunities are valuable as they can be a faster route out of unemployment, particularly when staying unemployed is costly.

These two measures, the WTP for formalization and the welfare loss (WL) for losing access to the informal sectors, can be interpreted as summary measures of the attractiveness of these sectors. Through counterfactual exercises, I show how these measures respond to changes in the policy and labor market environment and are intrinsically associated with individual labor market responses.

[2]The minimum wage mechanically reduces the overall WTP. Workers cannot accept formal wages below the statutory minimum. Therefore, even if an individual would accept a lower formal wage, resulting in a high WTP, they are constrained to accept at least the minimum wage.

The first counterfactual exercise decomposes the effects of the pension reform implemented in 2008. The reform introduced a bonus to the final pension benefits and raised the early retirement restrictions. The bonus was a decreasing function of individual pension benefits with a priori undefined effects on labor market participation. I show how the bonus did not disincentivize formal employment, with no change in the employment distribution. When we take the changes in early retirement into account, workers delay retirement and the proportion of individuals in the formal sector increases. This result highlights how the government can use different aspects of the pension system to achieve the desired results. It also reinforces the finding from the 2004 reform that early retirement policies are important and may exhibit large effects. As there are no changes in the incentives pre-retirement, we observe no changes in either the WTP or the WL.

The Chilean government recently started to debate new changes to the pension system, particularly increasing the minimum pension floor. I simulate individual responses to a reform that doubles the minimum pension and increases the pension contribution rates from 10% to 16.5%.[3] The model predicts significant disincentive effects for formal employment, which falls 10.8%. The computed WTP falls and the WL rises. WTP decreases because the value of a formal job is reduced. Individuals can access higher benefits regardless of their pension contribution history. This is the same force that leads to increased welfare losses associated with losing access to the informal sector and self-employment. Informal opportunities are even more valuable under the new regime.

Lastly, as job search features a prominent role in the analysis and discussion of informality, I simulate a counterfactual policy that increases the arrival rate of formal jobs for unemployed individuals by 25%. Such a policy would effectively re-direct workers from informal and self-employment to the formal sector, increasing the overall proportion of formal workers by 6.7%. This exercise shows how the two summary measures, WTP and WL, can also move in the same direction. With this counterfactual, both WTP and WL decrease. As unemployed individuals are more likely to find jobs, the value of a formal job decreases. This is because the associated protection through unemployment insurance becomes less necessary. At the same time, WL decreases because the insurance of a faster route for the unemployed becomes less

[3] As this was one of the first proposals.

valuable.

In summary, through both the reduced-form analysis of the pension reform and the model-based counterfactual simulations, I show how social security and insurance affect employment decisions. Savings have an essential role. It affects the formal and informal job acceptance rates and can be used to invest in physical capital for self-employment activities. Formal jobs are valuable, as they are more stable, have better job prospects, and are connected with several insurance programs. Conversely, informal jobs also offer substantial value as informal opportunities are valuable insurance against unemployment risk. Moreover, these insurance values can be interpreted as summary measures of the overall attractiveness of different types of employment, given the policy and labor market environment.

This paper contributes to several strands of the literature. First, there is a large literature studying firms' and workers' formality decisions, mostly using a search framework.[4] Most of this work has focused on the role of firms complying or not with the labor market regulations, with risk-neutral individuals comparing formal and informal offers in terms of earnings and future employment opportunities.[5] This paper includes risk aversion and savings in this search framework with informality. This novel enhancement is important and fruitful. First, it is essential to discuss the role of risk and the value of insurance provided by social security in workers' labor market decisions. Second, it allows the labor market behavior to differ depending on the level of asset accumulation. Third, the endogenous savings decision additionally allows me to consider the physical capital investments made by self-employed individuals. Closer to this paper are Herreño and Ocampo (2023), who study how workers choose between formal jobs and self-employment in Mexico, and Cirelli et al. (2021) and Bloise and Santos (2022), who study the design of unemployment insurance in the presence of informality. My paper mainly differs by introducing the safety net associated with formal employment which comprises the main social insurance programs. This is essential to capture the insurance provided and all the dynamic incentives associated with employment choices. Moreover, this paper also differs by account-

[4]Zenou (2008), Albrecht et al. (2009), Ulyssea (2010), Bosch and Esteban-Pretel (2012), Lopez Garcia (2015), Meghir et al. (2015), Pardo and Ruiz-Tagle (2016), Albertini and Terriau (2019), Narita (2020), Haanwinckel and Soares (2021), Bobba et al. (2021, 2022), da Costa and Lobel (2022), Conti et al. (2023).

[5]The exceptions are Pardo and Ruiz-Tagle (2016), da Costa and Lobel (2022), Conti et al. (2023) where workers are risk-averse.

ing for heterogeneity in the informal sector, differentiating informal employees and self-employed individuals, who differ across many dimensions in the data.

The effects of social security on formality decisions have also been studied in the literature. Several programs have been analyzed, including unemployment insurance and severance payment, health insurance, minimum wage, and pensions.[6] I make two contributions to this literature. First, I estimate the causal effects of strengthening the requirements for early retirement on retirement before the normal retirement age, pension contributions, and employment. I show how the changes reduced early retirement remarkably but did not translate to increased pension contributions of the same magnitude. Second, I develop a life cycle model insurance against shocks, both in the short and long run. I show the importance of considering how formal employment grants access to a bundle of social insurance programs.

Lastly, my paper relates to the literature on self-employment in developing countries, particularly in the context of urban informality in Latin America. Most informality literature either groups self-employed individuals with informal workers or excludes them from the data. As in Narita (2020), Bobba et al. (2021, 2022), and Moreno (2022), I stress that self-employment (i) is informal and (ii) should be modeled differently from employed individuals working informally for firms. I show that self-employment and informal jobs differ over the life cycle and have different job characteristics, mainly in terms of hours of work and workplace. The richness of my data allows me to present evidence consistent with the pre-requisite of up-front start-up costs for self-employment and significant borrowing constraints. This is important when analyzing transitions to self-employment in developing countries.

2 Institutional Setting and Data

2.1 Social Insurance, Welfare Programs, and Income Tax

Pensions — Since 1980, Chile has had a fully funded individual capitalization system. Individuals contribute monthly to their accounts and choose private funds to

[6] Huneeus et al. (2012), Gonzalez-Rozada and Ruffo (2016), Gerard and Gonzaga (2021), Cirelli et al. (2021), Britto (2022), de Azevedo (2022), Bloise and Santos (2022), Audoly (2024), Calderón-Mejía and Marinescu (2012), Azuara and Marinescu (2013), Granda and Hamann (2015), Parente (2022), Engbom et al. (2022), Todd and Vélez-Grajales (2008), Attanasio et al. (2011), Behrman et al. (2011), Cruces and Bérgolo (2013), Joubert (2015), McKiernan (2021), Joubert and Todd (2022), Moreno (2022), Delalibera et al. (2023).

administer their pension wealth. The funds are illiquid until retirement. The normal retirement age is 60 for women and 65 for men. Formal workers are mandated to contribute 10% of their earnings to the pension system up to a cap.[7] In addition to the 10% pension contribution, workers pay administration fees and contributions towards disability insurance and survival pension, which total, on average, 2.2% of wages.[8]

Upon retirement, individuals can choose from various financial options, including the purchase of annuities, which insure individuals against longevity risk. Initially, individuals who had contributed for over 20 years were entitled to a minimum pension of around 85 thousand Chilean pesos.[9] Those who did not qualify for the minimum pension could receive an assistance pension that was 50% smaller. Retirement before the normal retirement age of 65 was possible if the resulting pension benefit was (a) greater than 110% of the minimum pension and (b) above 50% of the last ten-year average wage.

In 2004, the government strengthened the requirements for early retirement. Early retirement became possible only if the resulting pension was (a) above 150% of the minimum pension and (b) at least 70% of the last ten-year average wage. The formula to compute the average wage was also modified, imposing a cap of at most 16 months of zero earnings to be included in the ten-year window. Individuals who were 55 when the law was signed (born before August 1949) were exempted from the new requirements, which were gradually implemented in the following five years. This variation across cohorts and time will be essential to estimate the effects of this reform.

In 2008, a significant reform changed several features of the pension system. First, it abolished the 20-year requirement, replacing it with two new components. The first is a solidarity pillar, which entitles all citizens 65 or older to a minimum pension regardless of the contribution history. The second is a pension complement, which gives the minimum pension as a bonus withdrawn with an implicit tax rate of 30% (Joubert, 2015). The new minimum pension was set at 62 thousand pesos, around 45% higher than the previous assistance pension. The bonus is entirely offset

[7] Initially, the cap was 60UFs (approximately 2400 dollars), and it has been adjusted annually since 2011.

[8] Average value between 1993 and 2019.

[9] I use real values of Chilean pesos in August 2004. 1,000 pesos $\approx$ 1.50 USD.

for those receiving a pension of 195 thousand pesos, denoted by PMAS (*Pensión Máxima con Aporte Solidario*). The reform further enhanced the early retirement requirements, requiring the resulting pension to be at 80% of the PMAS, 23% higher than the previous requirement. Lastly, the reform made self-employment pension contributions mandatory starting in 2019. Enforcing this rule is challenging because it is difficult for the government to monitor self-employment activity.[10]

Severance Payments and Minimum Wage — All formal workers with tenure above 12 months are entitled to severance payments of one monthly wage for each year of tenure upon a lay-off event. There is a cap of 11 months (Huneeus et al., 2012). The statutory minimum wage is fixed annually by Congress. The value in 2004 was 120 thousand pesos for a 45-hour work week.

Unemployment Insurance — Unemployment insurance was introduced in 2002 as an individual account system. Contributions are mandatory for all formal workers and correspond to 3% of their monthly wages, up to a cap. Employees pay 0.6%, and employers pay the remaining 2.4% (1.6% goes to the employee's account and 0.8% to a solidarity fund). Workers who are laid off and have at least 12 months of contributions are eligible for unemployment insurance. Unemployment benefits are computed with decreasing replacement rates for five months, first using the funds in the individuals' accounts. If necessary, they can be complemented with resources from the solidarity fund. There are limits to accessing the solidarity fund to reduce moral hazard.[11]

Health — Chile has a mixed public and private health system. All workers, including the self-employed, have a mandatory contribution of 7% for health, subject to the same cap as the pension contributions. Retired individuals also contribute. Individuals are automatically affiliated with the public health fund (*Fonasa*) but may opt to transfer to a private provider.

In summary, formal workers pay approximately 20% of their wages in payroll contributions, while employers pay 2.4%.

Welfare Programs and Income Tax — Individuals with formal low-paying jobs and who have dependents with no earnings are entitled to a subsidy (*"Assignación*

[10]The 2008 reform also introduced additional changes for women and mothers. For details, check Joubert and Todd (2022).

[11]In 2009, a reform of the UI system extended access to solidarity funds for temporary workers. For details, please check Huneeus et al. (2012).

Familiar", AF). The benefit amount depends on family structure and earnings. For those not affiliated with the pension system, there is also a welfare program for low-income families (*"Subsidio Único Familiar'*, SUF). Similarly to AF, the benefit amount varies with the number of dependents. Chile has a progressive income tax, with eight brackets and marginal tax rates from 0 to 40%.

2.2 Data

This project uses two main datasets. The first is a longitudinal survey, "*Encuesta de Protección Social*" (EPS). The survey has seven waves between 2002 and 2019 and contains rich information on demographics, earnings, employment, and wealth.[12] Around 35,000 individuals were interviewed in total. Since the second wave, EPS has been nationally representative. All the labor market spells after 1980 were recorded, with information on the contractual relationship, firm size, work hours, occupation, and industry. After 2002, wages are also available for all spells.

Using the administrative dataset, "*Historia Previsional de Afiliados*" (HPA), I can link all surveyed individuals from EPS to the pension administrative data. This provides information on their monthly pension contributions since 1981. All the mandatory and voluntary contributions are recorded. After 2008, the balance in each pension account is also available.

Combining the two datasets yields rich longitudinal data with employment history, detailed pension contributions, and wealth, which are rarely available. I restrict the data to individuals born in 1940–1989. Therefore, individuals were at most 40 years old when the new pension system was introduced, and at least 30 years old when last observed. I restrict to men with at most high school degrees. The focus on men is due to the model limitation of not modeling fertility decisions. As shown by Berniell et al. (2021), women's labor market choices regarding employment type are strongly associated with fertility choices. I focus on individuals with at most high school education since this group has relatively higher levels of informality and for whom the tradeoffs of insurance and risk may be more sound.

To minimize recall bias, I only use labor market information for spells within 24 months of the reporting date. Additionally, to minimize concerns with business cycle fluctuations and changes in the minimum wage, I de-trend all the monetary values.

[12]Part of the 2019 wave interviews were scheduled for 2020 and were affected by the Covid-19 pandemic. I discard all information collected over the phone after the pandemic started.

For most of the analysis, I focus on the period between 2002-2015, corresponding to the time frame after the implementation of UI and before its expansion. The only exceptions are retirement and wealth at old ages, where all the data up to 2019 is necessary. Appendix B details the cleaning procedure and sampling restrictions.

I make use of several additional datasets. I use the National Employment Survey (*Encuesta Nacional del Empleo*) 2013–2018 to compute wages and earnings variability.[13] I use the Survey of Micro-Entrepreneurs (*Encuesta de Microempreendimento*) in 2011 to derive descriptive statistics for self-employed individuals, including capital used in self-employment. To compute the parameters that regulate pension benefits, I use pension requests and offers from SCOMP (*Sistema de Consutlas y Ofertas de Montos de Pensión*). Similarly, I use the sample of workers affiliated with unemployment insurance (*Muestra de Datos de Afiliados al Seguro de Cesantía*) to compute unemployment benefits' parameters. I obtained the mortality rates from the tables computed by the Chilean pension authority (*"Superintendencia de Pensiones"*).

2.3 Definitions: Formality, Informality, and Self-Employment

I use individuals' self-reported information from the main occupation and administrative data to classify their job spells into unemployment, formal job, informal job, or self-employment. If an individual reports being unemployed or self-employed, I classify them as such. If they report to be working for firms, I use the administrative data to classify if they were working formally or informally. Spells in which there were pension contributions for at least 50% of months are classified as formal jobs, and those that do not meet this threshold are informal.[14] I exclude spells where individuals were public employees or employers.

Self-employment is a highly diverse category encompassing several different activities. In my data, the five most typical occupations for self-employed are car, taxi, and van drivers (8.6%), managers of small enterprises in wholesale and retail trade (5.3%), carpenters and joiners (5.2%), field crop and vegetable growers (4.6%), and street and stall vendors (3.9%). More than 2/3 of the self-employed report working in one-employee firms.[15] After 12 months, only 3.4% report being an employer. This

[13] Even though the main dataset (EPS) has wage data, it is reported in spells, with no within-spell wage variation.

[14] I get a very similar classification if I instead used self-reported information on having a signed labor contract.

[15] Using the Survey of Micro-Entrepreneurs, which provides better coverage of self-employed in-

number is not much higher than the transition probability from formally employed individuals transitioning to an employer (1.7%).

About one-quarter of self-employed individuals had any pension contributions over a year. Only one-third are registered with the tax authority, which is the upper bound on formality since being registered does not imply paying taxes regularly or fully. Therefore, I consider self-employment as informal, comprising legal but unregulated activities (Ulyssea, 2010). There are, then, two distinct informal sectors in my analysis: wage earners who work for firms informally (*Informal Workers*) and *Self-Employed*. For the model, I will consider that formal employees pay social security contributions, and all their income is subjected to income tax. In contrast, informal employees and self-employed will be able to hide their labor earnings and, therefore, pay neither social contributions nor income tax.

Table 1 shows some descriptive statistics divided by individual level, labor market level, and wealth information. All monetary values are in real terms, in thousands of Chilean pesos in August of 2004 (1,000 pesos $\approx$ 1.50 USD). There are 6,613 individuals in the final sample. Their monthly pension contributions can be observed since 1981, totaling 2.7 million observations. As I only consider labor market information reported no later than two years, there are 616 thousand monthly observations.

3 Empirical Findings

This section explores three empirical findings that are important to guide the model design and estimation. I start by showing the causal effects of the 2004 pension reform. I then present key features from the three sectors of employment (formal and informal employees and self-employed). I show how they differ in age profile, hours of work, and workplace. The last exercise shows how self-employment activity is associated with investments in physical capital.

3.1 Effects of the 2004 pension reform

In 2004, Chile strengthened the requirements for early retirement. Individuals can retire before the normal retirement age if their resulting pension is above (i) an absolute threshold (A) and (ii) a fraction α of their previous average wages. The threshold and the fraction α were raised. Individuals born before August 19th, 1949, were exempted from the new rules. The new values were gradually implemented fol-

dividuals, this number is much higher: 91%.

Table 1: Descriptive Statistics

Variable	Mean	Median	Min	Max	Nobs
Individual level data					
Number of monthly observations	334.4	354	52	483	6,613
Year of birth	1964	1964	1940	1989	6,613
Labor market level data					
Unemployed	0.075	0	0	1	616,967
Formal Employees	0.433	0	0	1	616,967
Informal (total)	0.335	0	0	1	616,967
Informal Employees	0.132	0	0	1	616,967
Self-Employed	0.203	0	0	1	616,967
Contributing to Pensions	0.435	0	0	1	2,752,546
Hours of work (weekly)	47.5	47	10	90	482,670
Labor earnings (monthly)	172.0	152.3	32.0	419.7	323,086
Wealth data (in thousand pesos)					
Pension Wealth at age 30-35	3,225	2,706	0	13,220	6,799
Pension Wealth at age 50-55	9,853	7,379	0	51,926	12,087
Non-pension Wealth at age 30-35	4,333	687.5	-3,596	58,725	1,562
Non-pension Wealth at age 50-55	12,898	8,165	-1,893	123,868	2,671

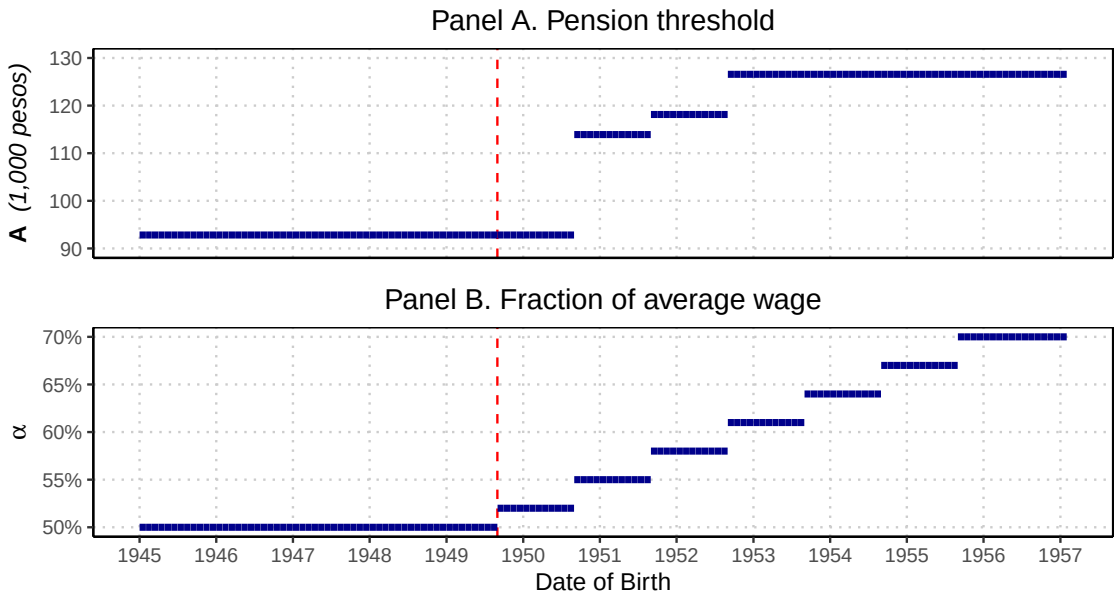
Notes: The monetary values are in thousands of Chilean pesos in 2004, approximately 1.5 US dollars. The columns show, respectively, the mean, median, minimum, maximum, and number of valid observations for each variable. Pension wealth, non-pension wealth, labor earnings, and hours are winsorized at the 1% level. Labor market information is only considered for spells reported within 24 months of reporting.

lowing the reform, making individuals of different cohorts experience different criteria to retire early. Appendix C shows the exact dates for each requirement.

Figure 1 below presents the two eligibility criteria for individuals to retire at age 55 if they were born between 1945 and 1957. The top panel shows the absolute threshold (A) and the bottom panel the required fraction of the average wage (α). Due to the gradual increase in requirements, individuals born right after August 1949 do not experience very different requirements.[16]

[16]Figure A.1 shows the proportion of retired individuals at 55 by quarter of birth. From the figure, it is clear that the proportion retired closely follows the increases in early retirement requirements.

