Labor market informality, risk, and insurance*

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Abstract

Distinct working arrangements offer different prospects for workers. Formal employment provides insurance requiring contributions and taxes. Informal and self-employment lack insurance but offer faster exits from unemployment. Workers face complex tradeoffs involving present and future risks, insurance, liquidity, and earnings. To understand how employment decisions depend on risk, savings, and insurance, I develop a life-cycle model of employment and savings in a frictional search environment. I estimate the model exploiting linked longitudinal survey and administrative Chilean data and policy reforms. Workers attribute substantial value to the insurance and stability provided by formal jobs: informal employees would give up one-third of their net earnings to formalize their jobs. At the same time, informal opportunities insure workers against unemployment risk. Counterfactual policy analyses reveal that ignoring risk aversion and the full insurance bundle embedded in formal employment leads to biased responses to social security reforms. The findings highlight that both formality and informality provide distinct forms of insurance, and that effective policy design requires accounting for the dynamic tradeoffs workers face over the life cycle.

1 Introduction

The International Labor Organization estimates that around 58% of global employment is informal.[1] Informal jobs do not comply with labor market regulations, have more volatile earnings, and do not directly contribute to social security (Engbom et al., 2022). Consequently, these workers have limited access to several social insurance programs, leaving them considerably more vulnerable to risks than those formally employed. However, if individuals

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

can more easily find informal jobs or engage in informal activities, their need for formal insurance may be reduced (Gerard and Gonzaga, 2021). The relationship between informality, risk, and insurance is thus multifaceted, involving complex tradeoffs faced by workers.

Formal jobs are more stable and associated with many benefits, including different insurance programs, such as unemployment insurance and pensions. This insurance covers individuals against various risks, both in the short and long term. Therefore, formal jobs are often assumed to be more valuable than informal ones. However, it is 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 misses the intertemporal dimension of employment choices, ignoring how current employment choices are intrinsically associated with future opportunities, risks, and protection. This incomplete characterization of the formal and informal tradeoff has strong implications for policy design, as it may misrepresent individual employment choices and responses to policy changes.

To address this gap, I develop a life-cycle model where agents choose employment and savings in a frictional and risky environment. This dynamic framework is well equipped to assess the role of risk and insurance in shaping employment decisions, both in the short and long run. The model is estimated using rich microdata and reduced-form results from pension reforms. Changes in social security policies are interesting to consider, as they are at the heart of the insurance and cost tradeoffs workers face when choosing employment types with differential access to these programs. The estimated model allows me to estimate the total value of formal employment, including better stability and search prospects and access to the safety net. The same framework is also useful for discussing and quantifying the buffer role of informal employment, which can also be viewed as insurance for workers. Importantly, this framework shows how ignoring the value agents place on insurance implies overly sensitive responses to changes in social security. For instance, it shows how considering short-term risk and insurance, such as coming from unemployment, plays an important role for the design of social security programs.

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 coexist 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 result 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 are rarely available.

Exploiting these data, I first show how three broad employment categories — formal employees, informal employees, and self-employed — have different characteristics, particularly in the age profile, working hours, workplace, and, importantly, different access to social security. These differences highlight the importance of considering these three categories as distinct employment types when analyzing and modeling individual labor market choices. Exploiting the longitudinal dimension, I show how the start of self-employment activity is associated with investments in business-related physical capital. This is important as it makes the entry into self-employment contingent on savings and/or the credit market, which is distinct from entry into formal or informal employment jobs.

The data are also useful to analyze individuals' responses to changes in social security. I exploit a pension reform implemented in 2004, which tightened the requirements for early retirement, which was discontinuously implemented across time and cohorts. Comparing adjacent cohorts, I estimate the causal effects of this reform, which shrunk early retirement by 16 percentage points (pp), a sizable reduction from a baseline retirement probability of 23%. As individuals stay longer in the labor force, we observe increases in formal and non-formal employment. This reform is interesting, as it affects the relative incentives of formal and informal employment, considering that only formal employees have access to pensions. This adjacent-cohort analysis captures the short-term causal effects of the reform on individuals close to retirement. However, it is silent on how younger cohorts may change their labor trajectories when facing a pension system that delays retirement. To answer this question, we need a dynamic framework.

Guided by these empirical findings, I develop a life-cycle model where risk-averse agents decide on savings and employment in a frictional environment. In the model, 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 involves 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 risks. First, they can accumulate savings and use it as a self-insurance 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. The government cannot monitor informal employees and the self-employed. They do not pay taxes or contribute to pensions but have limited access to social insurance through non-contributory welfare transfers and minimum pension guarantees. Retirement is an endogenous choice, capturing all incentives from the pension design.

I estimate the model primitives using the microdata and exploiting the pension reforms in a two-stage method of simulated moments. The model is estimated in a quarterly frequency to also capture short-run fluctuations in employment and income, instead of only annual employment choices. The estimated model makes three important contributions. First, it presents novel endogenous mechanisms to generate the labor market patterns over the life-cycle that do not rely on exogenous time-varying parameters. Second, it is well-suited to compute the insurance values from the formal and informal sector. Third, it can be used to study individual's responses to changes in social security, and how they depend on the value individuals place on different forms of insurance.

The model allows the job search behavior to be contingent on savings. Therefore, individuals with different levels of assets may have different reservation wages for offers in the formal and informal sector. That is the main channel through which the model 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. 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 accounts for the observed cross-sectional correlation of wealth and informality, not solely due to ex-post lower earnings in the informal sector but from active endogenous job choices.[2] Another important channel is the necessity of up-front investments in self-employment activity. This acts as an important barrier to entry into this sector. This barrier, along with amenities that are more valuable for older individuals, explains the observed increase in self-employment over the life cycle. The closest paper in the literature to explain the life-cycle allocation is Narita (2020), which has flexible arrival rates that change over the life-cycle. The contribution of the current paper is replicating the same life-cycle pattern without using age-dependent parameters, relying solely on the endogenous decisions of agents.

[2]This is a similar mechanism from Bilal and Rossi-Hansberg (2021). In their case, upon a negative shock, individuals can shift resources from the future to the present, by moving to a less-expensive region which is associated with worse labor market prospects. In my model individuals can also shift resources to the present by accepting a lower-pay informal job with worse future prospects rather than waiting longer for a formal job.

I use the estimated model to compute the overall value of a formal job. To do so, I compute the willingness to pay (WTP) for formalization that quantifies all benefits related to formal employment. On average, an informal employee would forgo 38.2% of their net earnings to have their job "formalized". Decomposing this number, around 76% of it is linked to higher stability and better job search prospects, and the remaining 24% to the insurance package. Both unemployment insurance and pensions contribute to this insurance value. The WTP is highly heterogeneous. It is notably higher for individuals with fewer assets, for whom the benefits of a formal job are more valuable.

Even though formal opportunities are valuable, informality may be an important way out of unemployment. Particularly because informal opportunities arrive faster than formal jobs. I use the model to compute how individuals value these opportunities by calculating the welfare losses associated with limiting access to informal jobs. Losing access to informal employment is highly costly, it is equivalent to reducing consumption and leisure by 11.9% over the life cycle. The loss is much higher for individuals born with no assets highlighting the insurance role of the informal sector. Informal opportunities are valuable as they can be a faster route out of unemployment, particularly when remaining unemployed is costly.

There is a large literature analyzing informality decisions (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). 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.[3] Therefore, there is no role for insurance programs nor additional value attributed to formal offers. This paper includes risk aversion, savings, and social security in this search framework with informality. This novel enhancement is important and fruitful. It is essential to discuss the role of risk and the value of insurance provided by social security in workers' labor market decisions. But it also interacts closely with the design of social security policies and their implications for informality. Closer to this paper are Herreño and Ocampo (2023), who study how workers choose between formal jobs and self-employment in Mexico. My paper mainly differs by introducing the safety net associated with formal employment. This is essential to capture the insurance provided and the dynamic incentives associated with employment choices. Moreover, this paper also differs by accounting for heterogeneity in the informal sector, differentiating between informal employees and self-employed individuals. This heterogeneity is essential to account for the

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

many ways they differ in the data and in response to changes in social security design.