Figure 1: Criteria for early retirement at age 55

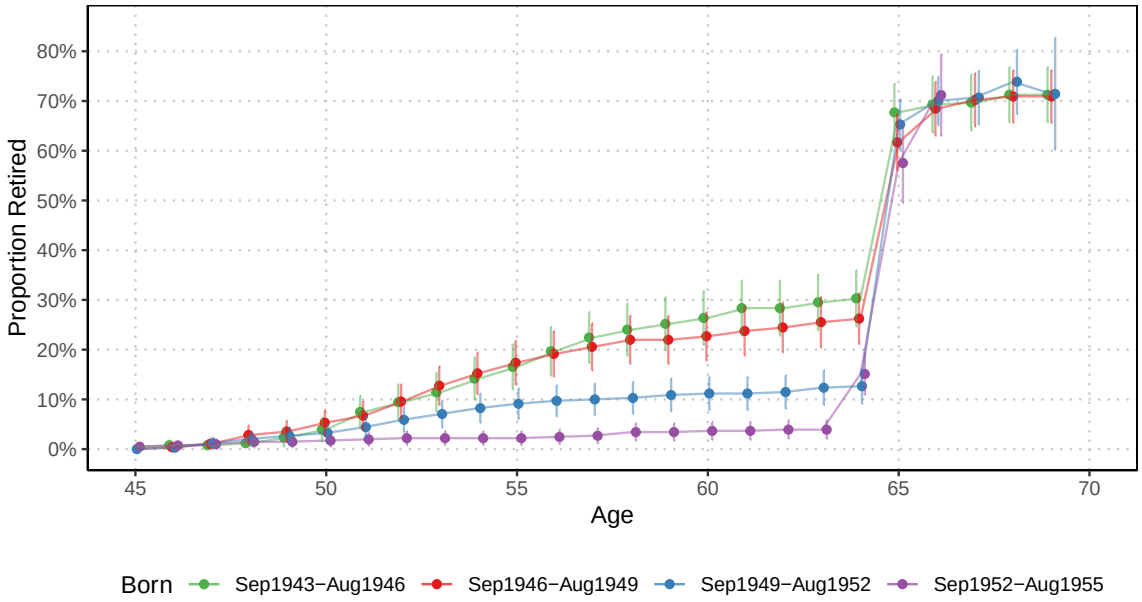


Notes: The figure shows the requirements for early retirement based on the month of birth. The top panel shows the pension threshold A measured in thousand pesos, and the bottom panel the fraction α of the average wage. Both requirements are for individuals at age 55.

Figure 2 shows the proportion of individuals retired by age and cohorts. To enhance precision, I group individuals born in intervals of 3 years, respecting the pension reform threshold in August 1949. Comparing the 1946–1949 (red) cohort with the following cohort born in 1949–1952 (blue), we can see the large effects of the reform. The retirement gap between ages 55 and 64 is 8–15pp. The figure also exhibits the cohort 1952–1955 (purple) that experienced more stringent requirements and presents larger gaps compared to the 1946–1949 cohort. The figure additionally includes the unaffected cohort born in 1943-1946 (green). We can see that they follow similar trends as the 1946–1949 cohort. The minor observed differences starting at age 57–58 could be driven by the subsequent 2008 reform, which also affected early retirement requirements. Reassuringly, as this reform only affects early retirement requirements, there are no differences after the normal retirement age (65).

I summarize these results in a regression comparing individuals born three years before the threshold established by the reform, between September 1946 and August 1949 (control), with those born in the following three years (treated). For those

Figure 2: Proportion retired by age and cohort



Notes: The figure shows the proportion of individuals retired for each age between 45 and 70. Each dot corresponds to the proportion of retired individuals for a given age and from a given cohort. The 95% confidence interval is also shown. The green color identifies the cohort born between September 1943 and August 1946, the red dots between September 1946 and August 1949, blue for the cohort September 1949–August 1952, and purple for those born in September 1952–August 1955.

born after the threshold, I separate those born one year after the chosen date, which experienced a modest increase in the requirements, from those born after September 1950, who faced more stringent requirements. The results are presented in Table 2 below.

In the first column, we can see that while 15.5% of individuals from the control group retired before age 55, those in the first treated group were 1.7pp less likely to be retired. This estimate is much larger and statistically significant for those in the second group; they are 9.3pp less likely to be retired. The second column shows the same results for being retired at age 63, individuals in the second group were 15.5pp (or 63%) less likely to be retired. In the third column, I present a placebo exercise. The reform did not modify any rule for retirement after the normal retirement age of 65. It is reassuring that the three groups do not present differential retirement patterns at age 66.[17] In the fourth column, I pool everyone aged between 50 and 63.

[17] I exclude ages 64 and 65 to avoid measurement errors from the exact birth and retirement dates.

Table 2: Effects of the 2004 reform

Outcome:	Retired				Contributing	Formal	Informal	Self-Employed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	0.155	0.246	0.636					
	(0.022)	(0.031)	(0.033)					
T1 (Sep1949–Aug1950)	-0.017	-0.062	0.018	-0.040	0.028	0.005	-0.007	-0.003
	(0.036)	(0.052)	(0.094)	(0.038)	(0.048)	(0.042)	(0.019)	(0.032)
T2 (Sep1950–Aug1952)	-0.093	-0.155	0.012	-0.105	0.044	0.052	0.003	0.045
	(0.028)	(0.037)	(0.060)	(0.032)	(0.037)	(0.039)	(0.016)	(0.030)
Age Fixed-Effects	-	-	-	Yes	Yes	Yes	Yes	Yes
Age Range	55	63	66	[50-63]	[50-63]	[50-63]	[50-63]	[50-63]
Observations	7,584	7,584	7,584	56,105	56,105	56,105	56,105	56,105

Notes: The table presents the results from the regressions comparing the control cohort, born between Sep1946–Aug1949 (the intercept), with two treated cohorts: T1 born between Sep1949–Aug1950 and T2 Sept1950–Aug1952. All the outcomes are binary variables: an indicator for retirement status (columns 1–4); an indicator for making pension contributions (column 5); and indicators for working as a formal employee, informal employee, or self-employed (columns 6–8). Clustered standard errors at the month of birth are in parentheses. As the results in columns 4–8 pool ages from 50 to 63, age fixed effects are included.

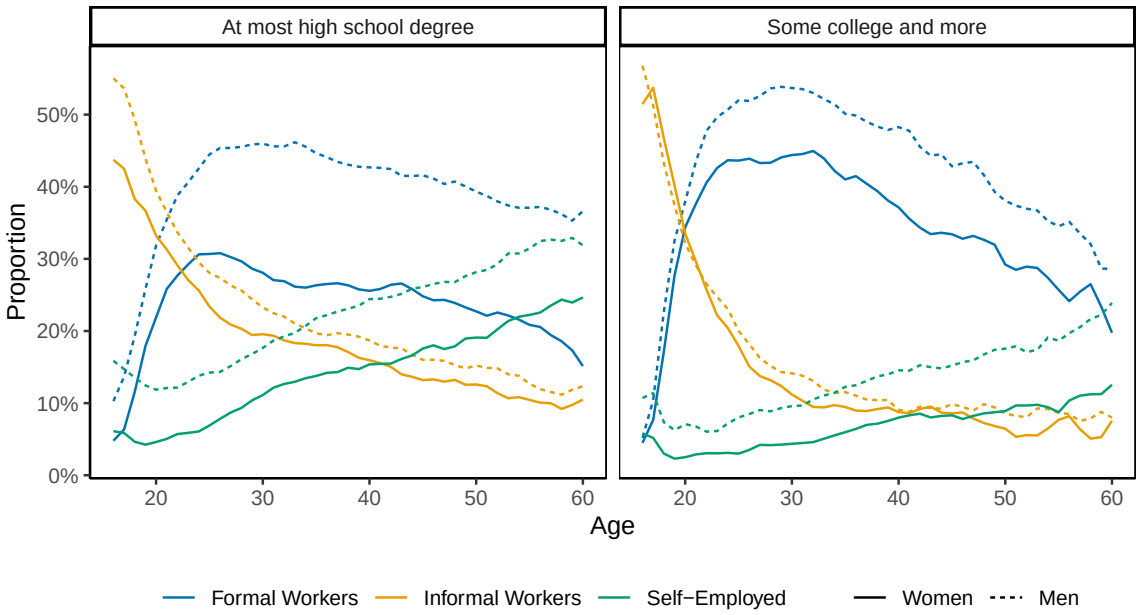
Individuals in the second group are 10.5pp less likely to be retired. In the fifth, I show the effects on the probability of making pension contributions. The effect is less than half of the estimated effect on retirement. The results in the following three columns show why: while the reform increased the probability of someone being in the formal sector by 5.2pp, it also increased the probability of being self-employed by a similar magnitude. As we saw in the previous subsection, most self-employed individuals do not make pension contributions. These results highlight the importance of taking informality decisions into account.

3.2 Key features of each sector of employment

Figure 3 displays the proportion of individuals in formal, informal, and self-employment over the life cycle. We can see robust life cycle patterns by gender and education level. Participation in the formal sector peaks at the early stages of the life cycle and starts to decline continuously around the 30s. Individuals are more likely to be employed as informal workers when young. The proportion of informally employed workers is approximately 20% for young people, it declines quickly and stays stable at meager rates. Self-employment rises monotonically and substantially over the life cycle. In my sample of interest, men with at most high school degree, self-employment corresponds to about 30% of the workforce in their 60s, as large as the formal sector for this age group.

The self-employed have different work arrangements compared to formal and

Figure 3: Proportion of workers in each sector over the life cycle



Notes: The figure plots the proportion of individuals working as formal workers (blue), informal workers (yellow), and self-employed (green) over the life cycle, separately by gender and by education level. The left plot is for individuals with at most high school degrees and the plot on the right is for the sample with some college education or more. Solid lines are for women and dashed lines are for men. The proportions consider all individuals in the labor force. The proportions do not sum to 100% because unemployed, public workers, and employers are not plotted.

informal employees. Among the self-employed, 22% work less than 35 hours, while only 1.8% of formal workers do the same. While more than 70% of formal employees work at the firm site, only 14.2% of self-employed do the same. The proportion of self-employed individuals working from home is nine times larger than formal employees.[18]

When starting a new self-employment activity, individuals may need resources to buy the necessary equipment and merchandise, adapt the workplace, pay for marketing expenses, and keep funding the business while acquiring a new customer base. To investigate this, I turn to the survey of microentrepreneurs, which asks respondents about the source of resources they used to start their self-employment activity. Almost 82% report using mainly their own savings and family and friends' resources. Only 10% use either public or private credit. A very small proportion of individuals, less than 5%, report not needing any investment to be self-employed. From the most

[18]Table A.1 shows the values for all sectors.

typical self-employment occupations, we can already see the importance of physical capital: vehicles (drivers), tools and machinery (carpentry or agriculture), and merchandise (vendors and salespersons). Indeed, around 77% of the surveyed individuals report having at least one asset associated with their economic activity.

In the main dataset, there is only a coarse category for wealth allocated to physical capital that only captures larger investments such as machinery, land, and livestock. Nevertheless, I explore the panel dimension of the data to assess whether self-employment entry and exit are associated with changes in physical capital. I group individuals according to their self-employment status in two consecutive surveys. $G = 00$ are those not self-employed in the first and the second survey. $G = 01$ indexes those not self-employed in the first survey, who became self-employed. $G = 10$ and $G = 11$ are defined similarly. To compare the proportion of individuals who report positive amounts of physical capital, I run the following regression:

$$Y_{it} = \sum_{g \in \{00,11,01,10\}} \beta_g G_{it} \times \text{Post}_{it} + G_{it} + \varepsilon_{it} \tag{1}$$

β_g is the change in the proportion of people holding any physical capital for each group g. Table 3 shows the results. We can see that for the groups that remained not self-employed or self-employed between the surveys, there is no difference in the proportion holding physical capital. However, those transitioning into self-employment are 4.3pp more likely to report having positive physical capital in the second survey. We see the opposite for those flowing out of self-employment, a reduction of 5.9pp.[19] These numbers are not larger because I can only identify physical capital in the main survey for a limited category of large investments. This evidence corroborates the above evidence showing how self-employed individuals invest in physical capital at the onset of their self-employment activity.

In summary, the three sectors have different age profiles and work arrangements. Particularly striking are the differences in part-time work and workplace for the self-employed. Also, self-employment activity requires initial investments that are usually paid using individual resources. All these characteristics will be important in how I model the three sectors. Additionally, we see how the more stringent requirements from the 2004 reform reduced early retirement, which did not translate to the same

[19] In the appendix figure A.2, I show the cumulative density function for this variable for the four groups.

Table 3: Transitions to and from self-employment and physical capital

Group	Coefficient
Group 00	-0.0005
(s.e.)	(0.0023)
Group 11	0.0034
(s.e.)	(0.0133)
Group 01	0.0434
(s.e.)	(0.0157)
Group 10	-0.0595
(s.e.)	(0.0161)
N Obs	17,536

Notes: The table shows the β coefficients from equation 1 for the four groups, separated by the status of self-employment (1 if the person was self-employed) in two consecutive surveys. Group fixed effects are added. Standard errors are clustered at the individual level.

increase in the probability of making pension contributions. The estimates of this reform on early retirement will be used in the model estimation.

4 Model

The model is populated by risk-averse individuals who decide their consumption, savings, and employment. Individuals can be unemployed, working for a firm (formally or informally), or self-employed. In the presence of search frictions, they can only start a new formal or informal job if they receive an offer. If the offer is accepted, workers move to this new job receiving the offered wage. If not, they continue with their status quo. Becoming self-employed is always an option, but it requires an up-front partially irreversible investment. Self-employment earnings are volatile. Workers in the formal sector pay social security contributions and taxes and are entitled to unemployment insurance, severance payments, and pensions. Agents decide endogenously when to retire and claim pension benefits. I now present each part of the model.

Timing — Agents are born at age $a_{\min}$ and enter directly into the labor market.

Age a is discrete and evolves deterministically in quarters. Time is relevant only to track cohorts that will experience the pension reforms at different ages. Excluding the pension reforms, I assume that the only source of non-stationarity comes from age, not time.[20] Individuals face mortality risk, surviving from age a to age $a+1$ with probability $(1-m_a)$. All individuals alive at age $a_{\max}$ die with probability one.

Types — Individuals are heterogeneous in three dimensions: birth year (cohort), ability (general and entrepreneurial), and initial wealth. The three dimensions are orthogonal. All cohorts are the same except for the age at which they experience the two pension reforms (in 2004 and 2008). Reforms come as surprises for the individuals.[21] Each individual is endowed with a general ability g and an entrepreneurial ability e. General ability impacts their productivity when working for firms, formally or informally. Entrepreneurial ability controls their productivity when self-employed. Abilities do not affect the arrival or exogenous destruction rates. Lastly, individuals may be born with different initial wealth, reflecting different family backgrounds or support. The state variable θ captures the type of individuals.

Labor Market Sectors — Agents can work for a salary — formally (F) or informally (I), be self-employed (S), or unemployed (U). I refer to these four labor market states as **sectors**. The formal and informal sectors are characterized by wage-posting firms as in Burdett and Mortensen (1998). Workers receive offers from these sectors at a given rate, and each offer has an attached wage. Offers can be accepted or rejected by the worker. Offers are drawn from different distributions for the formal and informal sectors. Formal jobs only offer wages above the statutory minimum. When working formally, individuals pay social security contributions and taxes. Self-employment is always an option, provided individuals pay the up-front investment X. Self-employed earnings are volatile and characterized by an AR(1) process. When terminating the self-employment activity, a fraction π of the investment can be recouped. Therefore, the model considers both liquidity and insurance constraints for self-employment activity, consistent with the findings by Bianchi and Bobba (2013). The formal and informal sectors only offer full-time jobs, while self-employed individuals can work part-time or full-time. Importantly, labor earnings from the informal

[20] The model is not suitable to explain business cycle fluctuations or growth, similarly to Meghir, Narita and Robin (2015) and Narita (2020).

[21] As the data only start in 2002, I do not consider the UI introduction. For simplicity, I consider that all changes implemented in the 2004 and 2008 reforms happened instantaneously. That is, there was no phase-in.

and self-employment sectors are not taxed or subject to social security contributions.

Labor Supply, Consumption, and Savings Decision — Individuals of type θ start a given period at age a, with unemployment insurance status n and pension wealth given by p. They bring k as assets from the last period and are employed in sector j with wage w. They decide the number of hours to supply h and consequently the number of hours for leisure ℓ, given the stock of hours per period $\bar{L}$. Agents also decide consumption and the amount of assets to leave for the next period, respecting the budget and borrowing constraints. The available resources are the assets from the last period, $k(1+r)$, and the net earnings from this period. The function $Y(\theta, j, w, h, k, b)$ obtains the net earnings, including social contributions, taxes, and welfare programs. The function also considers the interest accrued from the last period's savings k and unemployment benefits b. The details for this function can be found in Appendix D. Savings for the next period must be greater than the borrowing limit $\underline{B}$ and smaller than the total net earnings. I denote the value function for this period as $V_a(\theta, n, p, k, j, w)$.

$$
\begin{aligned}
V_a(\theta, n, p, k, j, w) = \max_{\tilde{k}, h, c, \ell} \Bigg\{ & \frac{\phi_j \left(c^{\nu} \ell^{1-\nu}\right)^{1-\gamma}}{1-\gamma} + \\
& \beta \Bigg((1-m_a) \mathbb{E}[V_{a+1}(\theta, n', p', k', j', w')] + m_a \Psi(\tilde{k}) \Bigg) \Bigg\} \qquad (2) \\
\text{s.t.} \quad & c + \tilde{k} = k + Y(\theta, j, w, h, k, b) \\
& \ell = \bar{L} - h \\
& \underline{B} \leq \tilde{k} \leq k + Y(\theta, j, w, h, k, b)
\end{aligned}
$$

The per-period utility function will be given by a CRRA function on a composite of consumption and leisure, with weights ν and $(1-\nu)$, respectively. The utility function allows the marginal utility of consumption and leisure to depend on the employment sector j through ϕ_j. This formulation captures (dis)amenities of each sector.

While deciding $(\tilde{k}, h, c, \ell)$, individuals take into account the continuation values at age $a+1$. An individual dies with probability m_a and bequeaths the remaining wealth, yielding him the utility $\Psi(\tilde{k})$. I use a standard specification from the bequest function as in French and Jones (2011) with bequest weight ψ and bequest shifter $\overline{K}$.

$$\Psi(k) = \psi \frac{\left(\overline{K} + k\right)^{1-\gamma}}{1-\gamma}. \tag{3}$$

If individuals survive to age $a+1$, they will receive labor market shocks that might destroy their current jobs or receive new offers from the formal and informal sectors. Therefore, individuals take expectations over the distribution of these shocks.

Labor market shocks and transitions — If employed workers receive a separation shock δ_j, they move to unemployment or self-employment, paying the self-employment investment cost. Self-employment activities can also be terminated at an exogenous rate δ_S. Individuals receive an offer from the formal sector with probability λ_j^F and from the informal sector with probability λ_j^I. Employed individuals may also receive offers. If individuals accept an offer from the formal or informal sector, they move to that job with the accepted wage w. To capture uncertainty on self-employment, their earnings are only realized after individuals decide to be self-employed and pay the initial investment.

I now show the exact formula of $\mathbb{E}[V_{a+1}(\theta, n', p', k', j', w')]$ for someone that is currently unemployed ($j = U$). To help with the notation, I will define $\tilde{V}_{a+1}$ as the best decision of this agent in case he does not receive any offer, which will be the decision to remain unemployed, go to self-employment, or retire (if $a \geq a_{\min}^{\text{Ret}}$).

$$\begin{aligned} \tilde{V}_{a+1}^U := \max \Bigg\{ & V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \\ & \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), V_{a+1}^{\text{Ret}}(\theta, \tilde{k}, y^P, q) \Bigg\} \end{aligned} \tag{4}$$

Note that when going to self-employment, individuals pay the upfront investment X, and do not know the future earnings $\tilde{w}$, which will be drawn from the distribution of self-employment earnings $W^S(\tilde{w})$. We can now define the expected value for the

unemployed individual:

$$\begin{aligned}\mathbb{E}_U[V_{a+1}(\theta,n',p',k',j',w')] = (1-\lambda_U^F)(1-\lambda_U^I)\tilde{V}_{a+1}^U + \\ \lambda_U^F(1-\lambda_U^I)\int \max\left\{\tilde{V}_{a+1}^U, V_{a+1}(\theta,n',p',\tilde{k},F,\tilde{w})\right\}dW^F(\tilde{w}) + \\ \lambda_U^I(1-\lambda_U^F)\int \max\left\{\tilde{V}_{a+1}^U, V_{a+1}(\theta,n',p',\tilde{k},I,\tilde{w})\right\}dW^I(\tilde{w}) + \\ \lambda_U^I\lambda_U^F\int\int \max\left\{\tilde{V}_{a+1}^U, V_{a+1}(\theta,n',p',\tilde{k},F,\tilde{w}), V_{a+1}(\theta,n',p',\tilde{k},I,\tilde{\tilde{w}})\right\}dW^F(\tilde{w})dW^I(\tilde{\tilde{w}})\end{aligned} \tag{5}$$

He does not receive any offer with probability $(1-\lambda_U^F)(1-\lambda_U^I)$. If that is the case, he chooses between moving to self-employment or remaining unemployed. If he receives a formal offer (with probability λ_U^F), he can decide between moving to the formal sector or his best choice. Note that he can make this decision after observing the wage drawn from the formal wage distribution $W^F(\tilde{w})$. We have a similar expression for the informal sector. The last case is if he receives both offers, then he can decide between the formal, informal, and the best choice.

The expression is similar for an individual in the formal sector earning w with two differences. First, the individual may lose his job, which happens with probability δ_F. In this case, the individual receives severance payments and can only move to unemployment or self-employment. The other difference is that in his best choice in the absence of labor market choices, he has four options, remaining in the same job, quitting and moving to unemployment, going to self-employment, or retiring (if that is already possible). Let this best choice be given by

$$\begin{aligned}\tilde{V}_{a+1}^F \coloneqq \max\Big\{&V_{a+1}(\theta,n',p',\tilde{k},F,w), V_{a+1}(\theta,n',p',\tilde{k},U,0), \\ &\int V_{a+1}(\theta,n',p',\tilde{k}-X,S,\tilde{w})dW^S(\tilde{w}), V_{a+1}^{\text{Ret}}(\theta,\tilde{k},y^P,q)\Big\}\end{aligned} \tag{6}$$

We are now equipped to define the expected value for the formally employed:

$$
\begin{aligned}
&\mathbb{E}_F[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\quad \delta_F \max\Bigg\{V_{a+1}(\theta, n', p', \tilde{k} + SP(w), U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} + SP(w) - X, S, \tilde{w}) dW^S(\tilde{w}), \\
&\qquad\qquad V_{a+1}^{\text{Ret}}(\theta, \tilde{k}, y^P, q)\Bigg\} + \\
&\quad (1-\delta_F)\Bigg[(1-\lambda_F^F)(1-\lambda_F^I)\tilde{V}_{a+1}^F + \\
&\quad \lambda_F^F(1-\lambda_F^I)\int \max\left\{\tilde{V}_{a+1}^F, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w})\right\} dW^F(\tilde{w}) + \\
&\quad \lambda_F^I(1-\lambda_F^F)\int \max\left\{\tilde{V}_{a+1}^F, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w})\right\} dW^I(\tilde{w}) + \\
&\quad \lambda_F^I\lambda_F^F\int\int \max\left\{\tilde{V}_{a+1}^F, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}), V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{\tilde{w}})\right\} dW^F(\tilde{w}) dW^I(\tilde{\tilde{w}})\Bigg]
\end{aligned}
\tag{7}
$$

If the individual is fired, he will receive severance payments, which is a function of his current wage. His future wealth will be increased by $SP(w)$. The dynamics of receiving offers are the same as for unemployed individuals.

For the informal sector, the expressions are very similar to those in the formal sector, except that workers do not receive severance payment in case of separation. For self-employed individuals, the choice in the absence of new offers involves remaining self-employed, quitting, or retiring. When remaining self-employed, individuals take in expectation the next period's earnings, which depend on the current earnings w. Additionally, if they exit self-employment, they recoup a fraction π of the initial investment X. The expressions for informal workers and self-employed are presented in the Appendix D.

Note that the savings individuals carry to the next period are only determined after the labor market shocks and decisions. The value effectively carried will depend on whether they were employed in the formal sector and the job was separated, decided to be self-employed and paid the initial investment (X), or exited self-employment and recouped a fraction of the investment.

$$
k' = \tilde{k} + SP(w)\mathbb{1}\{j = F \text{ and fired}\} - X\mathbb{1}\{j \neq S, j' = S\} + \pi X\mathbb{1}\{j = S, j' \neq S\} \tag{8}
$$

The borrowing constraint implies that moving to self-employment is an option if and only if $\tilde{k} + SP(w)\mathbb{1}\{j = F \text{ and fired}\} \geq X$.

Unemployment Insurance — At each point in time, individuals are in UI status $n \in \{0, 1, 2, ..., n_{\max}\}$. When $n = 0$, agents are either formally employed or have exhausted their UI benefits an no payment is received. When individuals are laid off from the formal sector, they move to $n = n_{\max}$ and will receive their UI benefits next period.[22] If individuals remain not formally employed, they move to $n' = n - 1$. When individuals accept a formal offer, they move to $n = 0$, an absorbing state.

The value of UI depends on their UI status n, pension wealth p, and age a. The unemployment status n determines the replacement rate individuals are entitled to according to the UI schedule. In reality, the benefits are a function of the individuals' UI accounts and wages. In the model, I approximate the available funds and the previous wages through their pension wealth and age.[23] Since the government cannot monitor informal jobs and self-employment, I allow individuals to continue receiving unemployment benefits when they work informally.

Pension contributions and retirement — When individuals work formally, they contribute 10% of their monthly wages into their pension account. Their previous pension wealth is updated by the prevailing interest rate for the pension system $(1 + r^P)$. Note that there are no pension contribution choices, they are intrinsically connected to the employment sector.

Individuals endogenously decide when to retire. In the model, the decisions of claiming pension benefits and retiring (exiting the labor market), are intertwined. There is no re-entry after claiming the benefits, making retirement a permanent choice. Individuals can claim early retirement between age $a^{\text{Ret}}_{\min}$ and the normal retirement age a^{Ret}. Those who did not retire at age $a^{\text{Ret}}_{\max}$ will claim benefits at this age. The pension benefit formula is represented by $y^p = \omega(\theta, a, p)$. The pension wealth p will be fully annuitized, considering the claimant's age a. The final pension may depend on the policy environment resulting from the cohort (θ) and age (a).

[22] In Chile, workers can also access individual UI funds when quitting. As I do not model the individual UI accounts, I do not allow for this possibility in the model. This can be seen as an additional advantage from the formal sector that is not modeled explicitly.

[23] Note that whenever the individuals contribute to pensions, they are necessarily formally employed and, therefore, also contributing to UI. This makes pension wealth a good proxy for the available UI funds. The R-squared for the regression predicting the UI stock is 0.41 and for the model predicting last year's average wage is 0.27.

Retirement before the normal retirement age is possible if the resulting benefit meets the early retirement conditions, that is, $y^p \geq \max\{A, \alpha\overline{w}\}$.[24] I denote by q whether the individual retired before the normal retirement age ($q = 1$). The net income function is $Y^{\text{Ret}}(y^p, q, \theta, a, k)$, which is formally defined in the Appendix D. After retirement, the decision problem is simpler. Individuals decide solely how much to consume and save in each period. The only remaining uncertainty is on mortality.

Firms — Since this paper focuses on the tradeoffs that workers experience while making employment decisions, firms are not explicitly modeled. From the point of view of workers, firms generate in equilibrium the observed wage offers for the formal and informal sectors, $W^F(w)$ and $W^I(w)$, from which individuals draw offers according to the given arrival rates. Meghir et al. (2015) and Narita (2020) show how heterogeneous firms can rationalize these wage distributions with different fixed productivity levels, which maximize their profits by choosing the posted wage. When posting a higher wage, a firm of a given productivity level has lower profits. However, it can attract more workers from unemployment and other sectors while losing fewer workers from endogenous quitting.

5 Estimation

Estimation proceeds in two steps. Firstly, I estimate some parameters outside the model and set other parameters directly. These are primarily parameters from the policy environment. In the second step, I estimate some preference and technology parameters, using the methods of simulated moments. Before detailing the two steps, I first show how I parametrize the wage, earnings, and initial wealth distributions.

5.1 Parametrization

I parametrize the wages and earnings distributions for the three sectors. For the formal and informal sectors, the wage offers will come from a beta distribution, which is highly flexible with a parsimonious number of parameters. For each offer distribution, there will be two parameters capturing the support $(\underline{w}, \overline{w})$ and two scale parameters (ζ_1, ζ_2).

$$W^F \sim \beta(\zeta_1^F, \zeta_2^F; \underline{w}^F, \overline{w}^F) \quad , \quad W^I \sim \beta(\zeta_1^I, \zeta_2^I; \underline{w}^I, \overline{w}^I)$$

[24] The values of A and α will depend on the individual's cohort and policy environment, which are captured by θ and age a. The average wage $\overline{w}$ will be computed using the pension wealth stock and age.

I characterize self-employment earnings as an auto-regressive process of order 1, with auto-correlation ρ and innovations following a normal distribution.

$$\begin{aligned} w_0 &= \mu + \varepsilon_0 \\ w_t &= (1-\rho)\mu + \rho w_{t-1} + \varepsilon_t, \forall t > 0 \\ \varepsilon_t &\sim N(0, \sigma^2) \end{aligned} \tag{9}$$

For the initial wealth distribution, I assume that each individual initial wealth (k_0) is drawn from a truncated normal distribution

$$k_0 = \max\{0, k_0^*\}, \quad k_0^* \sim N(\mu_{k_0}, \sigma_{k_0}) \tag{10}$$

5.2 Estimation — First Step

Timing - Age runs quarterly, starting with 16 years up to 100 years. Individuals older than 50 can claim early retirement benefits, the normal retirement age is 65, and the maximum retirement age is 70. The stock of hours is 16 hours for every calendar day. Full-time employees work for 45 hours a week for 49 weeks in a year, while part-time self-employed work 28 hours a week for the same 49 weeks.[25]

Types - Types are defined by their cohort, ability, and initial wealth. Cohorts run from 1940 to 1989. I assume there are two sub-types regarding ability: type 1 (g_1, e_1), and type 2 (g_2, e_2). I use the normalization that $g_1 = 1$. I additionally assume that the first type cannot be self-employed ($e_1 = 0$) and assume that the proportion of type-1 individuals is the empirical proportion of individuals that are never self-employed (62%). For the initial wealth distribution, I choose (μ_{k_0} and σ_{k_0}) to minimize the empirical distribution of wealth from ages 16–23 (for a larger sample size). I obtain $\mu_{k_0} = -2,494$, and $\sigma_{k_0} = 3,205$.

Social Security - Formal employees pay 10% of their wages towards the pension system, 7% for health insurance, and 0.6% for unemployment insurance. These are the statutory rates. Additionally, formal workers pay 1.3% of administration fees.[26] Informal employees and self-employed individuals do not pay contributions. Retired

[25] Among the self-employed individuals working less than 40 hours, the median number of hours of work is 28.

[26] This number depends on the pension administrator, and it varies over time. 1.3% is the average value paid across all pension funds between 1993 and 2019, weighted by the number of beneficiaries in each fund. As the model does not entail disability risk, I remove the payment for disability insurance.

individuals pay 7% of their pension benefits as contributions to the health system.

Interest Rates - As the model abstracts from risk in the returns for both the pension and non-pension wealth, I use the procedure proposed by Kaplan and Violante (2014) and subtract the variance of returns from the mean returns to yield the estimated average (risk-free) return. I compute the interest rate for the pension wealth using the returns from 1982 to 2015.[27] I obtain an average annual (risk-free) return of 5.8%. For the general interest rate, since, in the data, most of the non-pension wealth comes from houses, I consider the housing returns in Chile between 2002 and 2020. The average annual return is 4.5%.

Pension Benefits - To compute the pension benefits, I first compute the annuitization rates, considering the interest rate in the model and the mortality vector as in Crawford and O'Dea (2020). I then use all the data from SCOMP to estimate the administrative costs that minimize the distance between the observed and predicted pension benefits (given pension wealth and age of retirement). For this analysis, I restrict the sample to individuals without beneficiaries who fully annuitize their pension wealth. The resulting administrative cost is 40.2%. This number is large mainly due to the high interest rate considered in the model (4.5%). Using an interest rate closer to the risk-free interest rate in Chile would yield more reasonable estimates of the administrative costs, around 26%.

Severance Payments - Severance payments are a function of earnings and tenure. Since the model does not keep track of tenure, I approximate the severance amount based solely on wage. Higher wages are associated with longer tenures in reality and in the model. To estimate this relationship, I draw on the administrative data for the UI system, predicting the severance payment amount of laid-off workers as a function of a quadratic on wage. The R-squared of this prediction is 0.44 for my sample.

Unemployment Insurance - The level and duration of UI benefits are a function of resources in the UI account and previous wages. I approximate both using the pension wealth and age. I first use pension wealth and age to compute the average wage workers experienced in their working lives. From the administrative data of the UI system, I approximate available resources as a function of wages.[28] I assume that

[27] After 2002, individuals can opt to distribute their pension wealth in five funds with different risk levels. I first compute the average monthly return weighted by each fund's volume of assets and then apply the procedure from Kaplan and Violante (2014).

[28] The R-squared for the regression predicting the UI stock is 0.41 and for the model predicting

laid-off workers receive three monthly benefits in the first quarter of unemployment, with replacement rates of 50%, 45%, and 40%. If they continue without formal employment, they receive the second quarter payments: the remaining 35% and 30% and the residual predicted funds.

Income Tax and Welfare Programs - The model considers smoother versions of the two welfare programs, a child tax credit (AF) and a welfare transfer (SUF). These programs have 3-4 levels of benefits depending on family structure and earnings. I implement a linear version of the benefits where those with 0 earnings receive the maximum benefits (4 thousand pesos for AF and SUF). This value is then withdrawn with a given implicit tax rate that offsets the benefits for the defined thresholds of the programs (360 thousand pesos). I consider the real brackets of the income tax schedule. I assume that informal employees and self-employed individuals can hide their earnings from the government, therefore, they do not pay taxes on their labor earnings.

Earnings - For the formal and informal wage distributions, I set the minimum and maximum of the support as their empirical counterparts in the observed wage distribution. For formal employment, I take into account the minimum wage, truncating the distribution at the statutory level. To compute self-employment earnings, I rely on the data from the National Employment Survey, which better captures within-spell volatility. To compute the persistence parameter (ρ), I take advantage of the fact that:

$$\rho = \frac{\text{Cov}(Y_t, Y_{t-2})}{\text{Cov}(Y_t, Y_{t-1})} \tag{11}$$

This allows me to use all observations from any period of the self-employment spell and does not require estimating the innovation variance. I set ρ directly as the empirical counterpart of equation 11, which implies a annual correlation of 0.67.

Risk-aversion - I set the coefficient of risk-aversion γ to three, which is the midpoint of the typical range of 2–4 used in the literature (Kotlikoff et al., 1999, Conesa et al., 2009, Nishiyama, 2011, O'Dea, 2018).

Recovery of self-employment investment and destruction rates I do not have data on direct self-employment investments. The only available data is the market

last year's average wage is 0.27.

value of the assets used for self-employment activity. Therefore, I cannot separately identify the investment X and the fraction of this investment that can be recovered (π). I set this parameter to 50%. Quitting from formal and informal jobs is extremely rare. Therefore, I set the destruction rates for these sectors to the average empirical transition from formal and informal employment to unemployment. These rates will be respectively 2.2% and 3.9%.

5.3 Estimation — Second Step

In the second step, I estimate all the remaining parameters (ξ) using the simulated method of moments. The estimation procedure will minimize the criteria function $M(\xi)'\Sigma_m M(\xi)$, where $M(\xi)$ is the function that computes the $M \times 1$ vector of moments from the $P \times 1$ parameters' vector ξ. Σ_m is the weighting matrix, which will be the inverse of the diagonal of the variance-covariance $M \times M$ matrix of the empirical moments from the data.[29] The details of the implementation of this estimation are presented in Appendix E.

The model does not allow for a closed-form solution, so formal identification of each parameter is infeasible. However, each estimated parameter is closer-linked to some specific moments from the data. I confirm these links with the sensitivity analysis proposed by Andrews et al. (2017), which transparently presents the connections between moments and parameters. All the parameters and the associated moments are presented in Table 4.

Among the preference parameters, the discount rate β can be inferred from the patterns of wealth accumulation over the life cycle. At the same time, the bequest weight ψ and bequest shifter $\overline{K}$ are linked to the wealth patterns for old ages, particularly from different moments of the wealth distribution. To identify these parameters, I include the 25th, 50th, and 75th percentiles of wealth over the life cycle, grouping ages in five-year intervals.

The consumption weight in the per-period utility function (ν) captures the relative importance of consumption and leisure. Two sets of moments help estimate this parameter: the proportion of self-employed individuals working part-time and the differential retirement trends generated by the 2004 reform. The reform captures precisely the willingness of individuals to retire early, forgoing a future income stream

[29] Σ_m is estimated using a bootstrap procedure with 2,500 replications.

by not staying longer in the labor force. The last preference parameter is the amenity value for self-employment.[30] This parameter will rely heavily on the life cycle patterns for self-employment. Notably, the increasing proportion of individuals switching to self-employment over the life cycle would imply higher amenities in this sector.

Table 4: Second step parameters

Parameter	Description	Most informative moments
Preference Parameters		
β	Discount factor	Wealth profile
ν	Consumption weight	Early retirement and part-time
$\psi, \bar{K}$	Bequest weight and shifter	Old-age wealth profiles
ϕ_S	Amenities for self-employment	Sector allocation over life cycle
Technology Parameters		
δ_S	Destruction rates for self-employment	Transitions from S to U
$\lambda_j^{j'}$	Arrival rates	Transitions from j to formal/informal
ζ_1^F, ζ_2^F	Shape parameters (formal wage)	Formal wage distribution percentiles
ζ_1^I, ζ_2^I	Shape parameters (informal wage)	Informal wage distribution percentiles
σ	Variance of self-employment earnings	Self-employment earnings distribution
X	Start-up cost for self-employment	Life-cycle transitions to self-employment
g_2,e_2	General and entrepreneurial abilities	Correlation of wages, self-emp earnings

Notes: j indexes the sectors in the model: unemployment (U), formal (F), informal (I), and self-employment (S).

The arrival and destruction rates can be inferred from the empirical transitions for each sector. All transitions for the j, j' pairs are included. I also include the proportion of individuals who stayed employed in the formal or informal sector with wage increases to inform the on-the-job arrival rates for the same sector.

For the wage distributions, I estimate the two shape parameters for the beta distribution of each sector. They will be closely linked to the percentiles of the wage distributions. I include all deciles from 10-90%. To better capture the bottom of the distribution, I include as moments the fraction of formal workers earning the minimum wage and the percentiles 1%, 2.5%, 5%, and 7.5% for informal earnings. For the self-

[30] I normalize the amenities for the formal sector ϕ_F to be 1, and I assume that the informal workers enjoy the same amenities. I can also set ϕ_U equal to 1 because the consumption-leisure weight (ν) can pin down the utility difference from formal employment to unemployment.

employment earnings, I estimate the variance of the innovation shocks. To provide information for this parameter, I use as moments the ventiles of the self-employment distribution, the mean earnings, and the variance of annual wage differences.

For the general and entrepreneurial abilities, I include as moments the correlation of wages of individuals who lost their jobs (involuntarily) and found jobs after 1-year in the same formal or informal sectors. The last parameter is the investment cost to be self-employed. X can be informed mainly by the market value of assets used in self-employment activity.

6 Results

6.1 Estimates and Fit

Table 5 presents the estimates for the parameters estimated in the second step with their computed standard errors. The discount rate β estimate is 0.94 (annually), slightly smaller than the typical estimates in life cycle models. The estimate for the consumption weight in the utility function ν is 0.39, which lies in the typical range for this parameter. It implies a coefficient of relative risk aversion of 1.78. The bequest shifter and weight are not directly interpretable. They imply a marginal propensity to consume in the last period of life (with certain death) of 5.9% (out of their total wealth). Appendix Figure A.3 shows the amount left as bequest as a function of wealth in the last period of life.

The estimate of amenities for self-employment implies that the same level of consumption yields 12.6% higher utility for self-employed individuals compared to formal workers. This is not surprising, considering the differences discussed in Section 2. Individuals likely value some features of self-employment, such as the possibility to work from home and flexibility in work hours.

The next set of estimates relates to search frictions. We can see that, in any state, the informal arrival rates are always higher than the formal ones. This indicates that is consistently easier to find an informal than a formal job. The quarterly (exogenously) destruction probabilities for self-employed is 0.008. It is worth noting that the model allows the possibility of voluntary quitting, which does not occur frequently. Figure A.4 shows how the model matches the transition rates well, which are intrinsically connected to these parameters.