The model is also an important tool to discuss the design of social security. I evaluate counterfactual exercises exploring changes in early retirement requirements, pension benefit formula, minimum pension guarantee, and pension contribution rates. The results show how the labor market responses can be heterogeneous across agents and over the life-cycle. For instance, the analysis of short and long-run effects of changing early retirement restrictions shows differential responses on formal employment depending on age and distance to retirement, highlighting the advantages of taking the dynamic decisions into account. Importantly, assessing how these counterfactuals would change when (i) abstracting away from risk-aversion or (ii) not considering the full-package of insurance, I show how individuals become overly responsive to changes in the pension system, in a biased way against the formal sector. When evaluating policies that decrease the incentives for participation in the formal sector (e.g. by increasing minimum pension guarantees), we would over-predict exits from formal employment.

The effects of social security on formality decisions have been studied in the literature. Several programs have been analyzed, including unemployment insurance and severance payment (Huneeus et al., 2012, Gonzalez-Rozada and Ruffo, 2016, Audoly, 2024, Gerard and Gonzaga, 2021, Cirelli et al., 2021, Britto, 2022, de Azevedo, 2022, Bloise and Santos, 2022), health insurance (Calderón-Mejía and Marinescu, 2012, Azuara and Marinescu, 2013), minimum wage (Granda and Hamann, 2015, Parente, 2022, Engbom et al., 2022), and pensions (Attanasio et al., 2011, Behrman et al., 2011, Cruces and Bérgolo, 2013, Todd and Vélez-Grajales, 2008, Joubert, 2015, McKiernan, 2021, Joubert and Todd, 2022, Moreno, 2022, Delalibera et al., 2023, Cabezon, 2023). I make two contributions to this literature. First, I develop a life cycle model including 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 and that ignoring one dimension makes individual's response overly sensitive to changes in social security design. Second, I estimate the short-term effects of strengthening the requirements for early retirement using an adjacent-cohorts design and the long-term effects through the model. The closest papers to mine are McKiernan (2021), Joubert (2015), and Joubert and Todd (2022) which develop life-cycle models to study pension design and informality. This paper mainly differs from also including short-term considerations with unemployment risk and unemployment insurance. The quantitative exercises show how this is an important margin for workers' decisions and how it also affects our interpretation from social security reforms. Ignoring unemployment risk and the short-term insurance leads to biased responses to changes in social security.

Lastly, my paper relates to the literature on self-employment in developing countries, particularly in the context of urban informality in Latin America. Most studies on informality either group self-employed individuals with informal workers or exclude them from the analysis. 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. 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, particularly as their decisions and responses may differ significantly from those of informal employees.

The remainder of the paper proceeds as follows. In Section 2, I discuss the institutional setting of social insurance in Chile and the data. Section 3 presents the empirical findings from the data and the pension reform analysis. Sections 4 and 5 discuss the proposed life cycle model and the estimation procedure. The model estimates are presented in Section 6. I present a series of counterfactual analyses in Sections 7 and 8. The last Section concludes the paper with some final remarks.

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 administer their pension wealth. The funds remain 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.[4] 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.[5]

Upon retirement, individuals can choose from various financial options, including annuities, which insure them against longevity risk. Initially, individuals who had contributed for over 20 years were entitled to a minimum pension of around 85 thousand Chilean pesos.[6] 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

[4]Initially, the cap was 60UFs (≈2400 dollars), and it has been adjusted annually since 2011.
[5]Average value between 1993 and 2019.
[6]I use real values of Chilean pesos in August 2004. 1,000 pesos ≈ 1.50 USD.

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 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 their 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 for those receiving a pension of 195 thousand pesos, denoted by PMAS (*Pensión Máxima con Aporte Solidario*). The reform further tightened the early retirement requirements, raising the threshold to 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.[7]

Unemployment Insurance, Severance Payments, and Minimum Wage — 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 laid off and with at least 12 months of contributions are eligible for unemployment insurance. Unemployment benefits are computed with decreasing replacement rates for five months, initially drawing from the individuals' accounts. If necessary, they can be complemented with resources from the solidarity fund. There are limits to accessing the solidarity fund to mitigate moral hazard issues.[8] All formal workers with tenure above 12 months are entitled to severance payments of one monthly

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

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

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.

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 (*"Asignación 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.[9] 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 the sample to men with at most a high school degree. The focus on men is due to the model

[9] Part of the 2019 wave interviews were scheduled for 2020 and were affected by the Covid-19 pandemic. I exclude all information collected via phone interviews conducted after the onset of the pandemic.

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 a 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. This group accounts for around 71% of the population.

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 detrend all the monetary values. For most of the analysis, I focus on the period 2002-2015, corresponding to the time frame after the implementation of UI and before its expansion. The only exceptions are retirement and wealth at older ages, for which 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.[10] I use the Survey of Micro-Entrepreneurs (*Encuesta de Microemprendimiento*) 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 Consultas 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 jobs, informal jobs, or self-employment. If an individual reports being unemployed or self-employed, I classify them as such. If they report working for firms, I use the administrative data to classify whether they work 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.[11] I exclude spells in which individuals were public employees or employers.

Self-employment is a highly diverse category encompassing several different activities.

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

[11]A similar classification is obtained when using self-reported information about having a signed labor contract.

In my data, the five most typical occupations for the 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.[12] After 12 months, only 3.4% report being an employer. This 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 informally for firms (*Informal Workers*) and *Self-Employed*. For the model, I 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 security contributions nor income tax.

3 Empirical Facts

Before proceeding to the full model, I explore the data and the 2004 pension reform to generate insights that guide the model design and estimation. I start by presenting 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. Then, I show how self-employment activity is associated with investments in physical capital. Lastly, I show the causal effects of the 2004 pension reform, which will be used in the model estimation.

3.1 Key features of each sector of employment

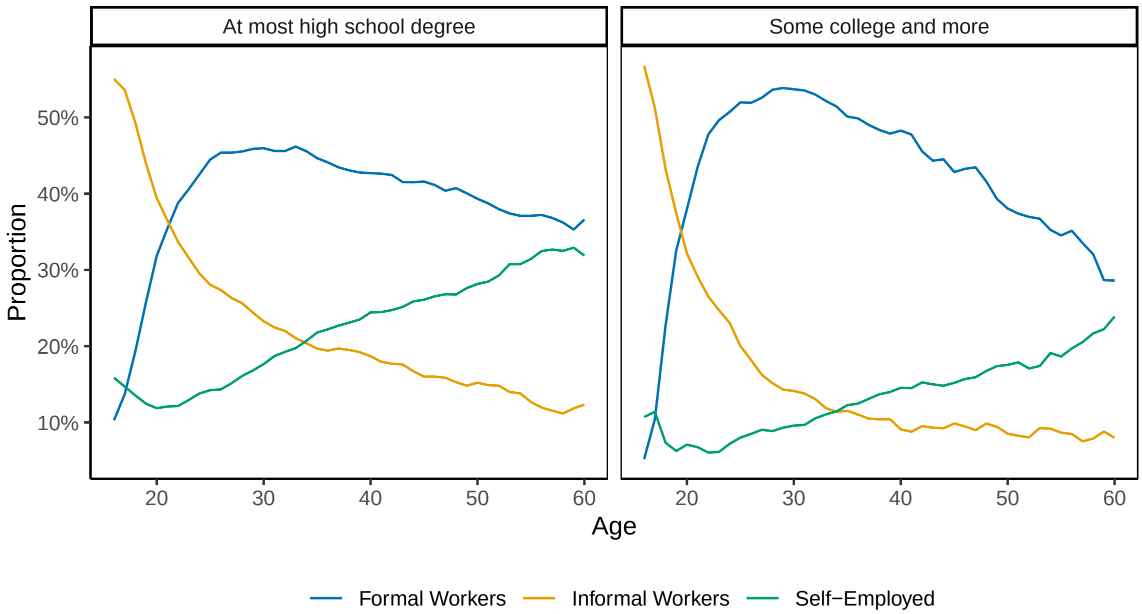
Figure 1 displays the proportion of individuals in formal, informal, and self-employment over the life cycle. We can see robust life cycle patterns by education level.[13] Participation in the formal sector peaks at the early stages of the life cycle and starts to decline continuously around the 30s. 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

[12] Using the Survey of Micro-Entrepreneurs, which provides better coverage of self-employed individuals, this number is much higher: 91%.

[13] Appendix Figure A.1 plots the same graph for women.

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.

Figure 1: Proportion of workers by employment type by age and education level



Notes: The figure plots the proportion of male individuals working as formal workers (blue), informal workers (yellow), and self-employed (green) over the life cycle, separately 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. The proportions consider all individuals in the labor force. The proportions do not sum to 100% because unemployed individuals, public sector workers, and employers are not included in the graph.

The self-employed have different work arrangements compared to formal and 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 higher than that of formal employees.[14]

3.2 Onset of self-employment activities

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

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

they used to start their self-employment activity. Almost 82% report relying primarily on 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 typical self-employment occupations, we can already see the importance of physical capital, such as 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 who were not self-employed in the first survey and 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 1 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.[15] These numbers are not large 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.

3.3 Effects of the 2004 pension reform

In 2004, the government 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 average wages. The 2004 reform raised the threshold and the fraction α. Individuals born before August 19th, 1949, were exempted from the new rules. The new values were gradually implemented, leading individuals from

[15] In the Appendix Figure A.2, I show the cumulative density function for this variable for the four groups.

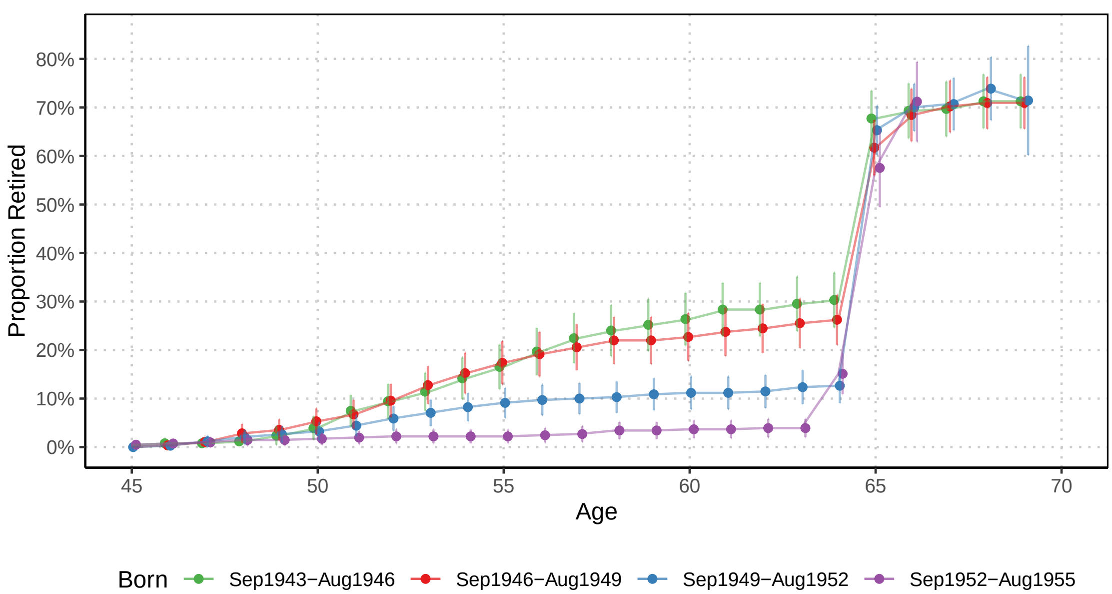
Table 1: Impacts of transitions to and from self-employment on physical capital

Group	Coefficient	Std Error
Group 00	-0.0005	(0.0023)
Group 11	0.0034	(0.0133)
Group 01	0.0434	(0.0157)
Group 10	-0.0595	(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.

different cohorts to face different criteria for early retirement. Appendix C shows the exact dates for each requirement and the specific requirements for some cohorts (A.15).

Figure 2: Proportion of retired individuals 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.

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 subsequent 1949–1952 cohort (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 differences observed starting at ages 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 six years (treated). The results are presented in Table 2. In the first column, we can see that while 15.5% of individuals from the control group retired before age 55, those in the treated group were 10.5pp less likely to be retired. The second column shows the same results for being retired at age 63. Treated individuals were 17.1pp (or 69%) 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 groups do not present differential retirement patterns at age 66.[16] In the fourth column, I pool everyone aged between 57 and 63. Individuals in the treated group are 16pp less likely to be retired.

In the fifth column, I show the effects on the probability of making pension contributions. The effect is smaller than the effect on retirement. Pension contributions increase by 12.6pp. The next three columns show the results for type of employment: formal, informal, and self-employed. The reform increased the probability of being in each group by 11.1, 1.5, and 4.6pp, respectively. That is, the reform induced individuals to not retire before the normal retirement age. Among these individuals staying longer in the labor force, the majority were in formal employment, with some share in self-employment. I will use these results in the model estimation, as they provide variation on retirement decisions and employment at older ages. Exploiting how the reform introduced discontinuous changes to adjacent cohorts is useful as it provides credible variation to estimate the causal effects of these early retirement requirements. However, it allows us just to estimate the short-term effects of the reform, that is, how individuals who are near retirement were affected. These results are silent on

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

Table 2: Effects of the 2004 reform on retirement and employment

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)					
Treated	-0.105	-0.171	0.004	-0.160	0.126	0.111	0.015	0.046
	(0.026)	(0.037)	(0.050)	(0.041)	(0.037)	(0.038)	(0.014)	(0.025)
Age Fixed-Effects	-	-	-	Yes	Yes	Yes	Yes	Yes
Age Range	55	63	66	[57-63]	[57-63]	[57-63]	[57-63]	[57-63]
Observations	12,492	12,492	9,642	34,379	34,379	34,379	34,379	34,379

Notes: The table presents the results from the regressions comparing the control cohort, born between Sep1946–Aug1949 (the intercept), with the treated cohorts, born between Sep1949–Aug1955. 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 57 to 63, age fixed effects are included.

how younger cohorts may react to the new regime. We need a model for the employment decisions given the social security design to speak more generally about the long-term effects of these changes.

4 Model

This section provides a detailed description of the model, which takes into account the insights from the previous section. 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.[17] Individuals face

[17]The model is not suitable to explain business cycle fluctuations or growth, similarly to Meghir, Narita

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 pension reforms (in 2004 and 2008). Reforms are unanticipated by individuals.[18] 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 offer only wages above the statutory minimum. Informal jobs can offer wages below or above the minimum wage, there is no restriction. As the model also features on-the-job search, it can account for wage growth over the life-cycle. When working formally, individuals pay social security contributions and taxes. Self-employment is always an option, provided individuals make 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 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

and Robin (2015) and Narita (2020).

[18] 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.

hours for leisure ℓ, given the stock of hours per period $\bar{L}$.[19] 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 $V_a(\theta, n, p, k, j, w)$.

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

The per-period utility function is 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, which yields 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 $\overline{K}$.

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

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 into unemployment or self-employment, paying the self-employment

[19] In the empirical specification, the decision on the number of hours will be discrete, working full-time or part-time.