Table 5: Parameters estimated in the second step

Preference	β	ν	ψ	$\bar{K}$	ϕ_S
estimate	0.944	0.390	141.9	8375.0	1.126
(s.e.)	(0.001)	(0.002)	(50.2)	(2911.1)	(0.016)
Formal Arrival Rates	$\lambda_{U,F}$	$\lambda_{F,F}$	$\lambda_{I,F}$	$\lambda_{S,F}$	
estimate	0.116	0.207	0.031	0.653	
(s.e.)	(0.003)	(0.011)	(0.002)	(0.102)	
Informal Arrival Rates	$\lambda_{U,I}$	$\lambda_{F,I}$	$\lambda_{I,I}$	$\lambda_{S,I}$	
estimate	0.213	0.976	0.117	0.957	
(s.e.)	(0.011)	(0.282)	(0.010)	(1.136)	
Wage (Shape)	ζ_1^F	ζ_2^F	ζ_1^I	ζ_2^I	g_2
estimate	6.086	16.942	11.304	48.887	0.559
(s.e.)	(0.453)	(1.028)	(1.330)	(4.736)	(0.005)
Self-Employment	δ_S	σ	X	e_2	
estimate	0.008	0.051	3365.3	0.684	
(s.e.)	(0.001)	(0.002)	(76.2)	(0.010)	

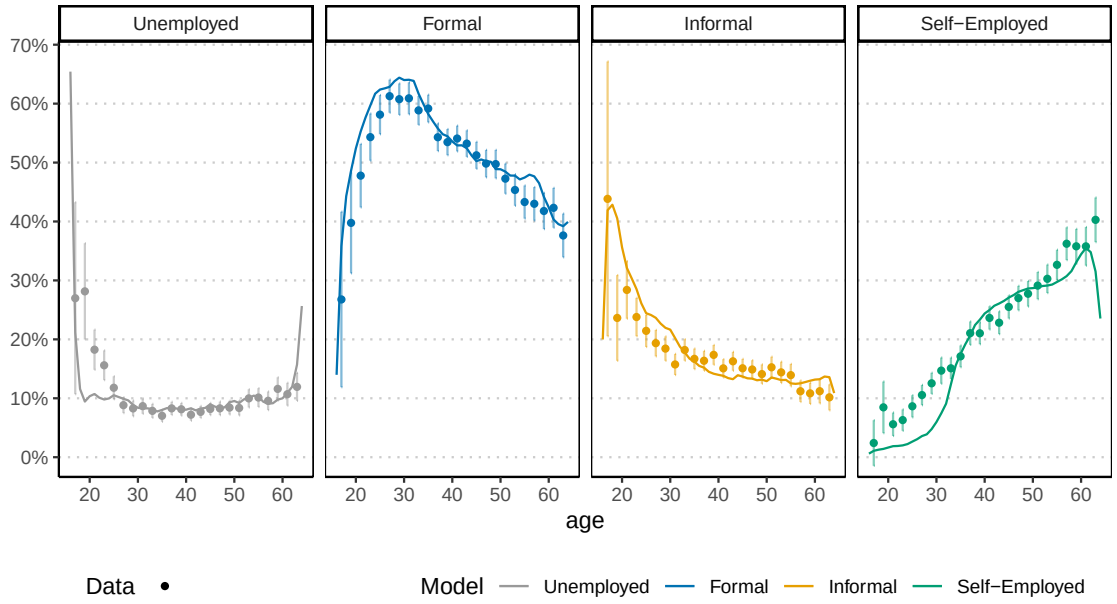
Notes: The table presents the estimates for each of the 22 parameters estimated in the second step through the method of simulated moments. The estimates for the standard error (denoted by s.e.) are in parentheses. They were computed using the numerical derivative for the criteria function.

The estimates imply average labor earnings of 169.7, 120.3, and 133.8 thousand pesos for the formal, informal and self-employed, respectively. The formal-informal gap is 29.1%. The variance of the innovation shock for self-employment earnings is 0.051. The type who can be self-employed (type 2) is less productive as a worker, than type 1 ($e_2 = 0.684$, $e_1 = 0$, $g_2 = 0.559$, and g_1=1.0). The estimated self-employment start-up cost is 3365.3 thousand pesos (23.5 average monthly wages).

The model performs well on targeted and non-targeted moments. Figure 4 shows how the model replicates extremely well the main trends of the labor market allocation over the life cycle. Figure 5 shows the match of the retirement patterns for individuals born five years before and after August 1949, which was the exemption threshold for the 2004 reform. We can see that the results replicate well the retirement patterns of these two cohorts, particularly the jump at the normal retirement age (65)

and the lower retirement rates before 65 for the cohort affected by the reform. The model does not capture some early retirement for individuals between 50-58 in both cohorts. This is likely due to special retirement rules for those employed in hazardous occupations. These special rules are firm-occupation specific; therefore, it is difficult to account for them in the data and the model. Figures A.5 and A.6 show the model fit of the earnings distributions.

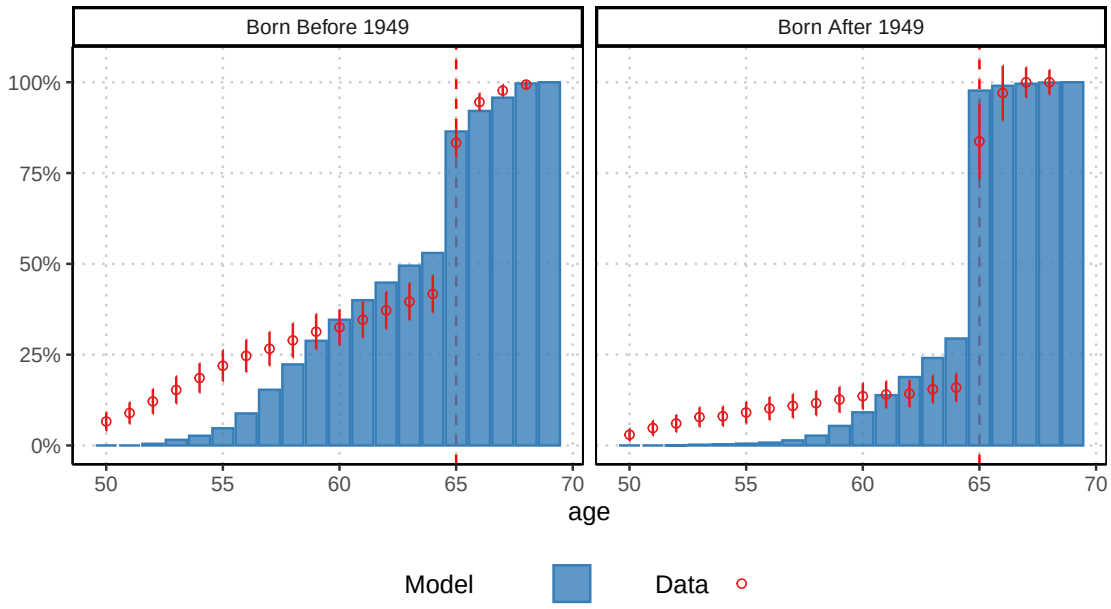
Figure 4: Life cycle employment trends



Notes: The graph shows the proportion of individuals in each sector (unemployment, formal, informal, and self-employment) over the life cycle. The dots represent each moment computed in the data, with the 95% confidence intervals. The lines are equivalent moments in the model.

Other targeted moments are the liquid wealth over the life cycle (Figure A.7), the proportion of individuals working part-time (Figure A.8), and the within-correlation of wages for wage-employment (Figure A.9). The model also performs well in non-targeted moments. Figures A.10 and A.11 show the average pension wealth and the number of pension contributions by age, with a very good fit. I also compute the sensitivity matrix proposed by Andrews et al. (2017), showing, transparently, the connection between moments and the estimates. The procedure and the results are presented in Appendix F. It is worth noting how most of the connections between moments and parameters we discussed in Section 5 are present.

Figure 5: Proportion retired by age and cohort



Notes: The figure plots the proportion of individuals retired by each age in the data (red circles, with the 95% confidence intervals) and in the model (blue bars). The panel on the left is for those individuals born five years before 1949 and the panel on the right is for those born five years after that. The first group was unaffected by the 2004 reform.

6.2 Life-cycle choices

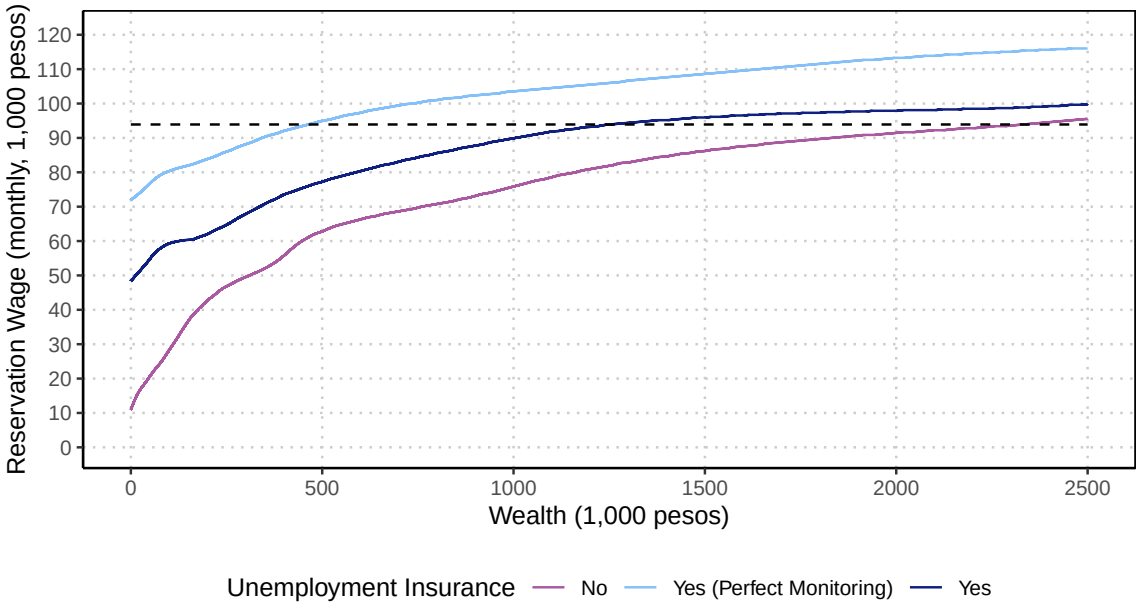
As Figure 4 shows, the model effectively replicates the allocation of employment types over the life cycle. As the model does not feature any age-dependent parameters, the endogenous mechanisms are responsible for generating the different labor market choices. The main mechanism is the search behavior being wealth-dependent. That is, individuals with different levels of wealth will behave differently in the labor market.

Figure 6 shows how the reservation wage for the informal sector depends on wealth and unemployment status of an unemployed individual.[31] We can see that unemployed individuals with low wealth and who do not receive unemployment insurance have significantly low reservation wages. They would accept offers paying around 10 thousand pesos monthly, which is much lower than the statutory minimum wage of around 92 thousand pesos (dashed line). The same individual with

[31]The figure plots the reservation wages for a 20-year-old unemployed individual from a given type and given pension wealth.

more wealth would have reservation wages nine times higher. This is the mechanism through which the model reproduces the decline in the informal sector over the life cycle. When individuals are younger and with low wealth they are more likely to accept offers from the informal sector. That decreases as they accumulate more resources.

Figure 6: Reservation wages for the informal sector



Notes: The figure shows the reservation wages for offers in the informal sector as a function of wealth. The reservation wage is computed for the entrepreneur type, at 20 years, before the pension reforms and with low pension wealth stock. The purple line shows the reservation wages for those not entitled to unemployment insurance (UI), the light blue line for someone entitled to UI with perfect monitoring, and the darker blue with imperfect monitoring. The reservation wage depends on all estimated parameters. The dashed line shows the level of the statutory minimum wage.

The figure also shows the value of unemployment insurance. The light blue curve shows the reservation wage for someone eligible to receive UI if there was perfect monitoring of the government. That is if it was impossible to accumulate informal earnings and UI benefits. While the entire reservation wage curve shifts up, it is particularly effective for low-wealth individuals, with reservation wages of around 70 thousand pesos. The darker blue curve shows the reservation wage of someone receiving UI with imperfect monitoring. The reservation wages are smaller compared to the case with perfect monitoring, as individuals could accumulate both informal earnings and UI benefits.

The level of assets also influences the self-employment choice through three mechanisms. First, as individuals need to pay the up-front self-employment start-up costs, those with savings below that threshold can not start a self-employment activity. Second, as self-employment brings earnings volatility, those with higher wealth can be better self-insured against this volatility. Their relative risk aversion is smaller. Third, as amenities for self-employment are multiplicative, they are more valuable as higher the consumption bundle one can afford. Transitions to self-employment are positively associated with savings and negatively with the current wage. Figure A.12 plots the decision to be self-employed as a function of current wealth and wages.

6.3 Formal insurance

A fundamental question when contrasting formal and informal choices is how valuable is a formal job. Formal employment offers more stability and better search prospects when compared to informal jobs, which is valuable for workers. Additionally, formal employment offers access to a variety of insurance programs, requiring social security contributions and tax payments. The model is well-equipped to compute the overall value of a formal job, taking into account all benefits and costs.

Table 6: Willingness to pay for formalization

Sector	Constrained	Unconstrained			
	Total	Total	Labor market stability/prospects	Insurance	Self-Emp Specific
Informal	18.7%	25.1%	15.6%	9.6%	-
Self-Employment	-9.9%	5.0%	-10.3%	10.7%	4.6%

Notes: The table shows the fraction of net earnings individuals working as informal employees (first row) or self-employed (second row) would be willing to forgo to be in the formal sector. The first column shows the overall average value, while the second columns show the average value for the individuals whose minimum accepted wage is above the statutory minimum wage. The last three columns decompose the unconstrained average value into, job stability and search prospects, insurance, and self-employment specific components (amenities, recovery of physical capital, and earnings volatility).

To address this question, I compute the willingness to pay (WTP) for formalization for informal employees and self-employed. That is, what fraction of their labor earnings they would be willing to forgo to have a formal job. Table 6 shows

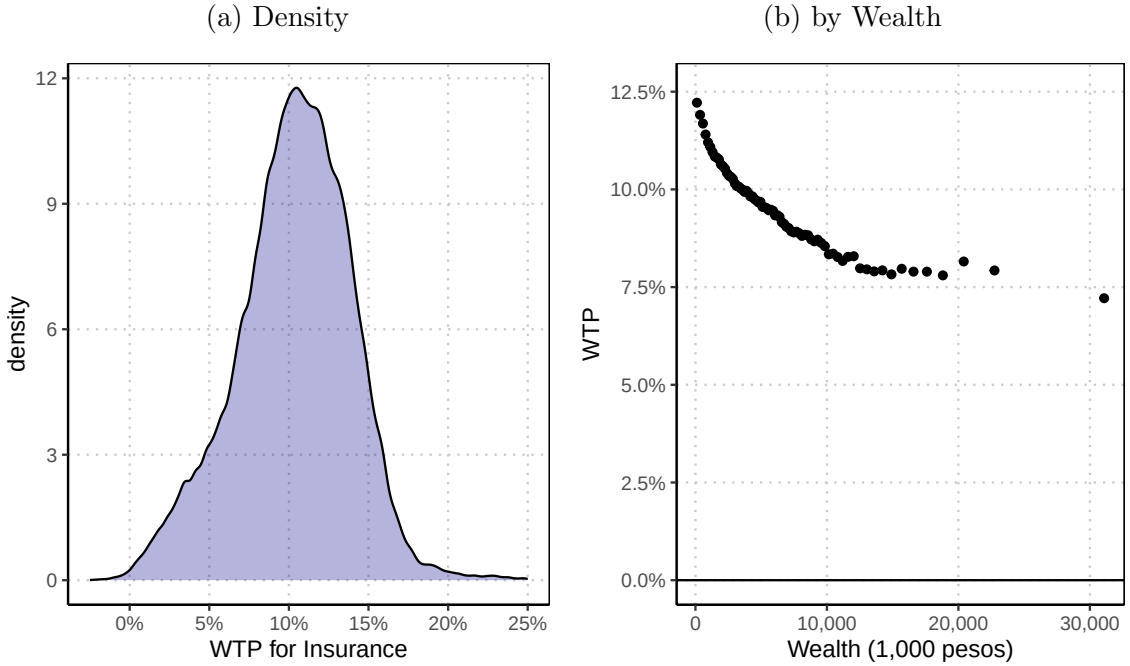
these average values.[32] The average informal employee is willing to give up 18.7% of their labor earnings to have their job formalized. This measure is on net earnings, that is, already taking into account the taxes and social security contributions. If an informal employee earns below the minimum wage, he cannot forgo any fraction of earnings to be in the formal sector, as his new wage would be below the statutory minimum. Therefore, for this measure, these individuals have a WTP of zero. The second column shows the total WTP for the unconstrained individuals, that is, whose final acceptable wage is above the minimum wage. The overall WTP rises to 25.1%. Interestingly, this value is higher than the total social security contributions, around 20% of wages. We can decompose the WTP, into the fraction that is attributable to formal jobs having better stability and job search prospects, which accounts for 62% of the total value, and to insurance, 38% of the value. That is, informal workers, would be willing to pay around 9.6% of their earnings to gain access to unemployment insurance, severance payments, pensions, and child benefits.

For self-employed individuals, we have a slightly different picture. Their overall WTP is negative, that is, they need to earn more in the formal sector to be indifferent between the two jobs. One of the reasons is that the exogenous destruction probability is much lower in self-employment, making involuntary transitions less common. However, for the unconstrained sample, we see a small positive WTP of 5.0%. The insurance value is close to the estimates for informal employees. Self-employed individuals are willing to forgo 10.7% of their earnings to access the package of insurance offered in the formal sector. The last column of Table 6 shows the WTP for self-employment-specific components. They include the within-job-spell variance of earnings, the recovery of start-up costs when leaving self-employment (liquidity access), and amenities. While amenities favor self-employment, the other two components overcome this effect, resulting in a net WTP of 4.6%.

Table 6 shows average values, however, they are highly heterogeneous. Figure 7a shows the density plot of the unconstrained WTP for insurance, combining informal and self-employed individuals. In panel 7b, I plot the binscatterplot of WTP by liquid wealth. We can see how insurance is more valuable for those with less liquid wealth. Individuals without wealth would be willing to forgo around 12.5% of their monthly net earnings to access insurance programs.

[32] I remove from the sample individuals earning below 1/4 of the minimum wage.

Figure 7: WTP for Insurance



Notes: The left panel plots the density of the willingness to pay for insurance, combining self-employed and employed workers. These are the values displayed in the fourth column of Table 6. The right panel plots the WTP for insurance as a function of wealth, using the non-parametric binscatterplot from Cattaneo et al. (2024). The non-parametric estimation controls for age, wage, pension wealth, sector, UI status, and type.

6.4 Informal insurance

Informal wage employment and self-employment can offer fast employment routes for workers. This appears to be the case in this setting, as the estimates of arrival rates for informal jobs are substantially higher than for formal employees. In any given status, individuals are more likely to receive informal than formal offers. Therefore, these sectors may offer substantial value for workers, particularly for those unemployed and with low wealth whether accessing any job fast is highly valuable.

I use the model to quantify the welfare associated with the existence of the informal and self-employment sectors. To do that, I shut down the access to each sector, separately for each individual, and compute the associated welfare loss. That is, those individuals have their arrival rates for the specific sector to be zero or an infinite investment cost to be self-employed. Table 7 presents the resulting average welfare losses. To benchmark results, I also show the welfare loss of losing access

to formal jobs. On average, shutting down access to informal jobs reduces welfare by 5.3%. This number is sizable, even compared to the welfare loss associated with closing access to formal jobs (18.1%). Losing access to self-employment is associated with approximately the same welfare losses, the average loss is 5.7%. These numbers are computed in partial equilibrium, that is, with no responses from the other sectors.

Table 7: Welfare loss for shutting down access to each sector

	Informal		Self-employment		Formal	
	Δ Welfare	(%)	Δ Welfare	(%)	Δ Welfare	(%)
Overall	-5.3%	(-)	-5.7%	(-)	-18.1%	(-)
By initial wealth,						
No wealth	-5.7%	(100.0%)	-5.5%	(100.0%)	-18.8%	(100.0%)
Low wealth	-4.5%	(78.3%)	-6.3%	(114.8%)	-16.6%	(88.2%)
High wealth	-2.3%	(40.3%)	-8.0%	(145.2%)	-10.9%	(57.7%)

Notes: The table shows the change in welfare when shutting down access to jobs in the three sectors: informal, self-employment, and formal. The first row shows the overall value, and the next three rows separately by the level of initial wealth. Columns 1, 3, and 5 show the welfare losses. Columns 2, 4, and 6 show the proportion of welfare loss compared to those born with no wealth.

There is heterogeneity in these losses. Table 7 also shows the average losses by initial wealth group.[33] The gradient is negative and steeper for the informal sector. Those born with no wealth experience losses 2.5 larger than those born with wealth. Interestingly, the wealth gradient is positive for self-employment. That is because young individuals born with wealth can use the initial wealth to pay the up-front investment for self-employment activities. Therefore, they are more harmed when this option is not available. Figure A.13 shows these losses by age and initial wealth.

[33]No wealth accounts for 78.2171% of the sample, low wealth for those born with some wealth up to the 95th percentile of the wealth distribution (that is, born with at most 2787.31 thousand Chilean pesos). High wealth corresponds to the remaining top 5%.

7 Counterfactuals

7.1 2008 Pension Reform

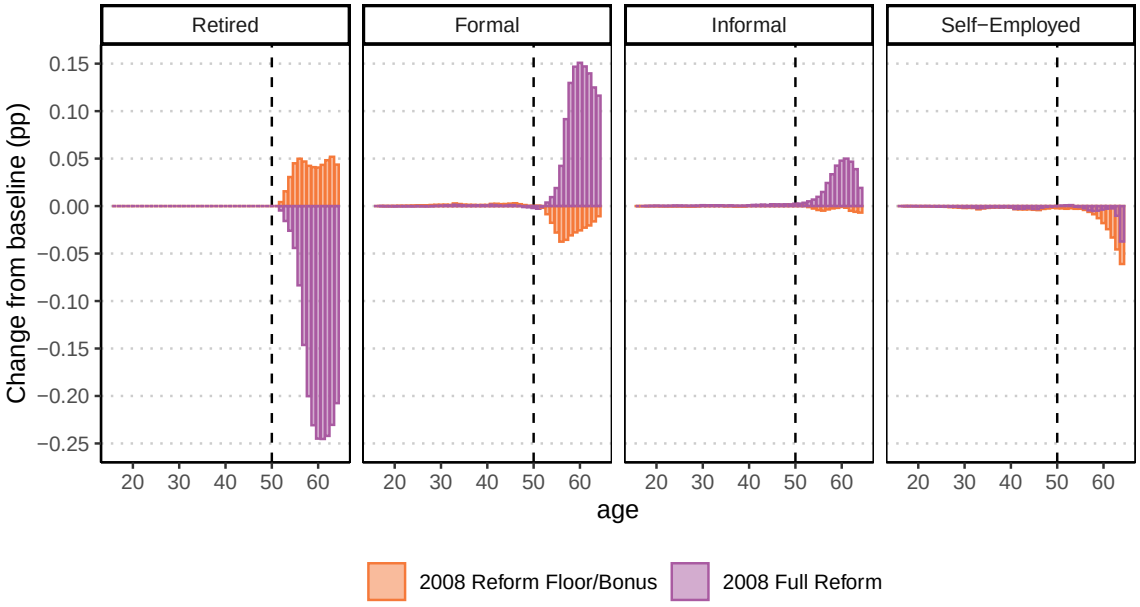
As discussed in the Institutional Setting section, in 2008, Chile implemented a large reform in the pension system. The main changes were the introduction of a new minimum pension and a bonus, and the strengthening of the early retirement restrictions. The new minimum pension was raised by 45%, and it was applicable to someone with no pension wealth. As individuals had positive pension wealth that could be used to self-finance pension benefits, the new value was offset with an implicit tax rate of 30%. It is difficult to assess the impacts of this change as while the income effect is the same for everyone, the sign of the income effect is undefined.[34] I use the model to assess the overall effect of the reform as well as to decompose the effects of the two changes. Figure 8 presents the results.

The bars illustrate the age-specific changes in the proportion of individuals retired, employed in the formal, informal, or self-employed. The orange bars show the counterfactual results of implementing only the new bonus and new minimum pension from the reform. First, we can see that there are no changes before age 50. All the changes come from individuals changing their behavior regarding early retirement. The new bonus induces more people to retire early, affecting employment negatively. The purple bars show the effects when, additionally, implementing the more stringent requirements for early retirement. This has a large impact, reducing early retirement by up to a quarter, and inducing positive employment effects for individuals aged 50–64. This exercise highlights how the government can use different instruments to balance incentives when reforming the pension system.

Table 8 shows the aggregate results for the 2008 pension reform (first row) before early retirement age. As we already saw in Figure 8, there was barely a change in the proportion of individuals working formally (column 1) or informally (column 2). The next two columns show that the estimates for formal and formal insurance also do not change. They display respectively, the change in the WTP for insurance, pooling informal employees and self-employed, and the change in welfare loss (WL) of shutting down both informal sectors.

[34] Figure A.15 shows the pre and post-reform benefits as a function of the self-financed pension (using the full pension wealth to buy annuities).

Figure 8: Counterfactuals: 2008 Pension Reform



Notes: The figure plots the change in the fraction of individuals retired (first panel), employed formally (second panel), informally (third plot), and self-employed (fourth panel) comparing the 2008 reform with the introduction of the bonus and new minimum pension floor (orange bars) and the full 2008 pension reform (purple bars). The changes are compared to the baseline economy and presented in percentage points variation for each age bracket.

Table 8: Counterfactuals and sectoral insurance

Counterfactual	Δ Formal Employment	Δ Informal & Self-Emp	Δ WTP Formal	Δ Welfare Closing Informal & Self-Emp
2008 Pension Reform	0.1%	-0.1%	0.2%	0.9%
2022 Pension Reform	-10.8%	17.2%	-3.7%	4.5%
Improving Search	6.7%	-9.2%	-2.8%	-49.3%

Notes: The table shows for each counterfactual exercise the percentual change in formal employment (first column), total informal employment, combining informal employees and self-employed (second column), the change in the willingness to pay for formal insurance (third column), and the change in welfare losses coming from shutting down access to informal and self-employment opportunities (fourth column). The first row presents the results for the counterfactual implementing the 2008 reform, the second row the new proposed reform, and lastly the last column the counterfactual improving search frictions, by increasing the arrival rates for formal jobs by 25% for unemployed individuals.

7.2 Raising the minimum pension

Since 2022 there have been discussions from the Chilean government to implement new changes to the pension system.[35] The main pillars of the new proporsals were to raise the minimum pension (doubling) and raise the pension contributions from 10% to 16.5%. I use the model to simulate the counterfactual of these two changes. Differently from the results from the 2008 Pension Reform, the model predicts large disincentive effects for formal employment at both pre and post-retirement ages.[36] The second row of Table 8 shows that formal employment falls by 10.8%, with an increase in informal employment by 17.2%. We can see that for this exercise, the formal insurance value decreases by 3.7%, indicating how the attractiveness of the formal sector also falls. With the reform individuals are entitled to higher pension benefits even in the absence of pension contributions, reducing the value of formal jobs. That also increases the welfare value of the informal sectors, the associated losses with shutting down these sectors increase by 4.5%.

7.3 Improving search

The last counterfactual explores what would happen if the search for formal jobs were improved. I simulate this counterfactual assuming that the arrival rate for formal jobs for those unemployed increases by 25%. This would generate large effects on employment, particularly for young individuals.[37] In Table 8 we can see that formal employment would increase by 6.7%. Interestingly, this last counterfactual shows how these two measures do not need to move in the same direction. The improvement on search leads to a large positive effect on formal employment. This is associated with a very large decrease in the value of the informal sectors, which is reduced by half. The insurance value of formal jobs is also reduced. This is expected, as the relative insurance value of unemployment insurance decreases when individuals can find jobs at faster rates.

7.4 Counterfactuals and insurance values

In section 6.3, I discussed how we can compute the value informal employees and self-employed individuals would be willing to give up to become formal em-

[35] For instance, check `https://web.archive.org/web/20240613153237/https://www.spensiones.cl/portal/institucional/594/articles-15494_recurso_1.pdf`

[36] Figure A.14a presents the results by age.

[37] Figure A.14b presents the results by age.

ployees (WTP) and the welfare costs associated with closing access to informal and self-employment. The counterfactuals show how we can interpret these values as summary measures of the attractiveness and insurance of these sectors. They respond to changes and are intrinsically associated with the estimated employment impacts for each scenario.

8 Conclusion

Informality corresponds to a large share of the labor force in developing countries. Individuals working informally do not contribute to social security and are usually excluded from the main social insurance programs. In this paper, I explore how individuals make savings and labor market decisions in the presence of informality, risk, and public insurance.

I develop a model where risk-averse individuals decide on savings and employment over the life cycle. The model contemplates important risks such as employment risks, uncertain prospects in the labor market, earnings volatility, and mortality risk. There is a rich characterization of social insurance through unemployment insurance, severance payments, and pensions. The introduction of savings is crucial as it allows the labor market behavior to be contingent on asset levels and accounts for investments in physical capital for self-employment activities. These mechanisms are important in explaining the observed life cycle allocation of sectors and other features of the data.

I use the model to estimate the value of formal jobs, arising from more stability, better job search prospects, and access to different formal insurance mechanisms, such as unemployment insurance, severance pay, and pensions. Informal workers are willing to forgo a substantial fraction of their earnings to be in the formal sector. At the same time, informal opportunities are valuable as they insure against unemployment risk. Through counterfactual exercises, I show how these two measures can be seen as summary measures of the attractiveness of these sectors, given the overall policy environment.

REFERENCES

Albertini, J. and Terriau, A. (2019). Informality over the life-cycle, *Journal of Economic Dynamics and Control* **105**: 182–202.

Albrecht, J., Navarro, L. and Vroman, S. (2009). The effects of labour market policies in an economy with an informal sector, *The Economic Journal* **119**(539): 1105–1129.

Andrews, I., Gentzkow, M. and Shapiro, J. M. (2017). Measuring the sensitivity of parameter estimates to estimation moments, *The Quarterly Journal of Economics* **132**(4): 1553–1592.

Attanasio, O., Meghir, C. and Otero, A. (2011). Pensions, work, and informality: The impact of the 2008 chilean pension reform.

Audoly, R. (2024). Self-employment and unemployment risk, *Technical report*.

Azuara, O. and Marinescu, I. (2013). Informality and the expansion of social protection programs: Evidence from mexico, *Journal of health economics* **32**(5): 938–950.

Behrman, J., Calderon, M. C., Mitchell, O. S., Vasquez, J. and Bravo, D. (2011). First-round impacts of the 2008 chilean pension system reform.

Berniell, I., Berniell, L., De la Mata, D., Edo, M. and Marchionni, M. (2021). Gender gaps in labor informality: The motherhood effect, *Journal of Development Economics* **150**: 102599.

Bianchi, M. and Bobba, M. (2013). Liquidity, risk, and occupational choices, *Review of Economic Studies* **80**(2): 491–511.

Bloise, C. R. and Santos, M. R. (2022). Unemployment insurance, informality, and precautionary savings, *Technical report*.

Bobba, M., Flabbi, L. and Levy, S. (2022). Labor market search, informality, and schooling investments, *International Economic Review* **63**(1): 211–259.

Bobba, M., Flabbi, L., Levy, S. and Tejada, M. (2021). Labor market search, informality, and on-the-job human capital accumulation, *Journal of Econometrics* **223**(2): 433–453.

Bosch, M. and Esteban-Pretel, J. (2012). Job creation and job destruction in the presence of informal markets, *Journal of Development Economics* **98**(2): 270–286.

Britto, D. G. C. (2022). The Employment Effects of Lump-Sum and Contingent Job Insurance Policies: Evidence from Brazil, *The Review of Economics and Statistics* pp. 1–18.

Burdett, K. and Mortensen, D. T. (1998). Wage differentials, employer size, and unemployment, *International Economic Review* pp. 257–273.

Calderón-Mejía, V. and Marinescu, I. E. (2012). The impact of colombia's pension and health insurance systems on informality.

Cattaneo, M. D., Crump, R. K., Farrell, M. H. and Feng, Y. (2024). On binscatter, *American Economic Review* **114**(5): 1488–1514.

Cirelli, F., Espino, E. and Sánchez, J. M. (2021). Designing unemployment insurance for developing countries, *Journal of Development Economics* **148**: 102565.

Conesa, J. C., Kitao, S. and Krueger, D. (2009). Taxing capital? not a bad idea after all!, *American Economic Review* **99**(1): 25–48.

Conti, G., Ginja, R. and Narita, R. (2023). The value of health insurance: a household job search approach, *Technical report*.

Crawford, R. and O'Dea, C. (2020). Household portfolios and financial preparedness for retirement, *Quantitative Economics* **11**(2): 637–670.

Cruces, G. and Bérgolo, M. (2013). Informality and contributory and non-contributory programmes. recent reforms of the social-protection system in uruguay, *Development Policy Review* **31**(5): 531–551.

da Costa, C. E. and Lobel, F. (2022). The cost of informality: An optimal taxation approach.

de Azevedo, R. R. (2022). Essays on job displacement insurance policies in developing economies.

Delalibera, B. R., Ferreira, P. and Parente, R. (2023). Social security reforms, retirement and sectoral decisions.

Engbom, N., Gonzaga, G., Moser, C. and Olivieri, R. (2022). Earnings inequality and dynamics in the presence of informality: The case of brazil.

French, E. and Jones, J. B. (2011). The effects of health insurance and self-insurance on retirement behavior, *Econometrica* **79**(3): 693–732.

Gerard, F. and Gonzaga, G. (2021). Informal labor and the efficiency cost of social programs: Evidence from unemployment insurance in brazil, *American Economic Journal: Economic Policy* **13**(3): 167–206.

Gonzalez-Rozada, M. and Ruffo, H. (2016). Optimal unemployment benefits in the presence of informal labor markets, *Labour Economics* **41**: 204–227.

Granda, C. and Hamann, F. (2015). Informality, saving and wealth inequality in colombia.

Haanwinckel, D. and Soares, R. R. (2021). Workforce composition, productivity, and labour regulations in a compensating differentials theory of informality, *The Review of Economic Studies* **88**(6): 2970–3010.

Herreño, J. and Ocampo, S. (2023). The macroeconomic consequences of subsistence self-employment, *Journal of Monetary Economics* **136**: 91–106.

Huneeus, C., Leiva, S. and Micco, A. (2012). Unemployment insurance and search effort in chile.

Joubert, C. (2015). Pension design with a large informal labor market: Evidence from chile, *International Economic Review* **56**(2): 673–694.

Joubert, C. and Todd, P. E. (2022). Gender pension gaps in a private retirement accounts system: A dynamic model of household labor supply and savings, *Journal of Econometrics* p. 105337.

Kaplan, G. and Violante, G. L. (2014). A model of the consumption response to fiscal stimulus payments, *Econometrica* **82**(4): 1199–1239.

Kotlikoff, L. J., Smetters, K. and Walliser, J. (1999). Privatizing social security in the united states—comparing the options, *Review of Economic Dynamics* **2**(3): 532–574.

Lopez Garcia, I. (2015). Human capital and labor informality in chile: a life-cycle approach.

McKiernan, K. (2021). Social security reform in the presence of informality, *Review of Economic Dynamics* **40**: 228–251.

Meghir, C., Narita, R. and Robin, J.-M. (2015). Wages and informality in developing countries, *American Economic Review* **105**(4): 1509–46.

Moreno, C. (2022). The impact of pension systems in labor markets with informality.

Narita, R. (2020). Self-employment in developing countries: A search-equilibrium approach, *Review of Economic Dynamics* **35**: 1–34.

Nishiyama, S. (2011). The budgetary and welfare effects of tax-deferred retirement saving accounts, *Journal of Public Economics* **95**(11-12): 1561–1578.

O'Dea, C. (2018). Insurance, efficiency and the design of public pensions.

Pardo, C. and Ruiz-Tagle, J. (2016). The dynamic role of specific experience in the selection of self-employment versus wage-employment, *Oxford Economic Papers* **69**(1): 189–212.

Parente, R. (2022). Minimum wages, inequality, and the informal sector, *Technical report*.

Todd, P. and Vélez-Grajales, V. (2008). How pension rules affect work and contribution patterns: a behavioral model of the chilean privatized pension system.

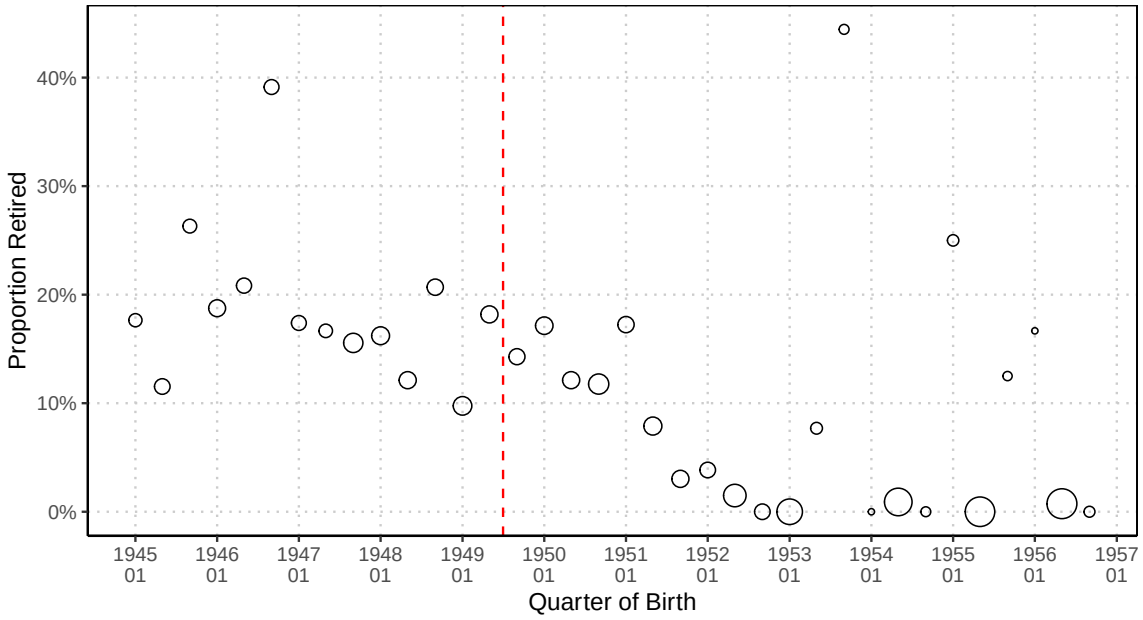
Ulyssea, G. (2010). Regulation of entry, labor market institutions and the informal sector, *Journal of Development Economics* **91**(1): 87–99.

Zenou, Y. (2008). Job search and mobility in developing countries. theory and policy implications, *Journal of development economics* **86**(2): 336–355.

Online Appendices

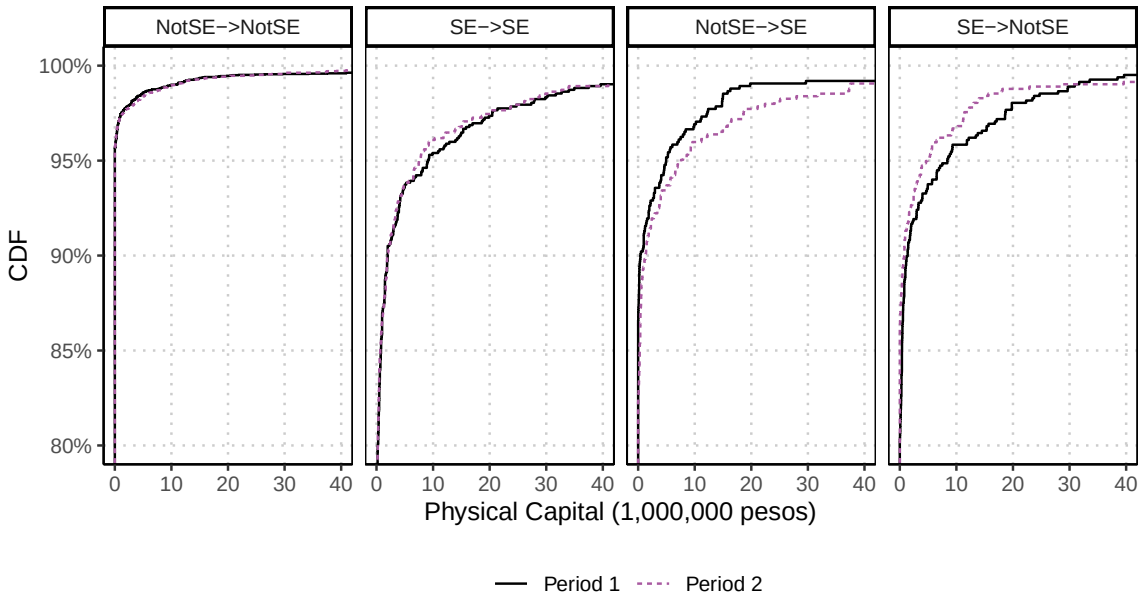
Appendix A - Appendix Tables and Figures

Figure A.1: Proportion retired at age 55 by quarter of birth



Notes: The figure shows the proportion of individuals retired by age 55 by quarter of birth. The size of each circle is proportional to the number of individuals. The vertical red line represents the threshold introduced by the 2004 reform.