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. There is on-the-job search, thereby allowing individuals to climb the job ladder. If individuals accept an offer from the formal or informal sector, they transition to that job at the offered 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 who is currently unemployed ($j = U$). To help with the notation, I will define $\tilde{V}_{a+1}^U$ as the best decision of this agent if he does not receive any offer, which will involve the decision to remain unemployed ($V_{a+1}(\theta, n', p', \tilde{k}, U, 0)$), go to self-employment ($\int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w})$), or retire ($V_{a+1}^{\text{Ret}}(\theta, \tilde{k}, y^P, q)$). Retirement is only an option if $a \geq a_{\min}^{\text{Ret}}$.

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

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:

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

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, remaining unemployed, or retiring. 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 shocks, he has four options: remaining in the same job, quitting and moving to unemployment, going to self-employment, or retiring (if already possible). This best choice is given by

$$\begin{aligned}\tilde{V}^F_{a+1} := \max\Big\{ & V_{a+1}(\theta, n', p', \tilde{k}, F, w), V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \\ & \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q) \Big\}\end{aligned} \tag{5}$$

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

$$\begin{aligned}
&\mathbb{E}_F[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\quad \delta_F \max\Big\{ V_{a+1}(\theta, n', p', \tilde{k} + SP(w), U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} + SP(w) - X, S, \tilde{w}) dW^S(\tilde{w}), \\
&\qquad V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q) \Big\} + \\
&\quad (1 - \delta_F) \Big[(1 - \lambda^F_F)(1 - \lambda^I_F) \tilde{V}^F_{a+1} + \\
&\quad \lambda^F_F (1 - \lambda^I_F) \int \max\Big\{ \tilde{V}^F_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}) \Big\} dW^F(\tilde{w}) + \\
&\quad \lambda^I_F (1 - \lambda^F_F) \int \max\Big\{ \tilde{V}^F_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w}) \Big\} dW^I(\tilde{w}) + \\
&\quad \lambda^I_F \lambda^F_F \int\int \max\Big\{ \tilde{V}^F_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}), V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{\tilde{w}}) \Big\} dW^F(\tilde{w}) dW^I(\tilde{\tilde{w}}) \Big]
\end{aligned} \tag{6}$$

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.

$$k' = \tilde{k} + SP(w)\mathbb{1}\{j = F \text{ and fired}\} - X\mathbb{1}\{j \neq S, j' = S\} + \pi X\mathbb{1}\{j = S, j' \neq S\} \qquad (7)$$

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, and 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 in next period.[20] 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.[21] 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 to 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.[22] Individuals can claim early retirement between age $a^{\text{Ret}}_{\min}$ and the normal retirement age a^{Ret}. Those who did not retire by age $a^{\text{Ret}}_{\max}$ will claim benefits then. The pension benefit formula is represented by

[20] 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.

[21] 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.

[22] In reality, some retirees continue to work. Unfortunately, the model does not have any forces to generate this behavior, as it would transform retirement into a purely financial decision.

$y^p = \omega(\theta, a, p)$. 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).

Retirement before the normal retirement age is possible if the resulting benefit meets the early retirement conditions, that is, $y^p \geq \max\{A, \alpha\overline{w}\}$.[23] 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 method of simulated moments.

5.1 Estimation — First Step

Before detailing the first step, I first show how I parametrize the wage, earnings, and initial wealth distributions. 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). I characterize self-employment earnings as an auto-regressive process of order 1, with auto-correlation ρ and innovations following a normal distribution. For the

[23]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.

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

Timing - Age is measured in quarters, 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 total stock of time is 16 hours per 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.[24]

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). The general ability for type 1 is normalized at 1. For simplicity, I assume type-1 workers cannot be self-employed.[25] As there is only one type who can be self-employed, I can normalize $e_2 = 1$ without loss of generality. The remaining parameters: g_2 and proportions of each type-1 will be internally estimated. 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 $\sigma_{k_0} = 3,205$. All agents start the model unemployed.

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 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, yielding annual return of 5.8%.[27] 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%. The borrowing constraint is set to zero, that is, individuals can save but not borrow.

[24]Among the self-employed working less than 40 hours, the median weekly work hours is 28.

[25]This is equivalent to setting a low value for e_1. In the data, there is a high proportion of individuals who are never self-employed. In the model, this could be characterized either by low entrepreneurial ability or high startup costs.

[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 incorporate disability risk, I exclude payments for disability insurance.

[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).

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 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 zero 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

[28]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.

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: $\rho = \mathrm{Cov}(Y_t, Y_{t-2})/\mathrm{Cov}(Y_t, Y_{t-1})$. 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 equal to the empirical ratio of covariances, implying an 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). Section 8 shows how the main results change with this parameter. Additionally, I also estimate this parameter in the second step, relying on life-cycle allocation for each sector. This yields an estimate of 2.98.

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 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 the recovery parameter π 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%.

5.2 Estimation — Second Step

In the second step, I estimate all the remaining parameters (ξ) using the simulated method of moments. The estimation procedure minimizes the criterion 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 closely 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 3.

Among the preference parameters, the discount rate β can be inferred from the patterns

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

Table 3: 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
μ,σ	Mean/variance of self-employment earnings	Self-employment earnings distribution
X	Start-up cost for self-employment	Life-cycle transitions to self-employment
g_2	General abilities	Correlation of wages
$p(\theta_1)$	Proportion of type-1	Proportion in each sector and earnings

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

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 into 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 precisely captures the individuals' willingness to retire early, forgoing future income to exit the labor force sooner. 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, including the proportion of individuals in each sector after the 2004 reform.

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

[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.

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 are closely linked to the percentiles of the wage distributions. I include all deciles from 10-90%. To better capture the lower tail of the distribution, I include as moments the share of formal workers earning the minimum wage and the percentiles 1%, 2.5%, 5%, and 7.5% for informal earnings. For the self-employment earnings, I estimate the variance of the innovation shocks. To provide information for this parameter, I use as moments the vigintiles of the self-employment distribution, the mean earnings, and the variance of annual wage differences.

For the general ability, I include as moments the correlation of wages of individuals who lost their jobs (involuntarily) and found jobs after 1-year in formal/informal occupations. The investment cost to be self-employed X can be informed mainly by the market value of assets used in self-employment activity. Lastly, the share of type-1 individuals $p(\theta_1)$ can be inferred from the proportion of individuals in each sector and the average earnings.

6 Results

6.1 Estimates and Fit

Table 4 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 estimated consumption weight in the utility function, ν =0.42, implies a coefficient of relative risk aversion of 1.84, within the typical range. 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 4.9% (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 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 it is consistently easier to find an informal than a formal job. For instance, an unemployed individual has almost twice the chance of receiving an informal offer than a formal one. The quarterly (exogenous) destruction probability for the 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 4: Parameters estimated in the second step

Preference	β	ν	ψ	$\bar{K}$	
estimate	0.945	0.419	240.1	6897.1	
(s.e.)	(0.001)	(0.004)	(56.2)	(5181.6)	
Formal Arrival Rates	λ_U^F	λ_F^F	λ_I^F	λ_S^F	
estimate	0.110	0.174	0.027	0.054	
(s.e.)	(0.003)	(0.008)	(0.001)	(0.006)	
Informal Arrival Rates	λ_U^I	λ_I^I	λ_I^I	λ_S^I	
estimate	0.191	0.850	0.204	0.973	
(s.e.)	(0.010)	(0.148)	(0.018)	(0.163)	
Wage (Shape)	ζ_1^F	ζ_2^F	ζ_1^I	ζ_2^I	
estimate	13.049	19.120	2.154	10.404	
(s.e.)	(0.895)	(1.157)	(0.213)	(0.685)	
Self-Employment	ϕ_S	δ_S	μ	σ	X
estimate	1.114	0.008	0.628	0.035	3499.1
(s.e.)	(0.013)	(0.001)	(0.009)	(0.001)	(61.1)
Types	g_2	$p(\theta_1)$			
(estimate)	0.521	0.345			
(s.e.)	(0.004)	(0.004)			

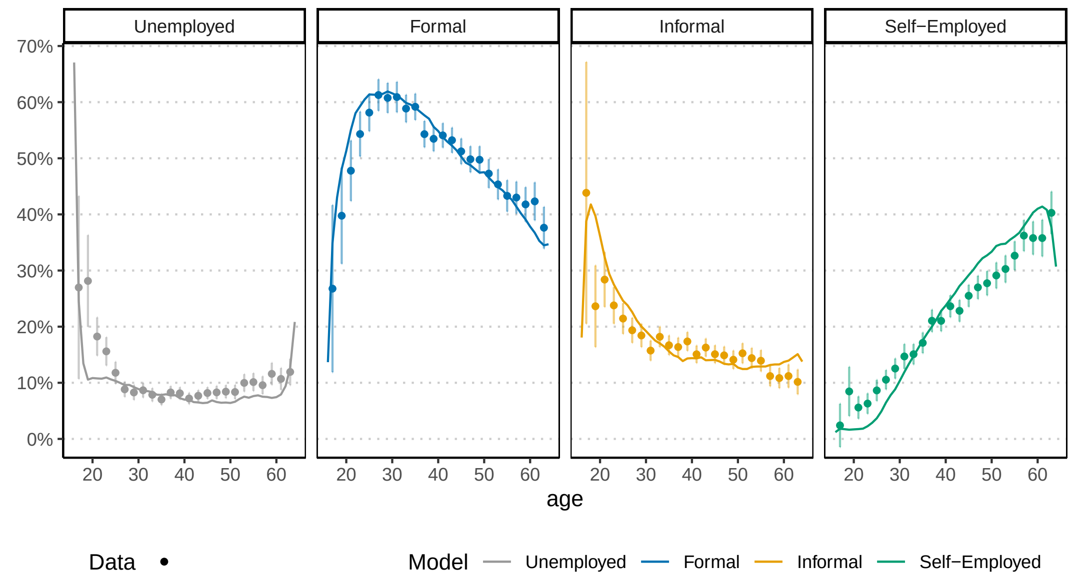
Notes: The table presents the estimates for each of the 23 parameters estimated in the second step through the method of simulated moments. Standard errors computed using the numerical derivative for the criteria function are in parenthesis.

The wage parameters imply hourly rates of 0.900, 0.672, and 0.717 thousand pesos for the formal, informal, and self-employed, respectively. The formal–informal wage gap is 25.3%. Type 1 has normalized ability g_1=1.000, and for type 2 we obtain g_2=0.521. That means that type-2, the type that can be self-employed, has an absolute (and comparative advantage) on self-employment. The estimated self-employment start-up cost is 3499.1 thousand pesos (25 average monthly wages).

The estimate of amenities for self-employment implies that the same level of consumption yields 11.4% 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 model performs well on targeted and non-targeted moments. Figure 3 shows how the model replicates extremely well the main trends of the labor market allocation over the life cycle. Figures A.5 and A.6 show how the estimates produce a good fit of the earnings distributions for the three sectors.

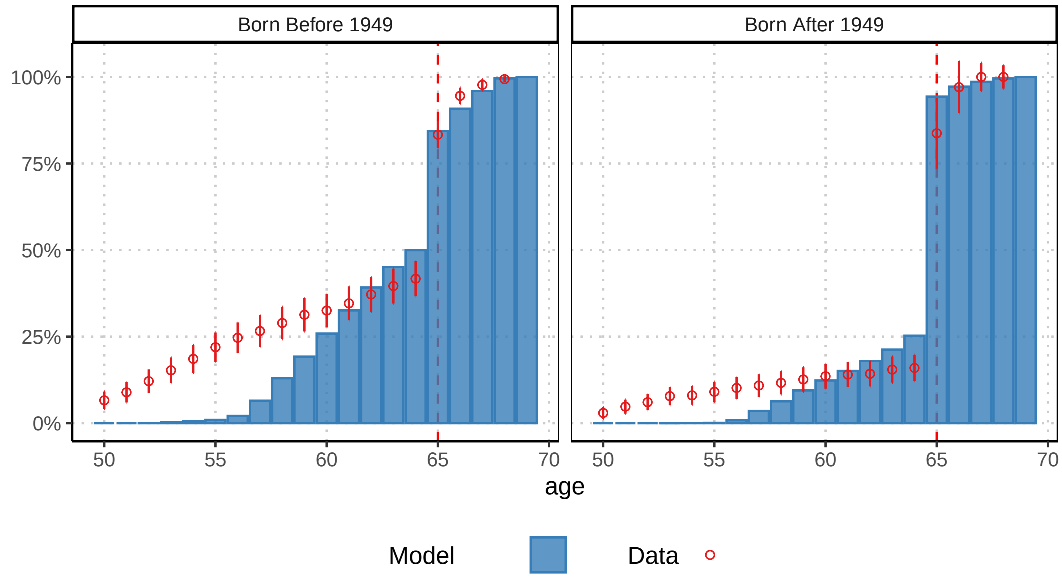
Figure 3: Life cycle employment trends



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 the equivalent moments in the model.

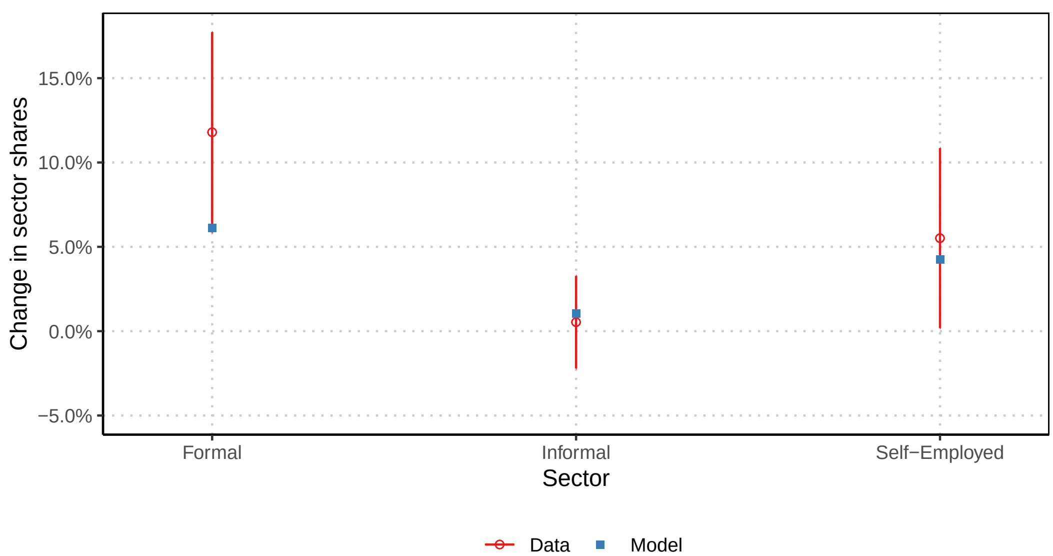
Section 3 presented the estimates for the causal effects of the 2004 pension reform on early retirement and the proportion of individuals working in each sector closer to retirement. Figure 4 shows the match of the retirement patterns for individuals born five years before and after August 1949, which 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 50-60 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. Figure 5 shows the fit of the increased probability of individuals affected by the reform (born after August 1949) to be working in the formal, informal, and self-employment at ages 57-63 (similar to the results presented in Table 2). The model reproduces the increase in formal and self-employment, and the null effect on informal employment.

Figure 4: 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.