Figure A.2: Self-employment and wealth allocated to physical capital



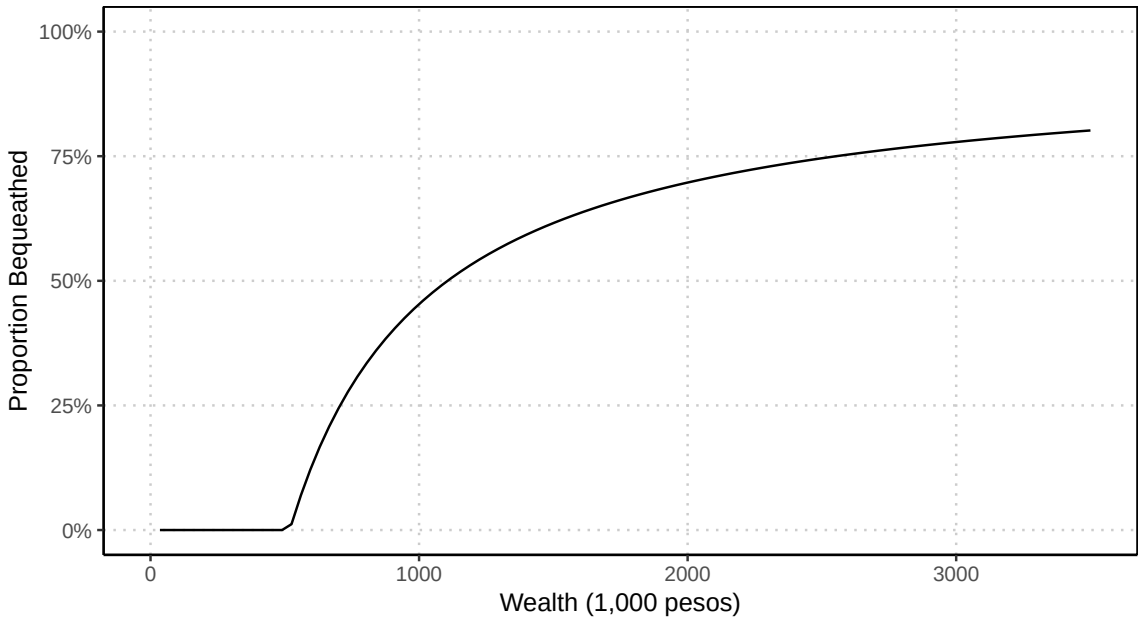
Notes: The figure shows the empirical cumulative density function (CDF) of the physical capital variable. The four panels plot the CDFs for different groups, classified as their employment status in two surveys. NotSE stands for those not self-employed. SE stands for those self-employed. Therefore, in the first graph, NotSE→NotSE stands for those not self-employed in the first period and who continued to not be self-employed in the second survey. The **solid black** plots the CDF for the first survey, and the dotted purple line shows the curve for the second period. For better visualization, the graph is truncated from below at the 80% level and from above at 50 million pesos.

Table A.1: Work arrangements

	Formal Workers	Informal Workers	Self-Employed
Panel A. Hours of work			
[1-20]	0.9%	2.9%	9.1%
[21-35]	0.9%	4.5%	12.8%
[36-44]	6.1%	8.3%	15.0%
[45-48]	73.8%	60.4%	26.7%
[49-100]	18.3%	23.9%	36.4%
Panel B. Workplace			
Firm Site	70.5%	56.2%	14.2%
Home	1.9%	3.6%	18.3%
Other houses	2.5%	5.7%	24.9%
In the streets	6.2%	9.2%	18.5%
Other	18.9%	25.3%	24.0%

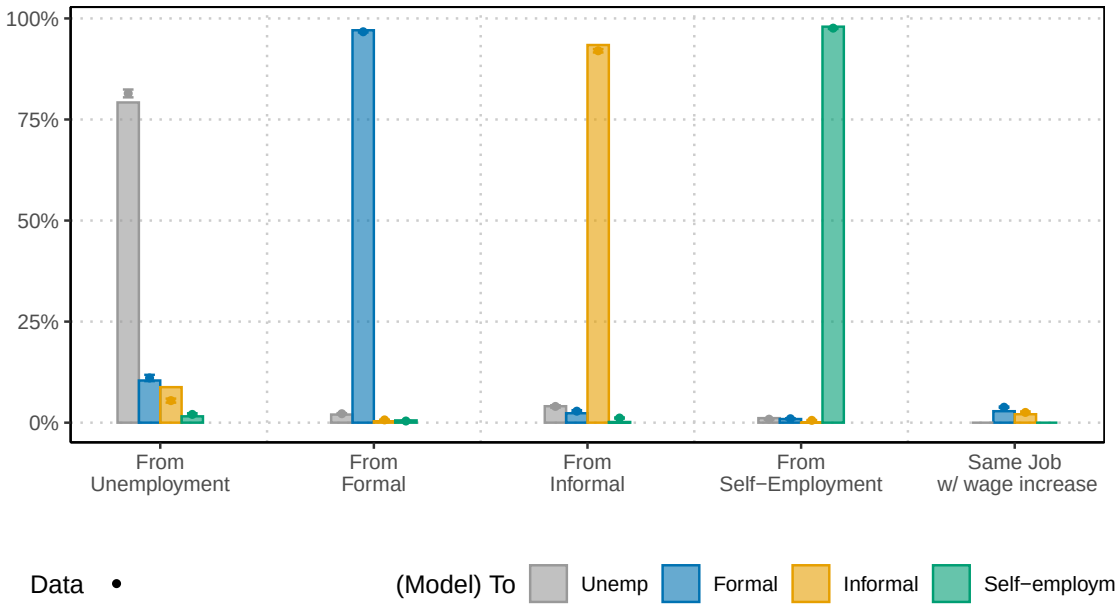
Notes: The table shows the distribution of hours of work (panel A) and workplace (panel B) for formal workers, informal workers, and self-employed individuals. In each panel, the columns sum to 100%.

Figure A.3: Proportion of wealth bequest as a function of wealth



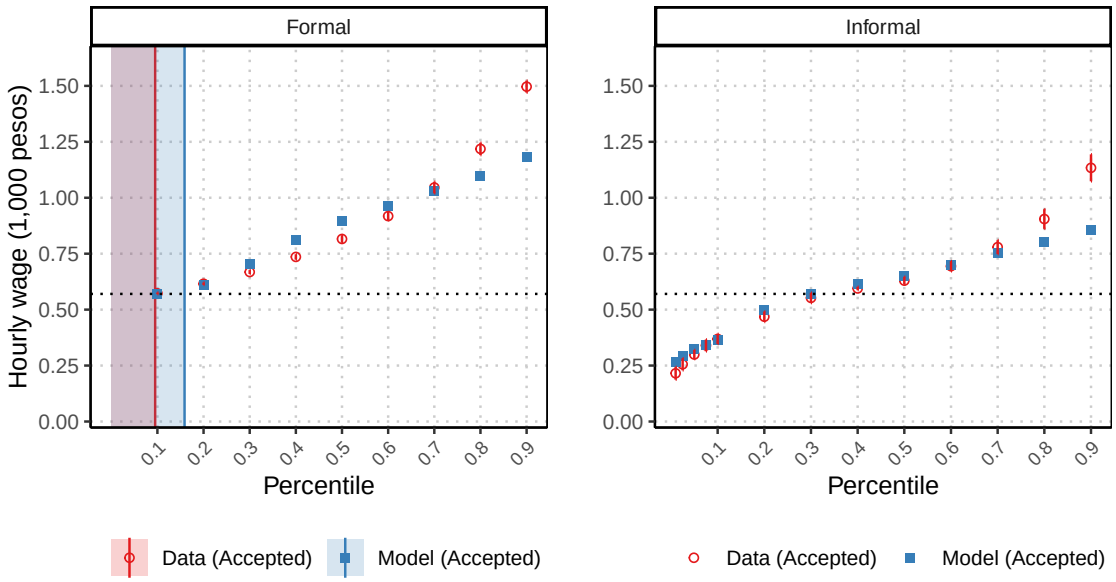
Notes: The figure shows the proportion of wealth bequeathed in the last period of life, when individuals face death with certainty. The function takes into account the interest rate (r), the discount rate (β), the coefficient of risk-aversion (γ), the consumption weight (ν), the bequest weight (ψ) and the bequest shifter ($\bar{K}$).

Figure A.4: Transitions in the model and in the data



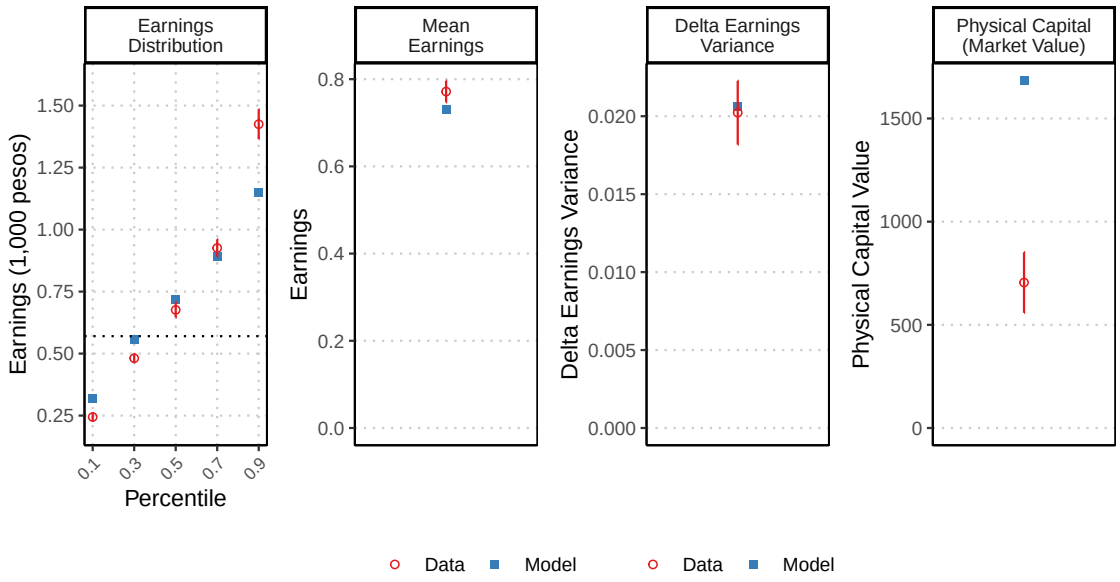
Notes: The figure shows the transitions rates in the data and simulated in the model. The colors highlight the destination sector (gray for unemployment, blue for formal, yellow for informal, and green for self-employment). The sector of origin is on the x-axis. The first four groups are for individuals coming from unemployment, formal, informal, and self-employment. The last group shows individuals staying in the same sector with wage increases (for formal and informal workers). The points are the data, with the 95% confidence interval. The bars are the respective number implied by the model.

Figure A.5: Formal and informal wage distributions (offered and accepted)



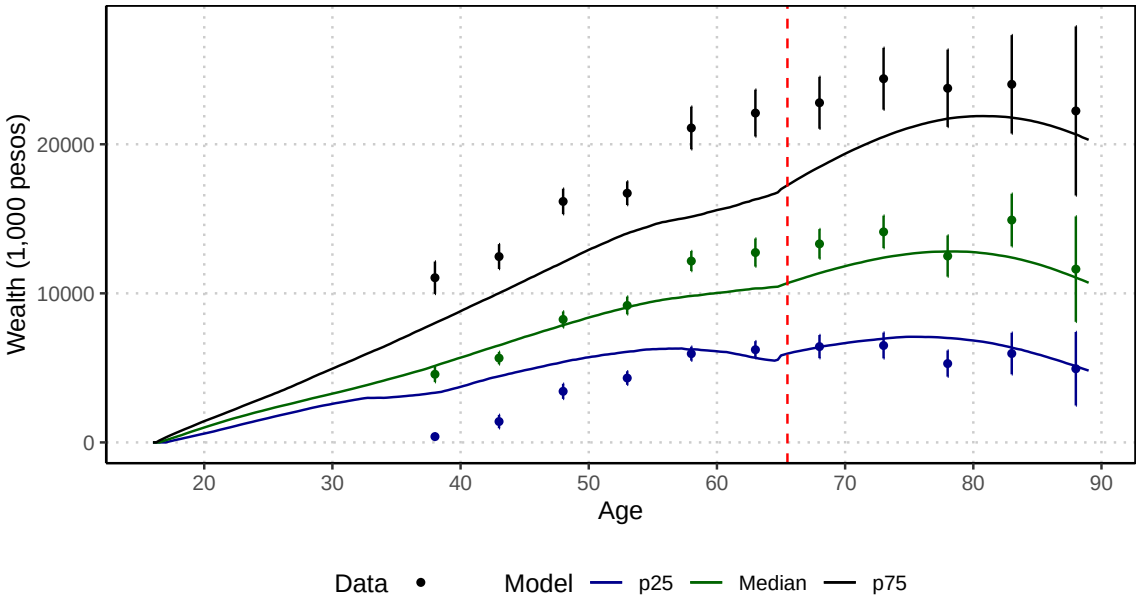
Notes: The figure shows percentiles of the earnings distribution for the formal and informal sectors, in the data and simulated in the model. The red circles show each percentile in the data, together with the 95% confidence interval. The blue squares show the equivalent percentiles in the model. Both circles and dots refer to the observed (accepted) wages.

Figure A.6: Self-employment earnings



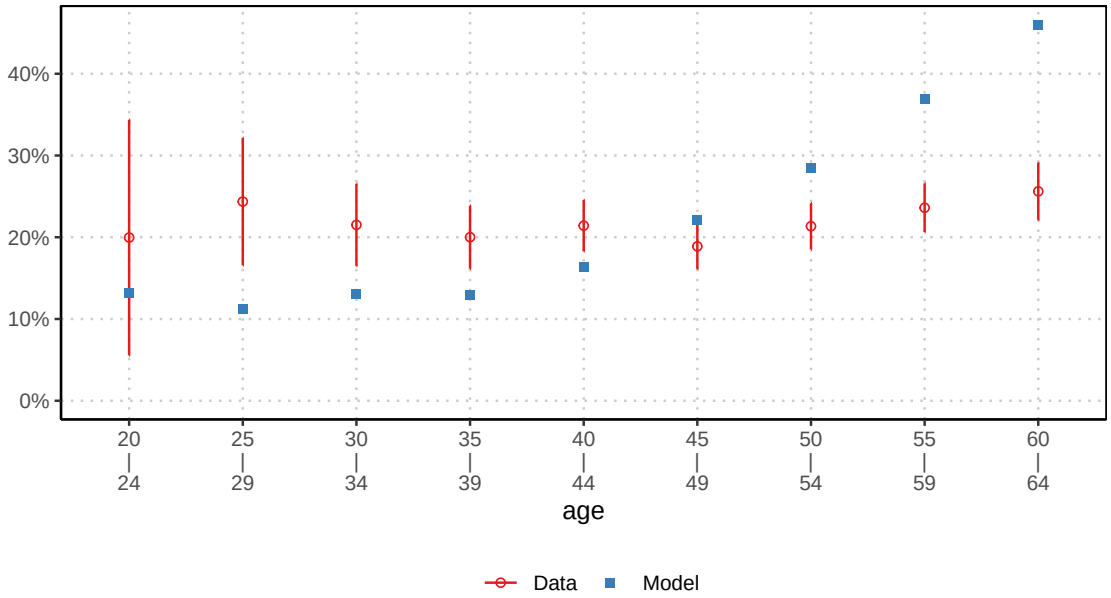
Notes: The figure shows moments of the earnings distribution for self-employed individuals in the data and simulated in the model. The red circles show each moment in the data, together with the 95% confidence interval. The blue squares show the equivalent moments in the model. The first panel shows the ventiles from the earnings distribution, the second plots the average earnings, and the third plots the variance of the first difference of earnings (earnings in period t minus earnings in period $t-1$).

Figure A.7: Wealth over the life cycle



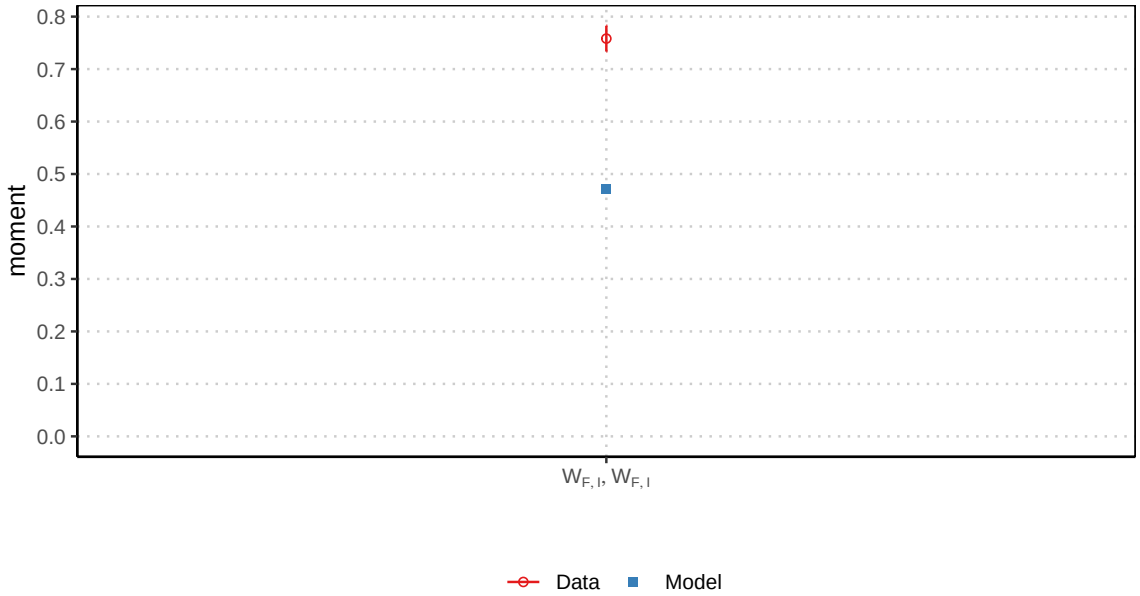
Notes: The figure shows the median (green), 25th percentile (blue), and 75th percentile (**black**) wealth over the life cycle in the data and in the model. The dots are the moments in the data, together with the 95% confidence intervals. The solid lines are the same moments in the model.

Figure A.8: Proportion of self-employed working part-time



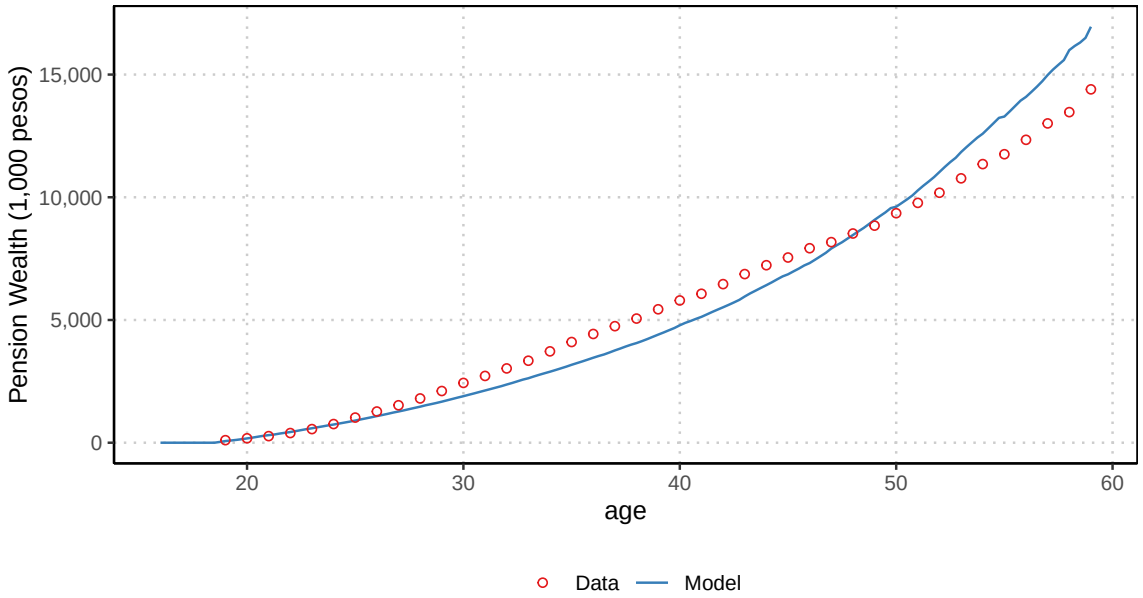
Notes: The figure shows the percentage of self-employed individuals working part-time in the data (red circles, with the 95% confidence interval) and in the model (blue squares).

Figure A.9: Within-individual correlation of wage employment



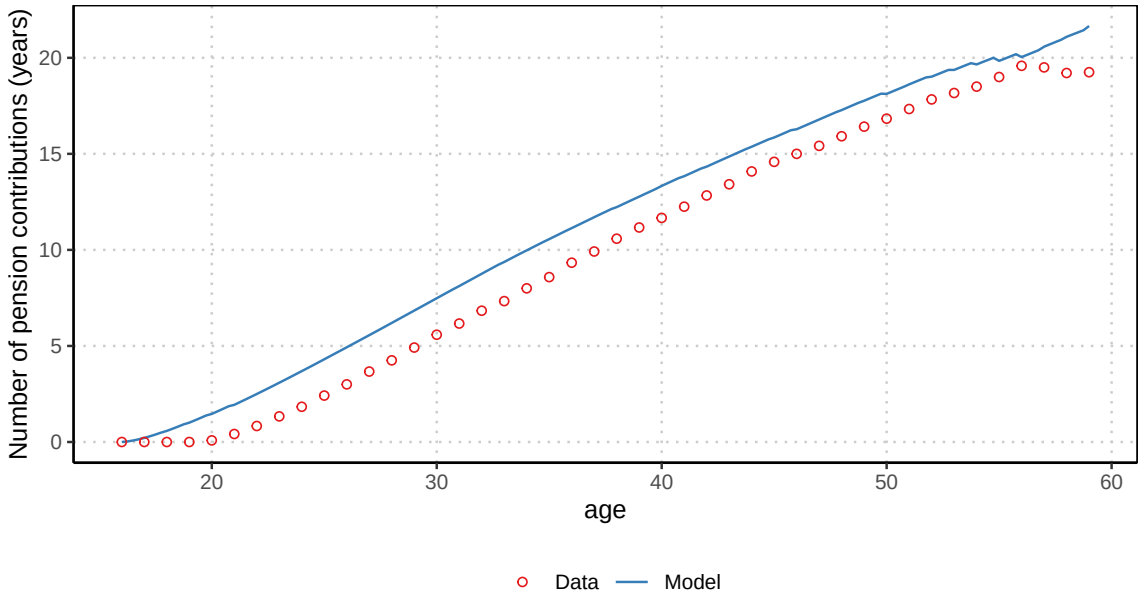
Notes: The figure plots the within-individual correlation of wages, combining formal and informal jobs in the data (red circle, with the 95% confidence interval) and in the model (blue square).