Figure 5: Change in sectoral allocation from the 2004 reform



Notes: The figure plots the change in the proportion of individuals in each sector at ages 57–63 by the cohort not affected by the 2004 reform (those born in 1946-1949) and those affected (born 1950-1956). The red circles show these differences in the data, together with the 95% confidence intervals. These numbers are similar to those presented in Table 2. The blue squares show these differences 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 (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.

6.2 Life-cycle choices

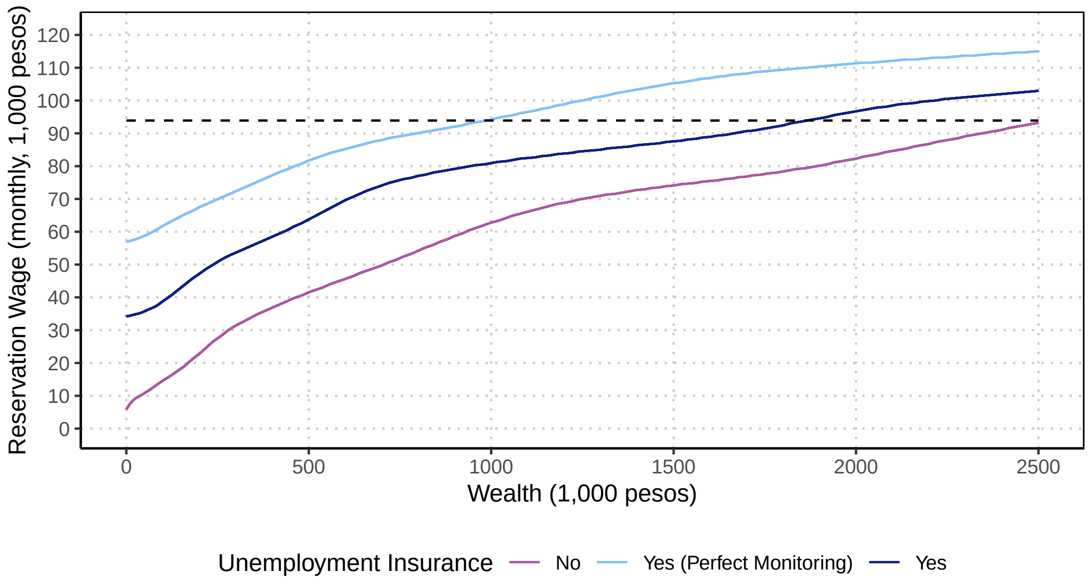
As Figure 3 shows, the model effectively replicates the allocation of employment types over the life cycle. As the model does not feature any age-dependent parameters, the endogenous mechanisms are responsible for generating the different labor market choices. The main mechanism is the search behavior being wealth-dependent. That is, individuals with different levels of savings will behave differently in the labor market.

Figure 6 shows how the reservation wage for an informal job depends on wealth and unemployment status of an unemployed individual.[31] We can see that unemployed individuals with low wealth and without unemployment insurance have significantly low reservation wages. They would accept offers paying around 10 thousand pesos per month, which is much lower than the statutory minimum wage of around 92 thousand pesos (dashed line). The same individual with more wealth would have reservation wages ten 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 have low wealth, they are more likely to accept offers from the informal sector. That decreases as they accumulate resources.

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 60 thousand pesos. That is, individuals with no savings would only accept informal jobs paying six times more if they are entitled to UI, compared to those not receiving unemployment benefits. However, in reality, the government cannot perfectly monitor those receiving UI. The darker blue curve shows the reservation wage this case with imperfect monitoring, in which individuals can accumulate informal earnings and unemployment benefits. The entire reservation wage curve shifts down, compared to

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

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 value of the statutory minimum wage.

the full monitoring case. As individuals can accumulate informal earnings with UI benefits, informal offers are more attractive than the same offers under the full-monitoring case.

In addition to being one important driver of the informal sector choice, the level of assets also influences the transitions to self-employment through different mechanisms. First, as individuals need to pay the up-front self-employment start-up costs, those with savings below that threshold cannot 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 the higher the consumption bundle one can afford. Therefore, through these three mechanisms, transitions to self-employment are positively associated with savings. Figure A.12 plots the decision to be self-employed as a function of current wealth and wages. The model can therefore encompass both the liquidity and insurance constraints that individuals face when deciding to be self-employed, as discussed by (Bianchi and Bobba, 2013).

6.3 Formal insurance

A fundamental question when contrasting formal and informal choices is how valuable a formal job is. Formal employment offers more stability and better search prospects than 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 5: Willingness to pay for formalization

Sector	Constrained	Unconstrained			
	Total	Total	Labor market stability/prospects	Insurance	Self-Emp Specific
Informal	16.9%	38.2%	30.9%	9.8%	-
Self-Employment	-11.1%	-6.5%	-6.2%	9.5%	-5.5%

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 mean value imposing the minimum wage. The second column shows the mean value for the individuals, ignoring the 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 net labor earnings they would be willing to forgo to have a formal job.[32] Table 5 shows these values. Informal employees are willing to give up, on average, 16.9% of their labor earnings to have their jobs formalized. This measure is on net earnings, that is, already taking into account taxes, social security contributions, and welfare programs. To compute this WTP, I also took into account the minimum wage. If an informal employee accepts a larger wage cut, that would make their final accepted formal wage below the statutory minimum, I use the censored minimum wage

[32] Following the model notation, let $V_a(\theta, n, p, k, j, w)$ be the utility of an individual of type θ, at age a, with UI status n, pension wealth p, liquid wealth k, and employment status j with wage w. Moreover, let $Y(j, w)$ return the net income. We have trivially that $Y(I, w) = w$ as informal employees do not pay taxes or make social security contributions and $Y(F, w) < w$. Let w^* be the wage that makes individuals indifferent between the two jobs, that is:

$$w^* := V_a(\theta, n, p, k, I, \tilde{w}) = V_a(\theta, n, p, k, F, w^*).$$

The WTP is then defined as $WTP(a, \theta, n, p, k, I, \tilde{w}) := \frac{\tilde{w} - Y(F, w^*)}{\tilde{w}}$. The definition for self-employed individuals is analogous.

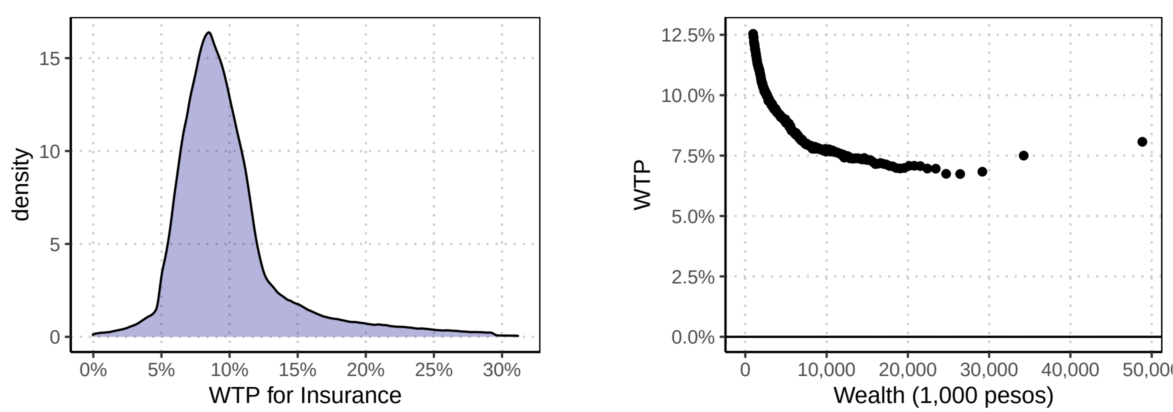
in the calculation. Moreover, if someone has informal earnings below the minimum wage, he cannot forgo any fraction of earnings to be in the formal sector, as his new wage would be below the statutory minimum. The second column of Table 5 shows the unconstrained WTP, ignoring the minimum wage. The value raises to 38.2%.