Figure A.10: Untargeted moment: Pension Wealth



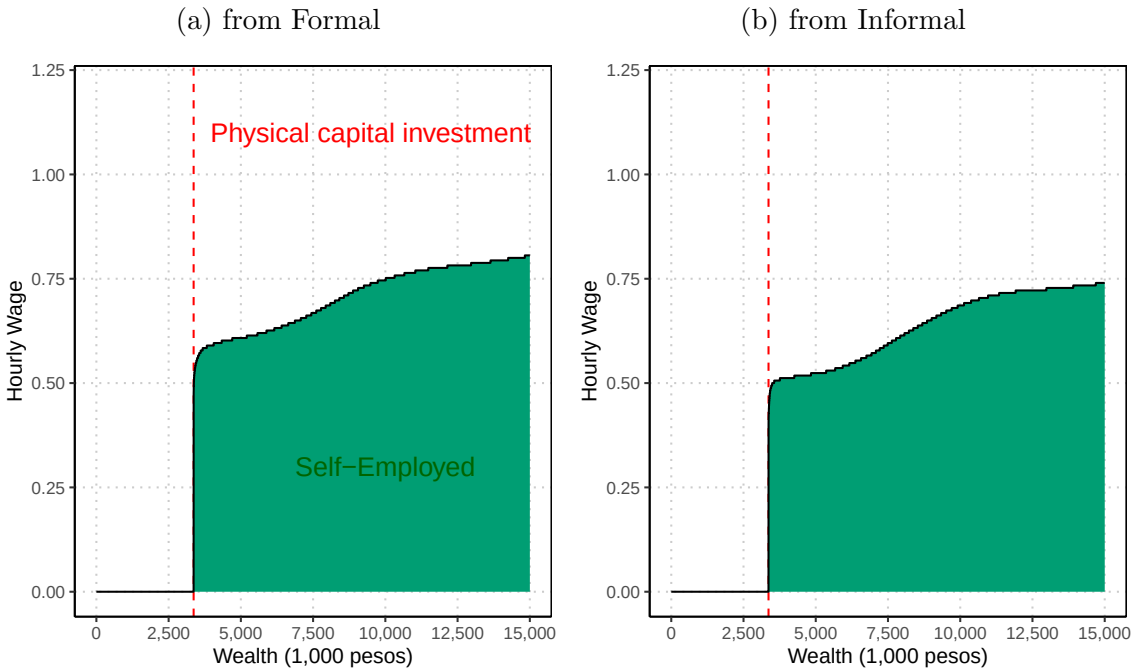
Notes: The figure shows untargeted moments, the average pension wealth (in thousand Chilean pesos) over the life cycle, in the data (red circles) and simulated in the model (blue).

Figure A.11: Untargeted moment: Number of years of pension contribution



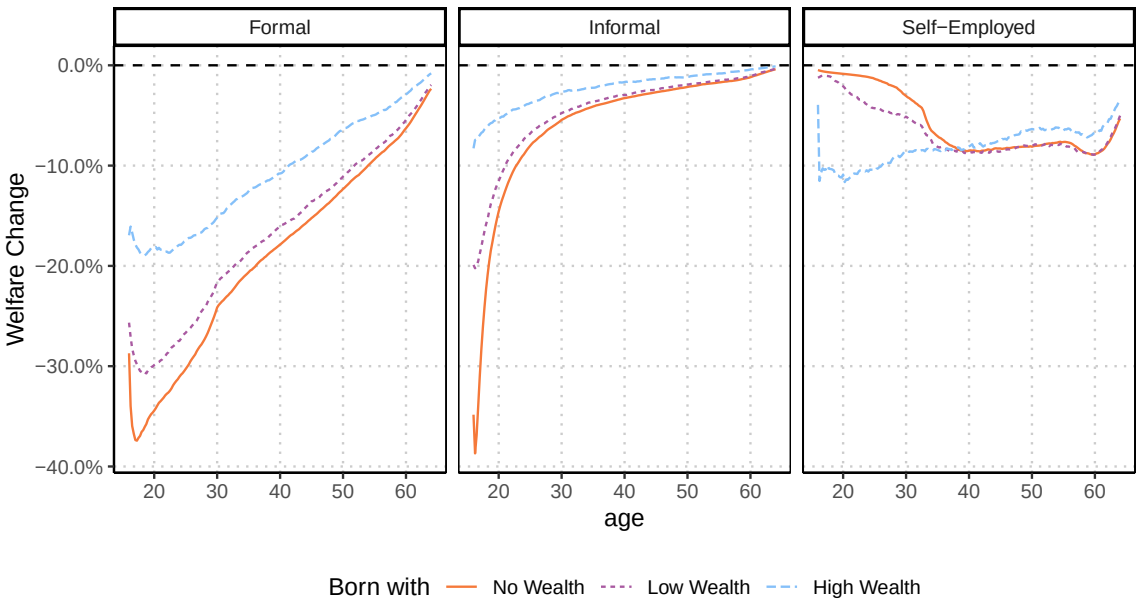
Notes: The figure shows untargeted moments, the average number of years of pension contributions over the life cycle, in the data (red circles) and simulated in the model (blue).

Figure A.12: Transitions to self-employment



Notes: The figure shows the decisions to transition into self-employment from formal (left panel) and informal employment (right plot), as a function of wealth (x-axis) and hourly wages (y-axis). The area denoted in green is the combination of wage and wealth that individuals would prefer to move to self-employment than keeping the same formal or informal job. The vertical dashed line exhibits the initial physical capital investment required for self-employment activity. The plot represents the decisions of an individual aged 20 years and with no pension wealth.

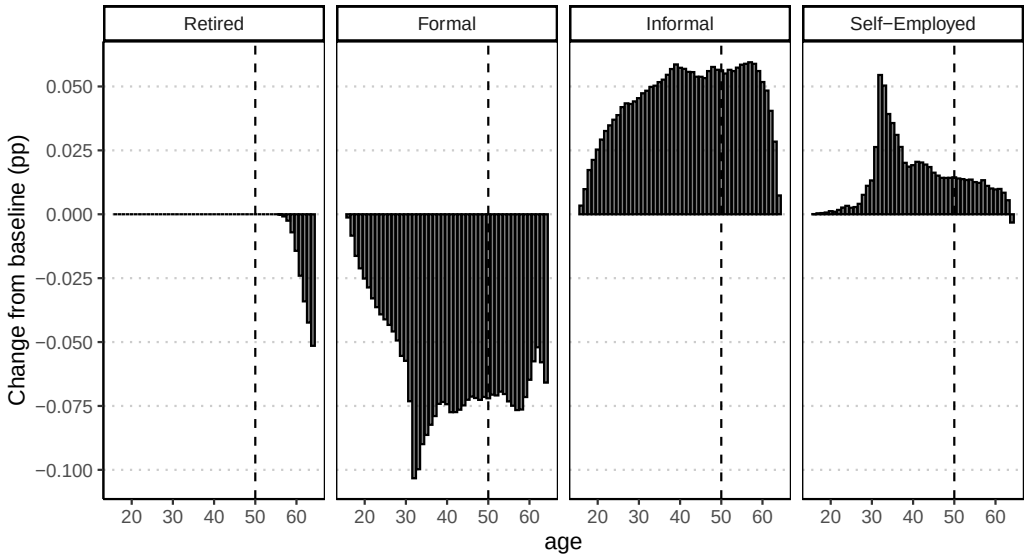
Figure A.13: Welfare losses by sector, initial wealth, and age



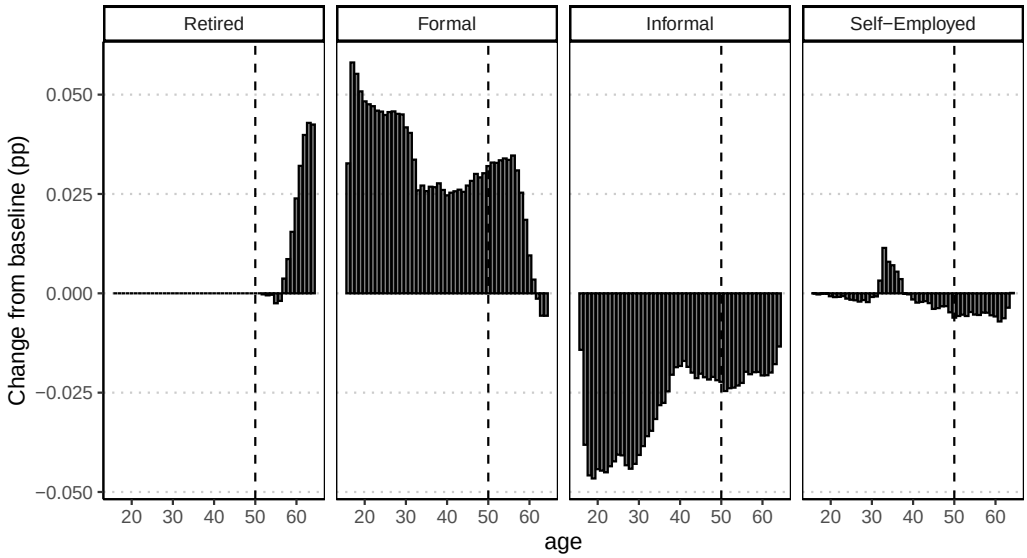
Notes: The figures plot the welfare losses associated with losing access to opportunities from the formal (left panel), informal (mid panel), and self-employment (right panel) for different ages. The three curves show the losses for individuals born with no wealth (orange), low wealth (purple), and high wealth (blue).

Figure A.14: Counterfactuals

(a) Future Pension Reform

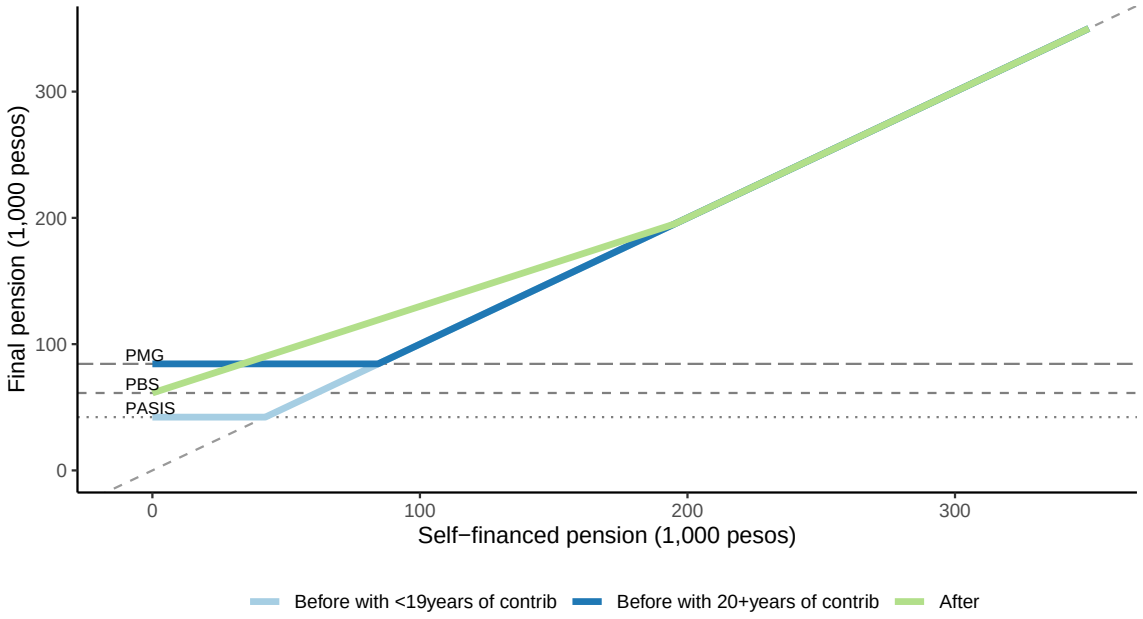


(b) Improving Formal Labor Search



Notes: The figure plots the change in the fraction of individuals retired (first panel), employed formally (second panel), informally (third plot), and self-employed (fourth panel) comparing the future reform (figure (a)) and improving in formal labor search (figure (b)). The changes are compared to the baseline economy and presented in percentage points variation for each age bracket.

Figure A.15: 2008 Pension Reform — Resulting Pension Benefits



Notes: The figure plots the relationship between the individual self-financed pension, annuitizing their entire pension wealth upon retirement and the final pension received under different pension regimes. The darker blue curve shows the final pension before the 2008 reform for individuals with more than 20 years of contribution, who were eligible for the minimum pension at the PMG level. The lighter blue is for individuals with at most 19 years of pension contribution, who were eligible for the minimum pension at the PASIS level (50% of PMG). The green curve plots the final pension after the 2008 reform. Everyone is eligible to at least the PBS level, despite the history of contribution. The new minimum pension was introduced to everyone as a bonus with an implicit tax rate of 30%.

Appendix B - Data cleaning

B.1 Data description and source

Table A.2 lists all the microdata used in this project. The two main datasets are the EPS and HPA. The four additional datasets (EME, ESI, UI Admin, and SCOMP) are used to compute additional moments and to estimate parameters governing the social insurance programs.

Table A.2: Data sources — microdata

Short Name	Period	Full Name	Description
EPS	2002-2019	Encuesta de Protección Social	Longitudinal survey (7 waves)
HPA	1981-2019	Historia Previsional de Afiliados	Administrative data from the pension system. Monthly contributions (entire period) and pension wealth (starting in 2008).
EME	2011	Encuesta de Microempreendimento	Survey targeting employers and self-employed
ESI	2013-2018	Encuesta Nacional del Empleo	Longitudinal labor survey
UI Admin	2002-2019	Muestra de la Base de Datos de Afiliados al Seguro de Cesantía	Administrative data on the unemployment system. Contains data on the participant workers, monthly payments, UI requests
SCOMP	2004-2020	Sistema de Consultas y Ofertas de Montons de Pensión	Administrative data from the pension system. Contains information on pension requests and payments.

On top of the microdata detailed in Table A.2, I use the following aggregated data and time series:

- Minimum Wage, from the statutory minimum wage

- Mortality tables, from *Superintendencia de Pensiones, Gobierno de Chile*
- Commissions charged by the pension administrators, from *Superintendencia de Pensiones, Gobierno de Chile*
- Monthly returns on pension funds, from *Superintendencia de Pensiones, Gobierno de Chile*
- Housing returns, from Organisation for Economic Co-operation and Development (OECD)
- Exchange rate between Chilean pesos and Unidades de Fomento, from *Banco Central de Chile*

B.2 Data Manipulation

B.2.1 EPS and HPA

I first take advantage of the common identifiers in the two datasets and merge all individuals in EPS and HPA. Whenever there is data on the date of birth or date of death in the HPA, I use this information. If that is not available, I rely on the self-reported data from the survey. For the educational variable, I consider the maximum reported over all the EPS waves. I excluded individuals with inconsistent gender or year of birth over the EPS waves (246 observations).

For the labor market information, I convert the reported labor market spells into monthly information for the labor market. Whenever two spell reports overlay, I kept the one where the report was closer to the reported event. I create an identifier for each spell to be able to analyze job-to-job transitions. To identify the same spell reported in two waves, I use the information on whether that employment relationship ended, the reason for termination, and the firm's characteristics and type of contract.

For information on wealth, in order to maximize the number of observations and harmonize across different waves, whenever an individual reported wealth categories in ranges, I use the mid-range value. Pension wealth is only available after 2008. For the period between 1981-2007, I construct an approximated pension wealth using the monthly contributions to pension and the average monthly return on the pension system across different pension administrators.

All the monetary values are considered in real terms, using the exchange rate

between Chilean pesos and Unidades de Fomento. All monetary values are set on Chilean pesos of August 2004. For earnings information, I de-trend them using the following regression:

$$log(w_{it}) = \alpha + \beta t + \varepsilon_{it},$$

for all reported wages in the administrative data. The trend is defined as zero value ($t = 0$) in August 2004. I them use the estimated $\hat{\beta}$ to de-trend all earnings in the formal, informal, or self-employment sectors. I compute hourly wages for those working between 10 and 60 hours, and trimming the bottom and top 2%.

For most of the analysis, I restrict the sample to individuals born between 1940 and 1989 and information from 2002–2015, when individuals were between 16 and 70 years of age. As reported in the main text, I restrict the data to men with at most high school education. I also excluded from the data individuals that report to work in the formal sector for at least 12 months, were born before 1965, and are not enrolled in any pension administrator fund. These individuals are likely to not have switched to the new pension system in 1980.

For retirement patterns, I use data up to 2019 to capture retirement at ages 65-70 for the cohort born in 1950–1954. I use wealth moments for ages 70–89, therefore, only for these moments, I use individuals born between 1915-1949. All labor market information only uses data recorded at most two years after the reported event.

B.2.2 Other Microdata

The cleaning procedure and sampling restrictions in the other dataset mirror the procedure of the two main datasets as closely as possible. For EME, I consider only men, with at most high school education reporting to work as self-employed. I use the survey in 2011, as it is the survey that records the value of assets used in self-employment activity.[38] I compute the total value of reported assets, summing the value of all reported assets. When they were reported in a range, I use the mid-range value.

For the ESI data, I combine the surveys from 2013–2018 for men with at most high school education. To reliably estimate the hourly wage, I only consider work spells with working hours between 10 and 60 hours, and I trim the top and bottom

[38] The 2009 survey also records this value, but the wording and structure of questions were different than in 2011, making it difficult to make them compatible. I prioritize 2011 as it has a larger sample.

2%. I also apply the same de-trend procedure from the main datasets. I keep only individuals who reported working as self-employed in two surveys, where the reporting was less than 12 months apart, and the spell duration was greater than 18 months in the second report. That implies that I am not considering self-employment earnings for the first six months of business.

For the administrative data on the UI system, I combine the files from the 3%, 5%, and 12% sampling, resulting in a dataset corresponding to 20% of individuals enrolled in the UI system. Whenever I need the links of users and firms, I only keep individuals with a unique link, that is, their personal identifiers and the firms' identifiers are unique. As in the main sample, I keep only men with at most high school education.

Lastly, for the SCOMP, I restrict the data to men. Unfortunately, in this dataset, I cannot restrict to individuals with at most high school education since there is no information on the educational level. I use these data to estimate the pension administrative costs. In order to do so, I further restrict to individuals who opt for the full annuitization option, without beneficiaries, and who did not claim special coverage.

B.2.3 Aggregated Data

I use the mortality tables from the *"Instituto Nacional de Estadísticas"* (INE) for the year 2003. For the commission rates in the pension system, I use the data computed by the Sistema de Pensiones for the period 1993–2019. For each month, I compute the average charged commission, weighting each pension administrator's commission rate by the number of enrolled individuals. To obtain the average return on the pension funds, I use data from Sistema de Pensiones on the monthly returns for each pension type. There are five funds, A–E, where A is the safest and E the riskiest. I use data in the interval 1982–2019. I first obtain monthly returns by getting the weighted average of each fund's return. The weights are the amount of resources in each fund.

Appendix C - 2004 Reform

Early retirement is allowed if the resulting pension benefit (y_p) is greater than a pension threshold A and a fraction α^w of the last 10-year average wage ($\overline{w}$). Therefore

early retirement is possible, if and only if:

$$y_p \geq A \quad \text{and} \quad y_p \geq \alpha^w \overline{w}$$

The 2004 reform changed three aspects of these requirements. It raised A by 36% and also the fraction α_w from 50% to 70%. It also changed how the last-10 year average wage was computed by limiting the number of months with zero earnings that can enter the average $\overline{w}$. The table below shows how these changes were gradually implemented.