One of the benefits of computing these numbers in the context of the model is that we can decompose this WTP, into the fraction that is attributable to formal jobs having better stability and job search prospects, which accounts for 76% of the total value, and to insurance, 24% of the value. In other words, informal workers would be willing to pay around 9.8% of their earnings to gain access to unemployment insurance, severance payments, and pensions.

For self-employed individuals, we have a different picture. Their overall WTP is negative, the mean value is -11.1%. One of the reasons is that the exogenous destruction probability is much lower in self-employment, making involuntary transitions less common. That makes the WTP for the stability and search prospects to be -6.2%. Another reason is the self-employment specific amenities, which favor self-employment (third column). They include the within-job-spell variance of earnings, the recovery of start-up costs when leaving self-employment (liquidity access), and amenities. For the insurance part we can see a very similar value to informal employees. Self-employed individuals are willing to forgo 9.5% of their earnings to access the package of insurance offered in the formal sector.

Figure 7: WTP for Insurance

(a) Density (b) by Wealth



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 5. 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.

These values are highly heterogeneous across individuals. Figure 7a shows the density plot of the 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.

In summary, informal individuals have heterogeneous WTP to formalization. Informal employees have much higher values than self-employed individuals. This fact aligns with our findings from the life-cycle drivers of the labor market choices and emphasizes how different types of informal workers should be treated differently. Even within a sector, there is substantial heterogeneity, depending on age, wealth, and informal earnings. Around 40.3% of informal employees and 26.0% of self-employed individuals would be willing to pay more than the approximate total social security contribution of 20%. That is, even considering the minimum wage, around 32.0% of workers not included in the formal sector would be willing to pay more than the required social security contributions.

6.4 Informal insurance

Informal wage employment and self-employment can offer fast employment routes for workers. This is the case in this setting, as the estimates of arrival rates for informal jobs are much 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, for which accessing any job fast is highly valuable.

I use the model to quantify the welfare associated with the existence of these fast routes of employment offered by the informal and self-employment sectors. To do that, I restrict some individuals to not be able to move to these sectors and compute their associated welfare loss. I compute welfare in terms of lifetime consumption-leisure reduction.[33] I consider three scenarios: (i) restricting access to informal jobs, (ii) restricting access to self-employment, and (iii) restricting access to both informal and self-employment. Table 6 presents the results. To benchmark results, I also show the welfare loss of restricting access to formal jobs. On average, limiting access to informal jobs reduces welfare by 11.9%. That is, prohibiting the average individual from receiving informal offers is equivalent to their consumption and leisure being 11.9% smaller over their entire life. Restricting transitions to self-employment is associated with a much smaller loss of 0.5%. These numbers are computed in partial equilibrium, that is, with no responses from the other sectors.

[33]Let $V(c, \ell|\Psi)$ be the lifetime utility of the stream c and ℓ of consumption and leisure. I compute the loss associated with moving from policy environment Ψ to Ψ' to be given by ϑ such as $V(\vartheta c, \vartheta \ell|\Psi) = V(c', \ell'|\Psi')$. Where c' and ℓ' are the optimal responses under the new policy environment Ψ'.

Table 6: Welfare (consumption-leisure) loss for limiting access to each sector

Consumption-leisure equivalent	Informal		Self-employment		Formal	
	Δ	(%)	Δ	(%)	Δ	(%)
Overall	-11.9%	(-)	-0.5%	(-)	-17.0%	(-)
By initial wealth,						
No wealth	-13.1%	(100.0%)	-0.2%	(100.0%)	-17.6%	(100.0%)
Low wealth	-8.7%	(66.4%)	-0.3%	(194.8%)	-16.3%	(92.9%)
High wealth	-4.1%	(31.2%)	-6.5%	(3796.3%)	-10.7%	(61.0%)

Notes: The table shows the change in welfare when restricting 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 6 also shows the average losses by initial wealth group.[34] The gradient is negative and steeper for the informal sector. Those born with no wealth experience losses 3.2 times 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 this initial assets 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.

7 Counterfactuals

7.1 Changing requirements for early retirement

As discussed in Section 2, in 2004 Chile increased the requirements for early retirement, making it more difficult to retire before the normal retirement age (65 for men). The 2008 reform also increased these requirements further. In the empirical section 3, I exploit the fact that individuals born before August 1949 were exempted and contrast adjacent cohorts to estimate the causal effects of this reform. Figures 4 and 5 show how the model can generate the reduction in early retirement, the increase in formal and self-employment, and the mute

[34]No wealth accounts for 78.1% 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 2759.65 thousand Chilean pesos). High wealth corresponds to the remaining top 5%.

effects on informal employment.

The problem with this analysis is that it only captures a "short-term" effect of the reform. That is, it shows how early retirement and employment changes, for cohorts that had their almost entire labor market trajectories under different regimes. From the reduced form estimates, it is hard to extrapolate what these effects would look like for younger cohorts. I use the model to complete this analysis.

The first row of Table 7 shows the short-term effect of increases in early retirement restrictions from the pre-2004 level to the post-2008. The first three columns compare the labor market status for individuals aged between 50 and 65. We can see that the probability of being retired would fall by -6.80pp. As individuals stay longer in the labor force, the proportion of them working in the formal and informal sector goes up by 3.00 and 2.86pp. By construction, there is no difference when these individuals are 16–50, as the changes have not yet been implemented.

Table 7: Effects of changing early retirement (in pp)

	Age range (50-65)			Age range [16-50]	
	Retired (1)	Formal (2)	Informal & Self-Emp (3)	Formal (4)	Informal & Self-Emp (5)
Panel A - Short-term effects					
Effect	-6.80	3.00	2.86	0.00	0.00
Panel B - Long-term effects					
Effect	-7.47	3.21	3.25	-0.03	0.03

Notes: The table shows the changes on proportion of individuals retired (column 1), on formal employment (columns 2 and 4), and informal employment and self-employment combined (columns 3 and 5). All results are in percentage points. The first three columns restrict the sample to individuals aged 50–65, and the remaining to those younger than 50. The first row shows the results for the short-term effects, that is, when all individuals are exposed to the reform as soon as it happens (and they are at different ages). The second row shows the long-term effects for cohorts that lived always under the new rules.

In the second row of Table 7, I show the long-term effects of increasing early retirements. That is the difference between cohorts that always lived under the less versus the more stringent requirements for early retirement. We can see that the effects on early retirement are 10% larger. The reason is that the more stringent requirements introduce a small disincentive for working in the formal sector, there is a small shift from formal to informal work for individuals before retirement age. Therefore, they accumulate fewer pension contributions and are less likely to be ready to meet the requirements for early retirement. Contrasting the long-term effects, we can see that analysis based on the short-term effects would underestimate the effects on claiming early retirement and on older individuals working both formally and informally. However, in the opposite direction, the short-term effects would miss the small disincentives for formal participation for younger workers.

7.2 Changing pension benefits

In addition to the more stringent early retirement restrictions, the 2008 pension reform also introduced large changes in how final pensions were computed. It abolished the two minimums, depending on the number of years of contribution, replacing them with a unified new minimum, which was 45% higher than the older lower minimum. This value was applicable to someone with no pension wealth and over 65 years of age. 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 these changes as while the income effect has the same sign for everyone, the substitution effect is undefined, depending on individual characteristics. Figure A.14a shows the pre and post-reform benefits as a function of the self-financed pension. I use the model to assess the overall effect of these changes. The first row of Table 8 shows the results.