Table A.3: Early retirement requirements

Date	A	α^w	$\overline{w}$
(...) - August, 2004	110% PMG = 153	50%	$\overline{w}_{old}$
September, 2004 - August, 2005	110% PMG = 153	52%	$0.7\overline{w}_{old} + 0.3\overline{w}_{new}$
September, 2005 - August, 2006	135% PMG = 188	55%	$0.5\overline{w}_{old} + 0.5\overline{w}_{new}$
September, 2006 - August, 2007	140% PMG = 195	58%	$0.3\overline{w}_{old} + 0.7\overline{w}_{new}$
September, 2007 - August, 2008	150% PMG = 209	61%	$\overline{w}_{new}$
September, 2008 - August, 2009	150% PMG = 209	64%	$\overline{w}_{new}$
September, 2009 - August, 2010	150% PMG = 209	67%	$\overline{w}_{new}$
September, 2010 - June, 2012	150% PMG = 209	70%	$\overline{w}_{new}$
July, 2012 - December, 2019	80% PMAS = 260[a]	70%	$\overline{w}_{new}$

Notes: The table shows how the pension rules governing early retirement evolved over time. The first column shows the value of the pension threshold (A). The second column exhibits the fraction of the average wage (α). Lastly, the third column presents the formula to compute the last 10 years average wage, differentiating between the *old* formula, which did not impose limits on the number of months with zero earnings to be included and the *new* which limits it at 16 months in the 120 months period.
[a] Changed introduced by the pension reform in 2008.

Appendix D - Model specifications

D.1 Net income function

When in the labor market, the net income function for an individual of type θ, working in sector j, earning w, working h hours, bringing k as assets, and with

unemployment benefits given by b, is $Y(\theta, j, w, h, k, b)$.

$$Y(\theta, j, w, h, k, b) = \begin{cases} \Upsilon\Big(rk + SUF(k)\Big) + b & \text{, if } j = U \\ \Upsilon\Big(rk + g(\theta)wh + AF(wh) - \tau wh\Big) & \text{, if } j = F \\ \Upsilon\Big(rk + SUF(k)\Big) + b + g(\theta)wh & \text{, if } j = I \\ \Upsilon\Big(rk + SUF(k)\Big) + b + e(\theta)wh & \text{, if } j = S \end{cases} \tag{12}$$

The Υ function is the income tax, given by the tax schedule in Chile. I assume that individuals in the informal or self-employment sectors can hide their labor earnings and do not pay taxes on their labor earnings. Individuals in the formal sector pay social security contributions τ. There are two welfare programs, SUF for those not formally employed and a tax credit-like policy for the formal sector, AF. Lastly, individuals can receive unemployment benefits given by b. Notice how the total labor earnings is given by the wage rate w multiplied by the number of hours h and the general ability, $g(\theta)$ for the formal and informal sector and $e(\theta)$ for self-employed.

For retired individuals the net income function will depend on the baseline pension y^P, the policy environment to be determined by θ (cohort) and a (age), and the assets k.

$$Y^{\text{Ret}}(y^P, \theta, a, k) = \Upsilon\Big(rk + \tilde{y}^P(1 - \tau_H) + SUF(k)\Big) \tag{13}$$

,where

$$\tilde{y}^P = \begin{cases} y^P & \text{, if year} < 2008 \text{ or } a < 65 \\ y^P(1 + PBS(1 - \frac{y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 0 \\ y^P(1 + PBS(1 - \frac{\vartheta y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 1 \end{cases} \tag{14}$$

Retired individuals pay health insurance contributions (τ_H) and their net pensions depend on the pension environment (before or after 2008), age (less or more than 65), and whether they retired before or after the normal retirement age (q). PBS is the minimum pension introduced by the pension reform of 2008 and PMAS the maximum pension that receives PBS.

D.2 Value function for working in the informal sector

$$\tilde{V}^I_{a+1} \coloneqq \max\Bigg\{V_{a+1}(\theta, n', p', \tilde{k}, I, w), V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\Bigg\} \tag{15}$$

and

$$\begin{aligned}
&\mathbb{E}_I[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\quad \delta_I \max\Bigg\{V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), \\
&\qquad V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\Bigg\} + \\
&\quad (1 - \delta_I)\Bigg[(1 - \lambda^F_I)(1 - \lambda^I_I)\tilde{V}^I_{a+1} + \\
&\quad \lambda^F_I(1 - \lambda^I_I) \int \max\Bigg\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w})\Bigg\} dW^F(\tilde{w}) + \\
&\quad \lambda^I_I(1 - \lambda^F_I) \int \max\Bigg\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w})\Bigg\} dW^I(\tilde{w}) + \\
&\quad \lambda^I_I \lambda^F_I \int\int \max\Bigg\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}), V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{\tilde{w}})\Bigg\} dW^F(\tilde{w}) dW^I(\tilde{\tilde{w}})\Bigg]
\end{aligned} \tag{16}$$

D.3 Value function for self-employed

$$\tilde{V}^S_{a+1} \coloneqq \max\Bigg\{\int V_{a+1}(\theta, n', p', \tilde{k}, S, \tilde{w}) dW^S_w(\tilde{w}), V_{a+1}(\theta, n', p', \tilde{k} + \pi X, U, 0), V^{\text{Ret}}_{a+1}(\theta, \tilde{k} + \pi X, y^P, q)\Bigg\} \tag{17}$$

and

$$\begin{aligned}
&\mathbb{E}_S[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\quad \delta_S \max\left\{V_{a+1}(\theta, n', p', \tilde{k} + \pi X, U, 0), V_{a+1}^{\text{Ret}}(\theta, \tilde{k}, y^P, q)\right\} + \\
&\quad (1-\delta_S)\Bigg[(1-\lambda_S^F)(1-\lambda_S^I)\tilde{V}_{a+1}^S + \\
&\quad \lambda_S^F(1-\lambda_S^I)\int \max\left\{\tilde{V}_{a+1}^I, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, F, \tilde{w})\right\} dW^F(\tilde{w}) + \\
&\quad \lambda_S^I(1-\lambda_S^F)\int \max\left\{\tilde{V}_{a+1}^I, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, I, \tilde{w})\right\} dW^I(\tilde{w}) + \\
&\quad \lambda_S^I\lambda_S^F\int\int \max\Bigg\{\tilde{V}_{a+1}^I, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, F, \tilde{w}), \\
&\qquad\qquad V_{a+1}(\theta, n', p', \tilde{k} + \pi X, I, \tilde{\tilde{w}})\Bigg\} dW^F(\tilde{w}) dW^I(\tilde{\tilde{w}})\Bigg]
\end{aligned} \tag{18}$$

D.4 Optimization problem after retirement

$$\begin{aligned}
V_a^{\text{Ret}}(\theta, k, y^p, q) = \max_{k', c}\left\{u_j(c, \ell) + \beta\Big((1-m_a)V_{a+1}^{\text{Ret}}(\theta, k', y^p, q) + m_a b(k')\Big)\right\} \\
\text{s.t.} \quad c + k' = k + Y^{\text{Ret}}(y^p, q, \theta, a, k) \\
\ell = \bar{L} \\
\underline{B} \leq k' \leq k + Y^{\text{Ret}}(y^p, q, \theta, a, k)
\end{aligned} \tag{19}$$

Appendix E - Estimation

E.1 State Space

Table A.4 below presents the 10 state variables and how they are implemented in the numerical estimation.

E.2 Numerical implementation

The model is solved using backward induction, exploiting that individuals die with certainty when they reach 100 years of age. Therefore the value function for the last period is appropriately defined. I use numerical integration for the earnings variables using the Gauss-Legendre weights for the normal distribution (self-employed

Table A.4: State space

Variable	Type	# Points	Observations
Age	Discrete	340	Age in quarters from 16 years to 100
Type I	Discrete	3	Indexing policy environment
Type II	Discrete	2	Ability sub-type
Wealth	Continuous	13	Approximated using an age-specific grid with log-increasing points
Pension Wealth	Continuous	10	Approximated using an age-specific grid with log-increasing points
Retirement Status	Discrete	3	Non-retired, retired before 65, retired after 65
Sector	Discrete	4	Unemployed, Formal, Informal, Self-employed
Wage	Continuous	12	Approximated using Gauss-Legendre weights for integration
Hours	Discrete	2	Part-time or full-time
Unemployment Insurance Status	Discrete	3	$n \in \{0, 1, 2\}$

earnings) and the beta distribution (for formal and informal wage distributions). I use linear interpolation in one, two, and three dimensions to approximate the value for the three continuous variables. Given the concavity of the utility function, to improve the quality of the interpolation I compute the grids for wealth and pension wealth with the distance between points in log-scale. That increases the coverage of the low levels of wealth and pension wealth, where the utility function exhibits more curvature.

The optimization algorithm to solve the optimal value of savings for each point in the state space uses a derivative-free one-dimension Brent's algorithm. To optimize the SMM criteria function, I first use a global algorithm (Controlled Random Search), followed by a local optimization algorithm (Brent's algorithm). Both are derivative-free.

I compute numerical derivatives only to compute the standard errors and the sensitivity matrix proposed by Andrews et al. (2017). To do that, I compute numerical derivatives using two symmetrical deviations around each estimated parameter, with a step size of 2.5%.

Appendix F - Sensitivity Matrix

I compute the sensitivity matrix proposed by Andrews et al. (2017). I plot the results for each parameter in the collection of graphs below (Figures A.16–A.19). In the x-axis, there are the 212 moments used in the estimation, separated into 10 groups, which are described in Table A.5 below. Each circle reads as the impact of changing one standard deviation of that given moment on the estimated parameter. The color codes whether the impact is positive or negative. For instance, in the first plot of figure A.16 we can see that the moments that most affect the estimation of the discount rate β are those associated with the wealth (group 3) moments.

Table A.5: Groups of moments

Group	Description
G01	Transitions from j to j'
G02	Age profile for each sector
G03	Wealth age-profile
G04	Formal earnings distribution
G04	Informal earnings distribution
G06	Self-employed earnings
G07	Physical capital
G08	Retirement before/after 1949
G09	Proportion working part-time over life cycle
G10	Wage correlation

Figure A.16: Sensitivity Matrix - I

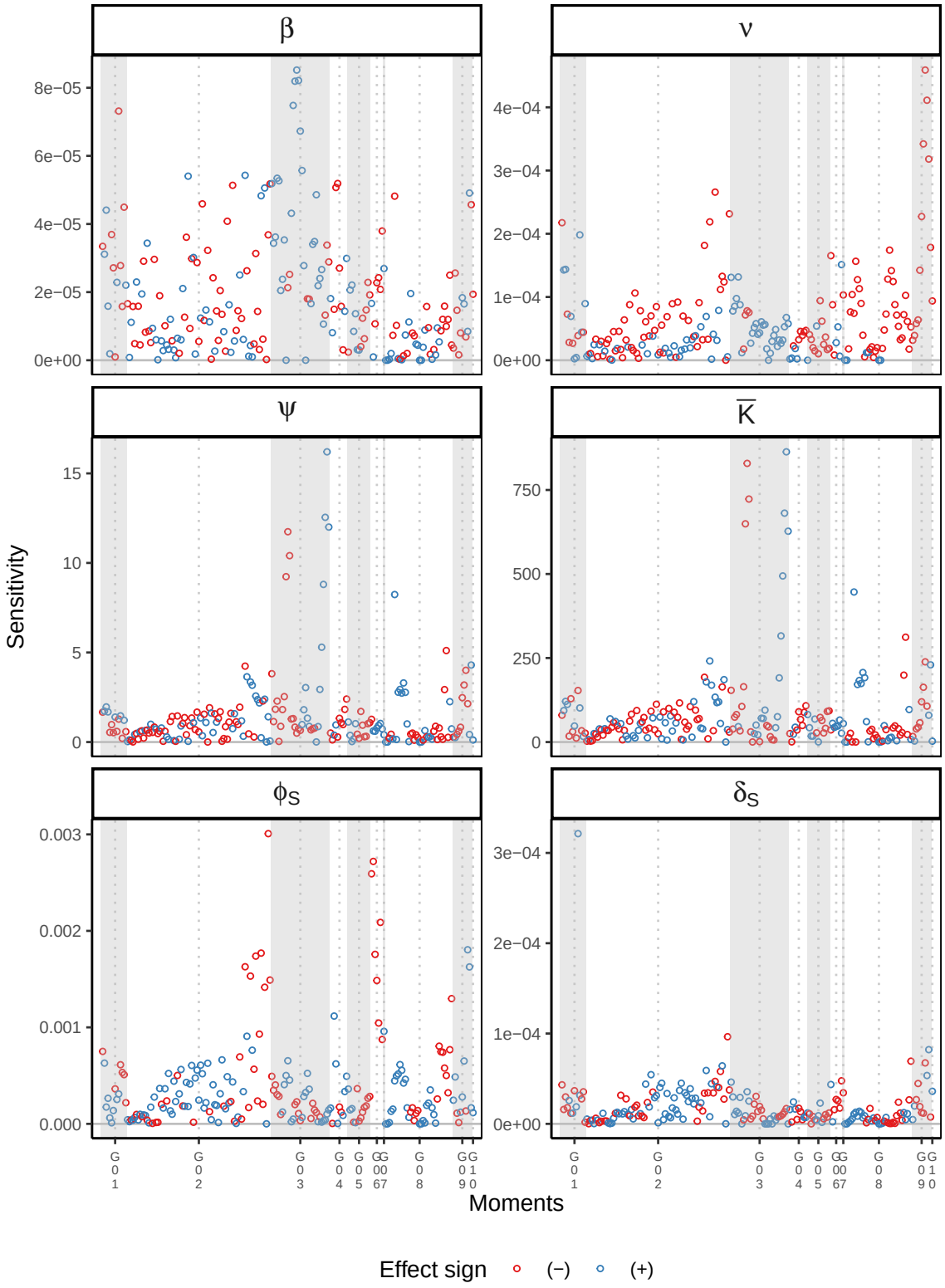


Figure A.17: Sensitivity Matrix - II

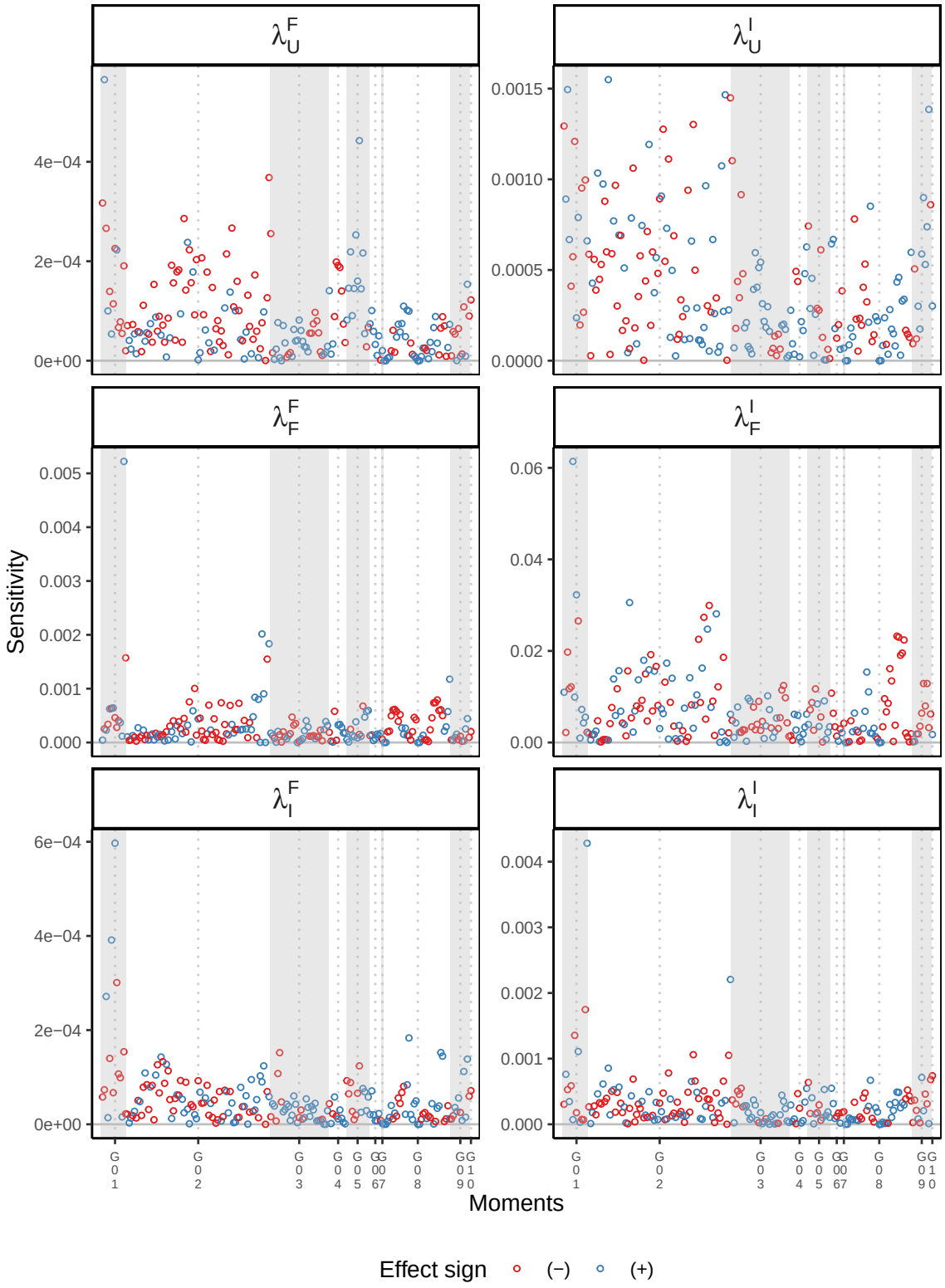


Figure A.18: Sensitivity Matrix - III

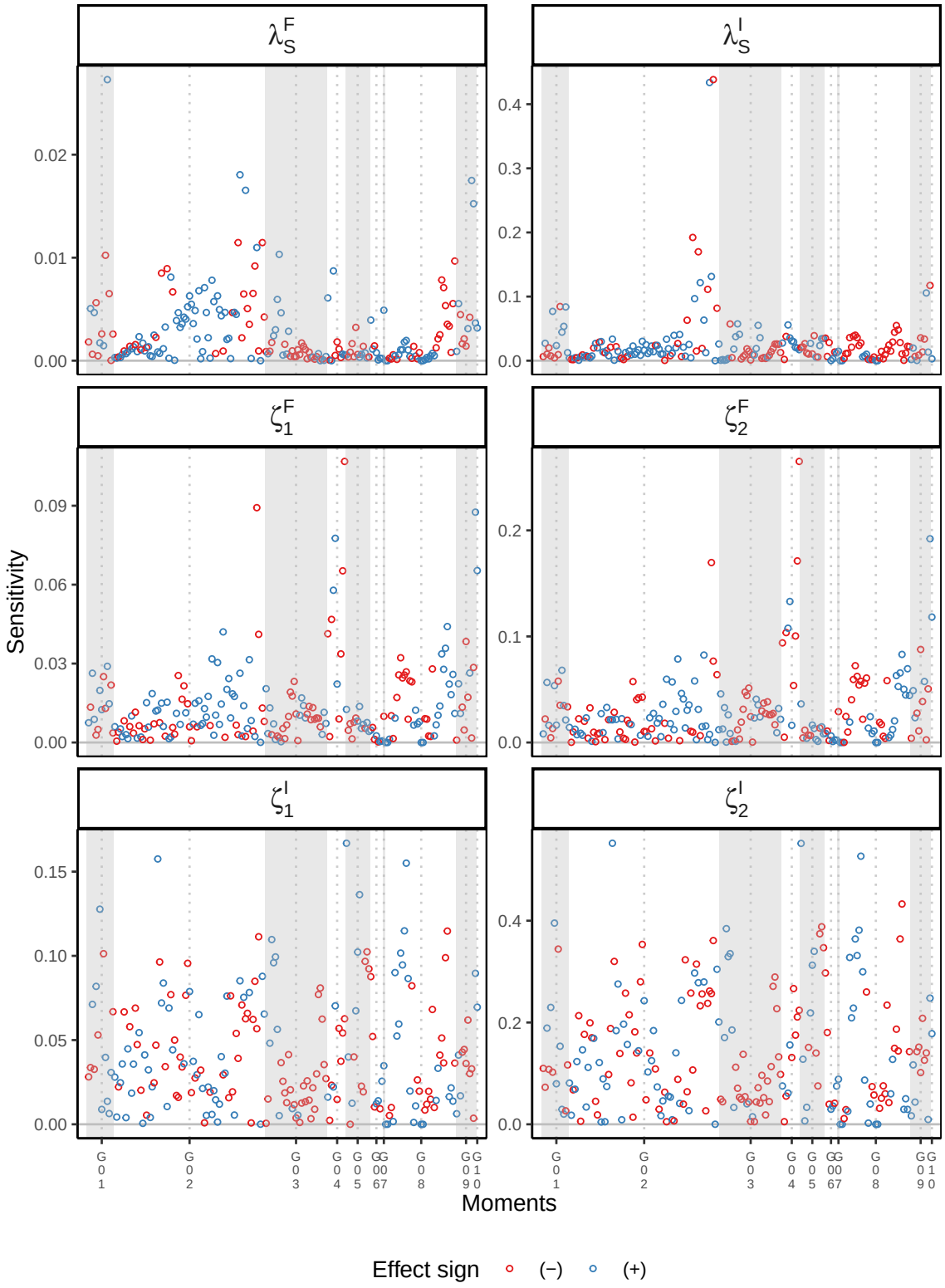


Figure A.19: Sensitivity Matrix - IV