Table 8: Counterfactuals and sectoral insurance

Counterfactual	Δ Formal Employment (pp)	Δ Informal (pp) & Self-Emp	Δ WTP Formal (pp)	Δ Welfare Closing Informal & Self-Emp (pp)
Change pension benefit from the 2008 reform	0.14	-0.47	0.23	0.00
Increase minimum pension	-5.27	5.19	-1.28	0.28

Notes: The table shows the change in: formal employment (first column), total informal employment, combining informal employees and self-employed (second column), willingness to pay for formal jobs (third column), and welfare losses coming from shutting down access to informal and self-employment opportunities (fourth column). All columns display changes in percentage points. The first row presents the results for the counterfactual implementing the change in benefits from the 2008 reform and the second row the increased minimum pension and additional changes from a new proposed reform.

We can see that the introduction of the new pension formula has a small positive effect on formal employment. Individuals were 0.14 percentage points more likely to be in the formal sector. In terms of employment in informal occupations, there is a reduction of 0.47pp. That is, the new pension formula did not disincentivize formal employment, with actually modest gains.

More recently, there have been discussions from the Chilean government to implement new changes to the pension system.[35] The main pillars of the new proposals are 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. Figure A.14b compares the budget constraint for the final pension for the post-2008 formula and the new proposal. Differently from the results from the 2008 Pension Reform, the model predicts large disincentive effects for formal employment. The second row of Table 8 shows that formal employment falls by 5.27pp, with almost the same increase in total informal employment. These changes were implemented in a budget-neutral exercise from the point of view of the government.

The third and fourth columns of Table 8 show how the WTP for formal jobs and the welfare loss associated with closing access to informal opportunities change with the counterfactual. With the 2008 reform, we see a very modest increase in the WTP and no change in the welfare loss. This is consistent with the small increase in formal employment; after the change, formal employment is slightly more valuable (as indicated by the higher WTP). In the second row, we see how there is a sizable decrease in the WTP of -1.28pp. The baseline WTP was 19.0%. The welfare losses are now bigger (in magnitude), as informal opportunities are more valuable. That is, we can see how these two measures show the (relative) attractiveness of formal jobs and, therefore, can act as summary measures of the effects of changes in the social security system. They respond to changes and are intrinsically associated with the estimated employment impacts for each scenario. Additionally, the two results show how the model can be used to assess potential effects of changes in social security design. Despite being similar, the two reforms generate very different effects on formal employment.

8 Risk-aversion, insurance, and sectoral decisions

The proposed and estimated model has novel mechanisms to understand the labor decisions of workers over the life-cycle, particularly relating to risk-aversion, savings behavior, and insurance. The risk-aversion parameter (the γ parameter of the instantaneous utility function $u(c, \ell) = \frac{(c^{\nu}\ell^{1-\nu})^{1-\gamma}}{1-\gamma}$) was set in the first stage to three, a mid-range value of the literature.[36] Now we analyze the sensitivity of our main results to changes in this parameter. This will be an interesting exercise, not only to assess deviations from this value, but also to shed some light on what we lose when abstracting from risk-aversion in the formality-

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

[36] In this formulation, the parameter also influences the intertemporal elasticity of substitution.

informality decisions.

Table 9 shows some of the results from previous sections under our benchmark value ($\gamma = 3.0$) and two small deviations ($\gamma = 2.7$ and $\gamma = 3.3$). In panel A we show how the two WTP for the formal sector (the total and the part attributable to insurance) changes with different values of γ. As expected, the WTP are decreasing in γ. However, the gradient is not very steep, indicating that even modest values of risk-aversion would still imply large WTP. In panel B, we can see the same for the consumption-leisure equivalent losses. The metrics for the losses coming from barring entry into informal or formal opportunities are both decreasing in γ, with the former exhibiting a steeper gradient. That is due to the fact that most of the cost of barring entry to informal opportunities is because it is costly to stay unemployed without alternative resources. This cost is increasing in γ. We observe a small increase in the value for self-employment, that is likely due to the fact that with lower risk-aversion this sector is more attractive, as the income fluctuations from the AR process are less penalized.

The lower part of Table 9 collects the response in terms of participation in the formal sector for some pension reform changes. The first one is the hindering of early retirement introduced with the more stringent requirements. We show here the long-term effects coming from the labor market responses before early retirement (age 16–50). The next two rows show results from the change in the formula for pension benefit (from the 2008 reform) and an increase in the minimum pension. All measures show the change in probability of participating in the formal sector in percentage points. From the results we can get a clear message, not only the individual supply responses depend on the level of risk-aversion, but ignoring it makes individuals overly sensitive to changes that are decreasing incentives to formal participation and under-sensitive to changes that are pro-formalization.

In the last two columns of Table 9 I also reproduce the main results of this paper in the benchmark model (with unemployment insurance) and without it.[37] Several papers of the social security literature abstract away from short-term decisions, risk, and insurance. As expected, we observe lower WTP and WTP for insurance. The formal sector is less attractive when we remove one of the main insurance components attached to formal jobs. Interestingly the welfare losses associated with losing access to informal and self-employment opportunities rises. As discussed in the previous section, this can be interpreted as insurance provided by these sectors. They become more valuable as individuals are exposed to unemployment risk without income protection from UI. In terms of individual responses to social security reforms

[37]The model without unemployment insurance adds back to workers' net earnings their fraction of UI contributions as well as firms' payment. Upon layoff, no benefits are received.

Table 9: Risk-aversion, insurance, and sectoral choices

	Risk-aversion			Unemployment Insurance	
	$\gamma = 2.7$	$\gamma = 3.0$	$\gamma = 3.3$	With UI	No UI
Panel A - Informal workers WTP for the formal sector					
WTP Total	37.0%	38.2%	39.3%	38.2%	32.2%
WTP Insurance	9.6%	9.8%	9.9%	9.8%	4.8%
Panel B - Welfare losses for no access to each sector					
Informal	-10.6%	-11.9%	-13.1%	-11.9%	-12.4%
Formal	-16.8%	-17.0%	-17.2%	-17.0%	-16.1%
Self-employment	-0.54%	-0.51%	-0.49%	-0.51%	-0.62%
Panel C - Changes in formal sector participation (pp)					
Hindering early retirement	-0.028	-0.026	-0.019	-0.026	-0.056
Change pension benefit (2008 reform)	0.126	0.137	0.158	0.137	0.002
Increase minimum pension	-5.695	-5.271	-5.028	-5.271	-6.804

Notes: The table reproduces the main results from the model for different parametric specifications and policy environment. The second and fourth columns are the same and are the benchmark results already presented in Tables 5,6,7, and 8. The first and third columns show results for changing the risk-aversion parameter to, respectively, 2.7 and 3.3. The last column show results for the same model with no unemployment insurance. Panel A shows numbers for the willingness to pay as defined in Section 6.3, measured in percentage terms. Panel B shows results for life-time consumption-leisure equivalent losses, measured in percentage terms. Lastly, Panel C shows results for changes in formal sector participation in percentage points. For instance, the first number -2.826% indicates that formal participation goes down by 0.028 pp.

we can see that abstracting away from UI would make changes that induce individuals away from the formal sector to be more extreme, and those that induce individuals towards the formal sector to be more muted. This is indeed because one important value of the formal sector, the short-term insurance offered, is not taken into account, making it overall less valuable.

Both analyses show a consistent image, ignoring the value of insurance that the formal sector brings, either by abstracting away from risk-aversion or by not considering the full package of insurance, makes the formal sector overall less valuable. As a direct consequence individuals are more resistant to being drawn into the formal sector and overly sensitive to changes that may push them away from formal opportunities.

9 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 a formal job. At the same time, informal opportunities are valuable as they insure against unemployment risk. Through counterfactual exercises, I show how these measures can be seen as summary measures of the attractiveness of these sectors, given the overall labor market setting and policy environment. Moreover, I show how ignoring risk-aversion or the full-package of insurance tend to find more elastic responses of policies that decrease the incentives for formal jobs.

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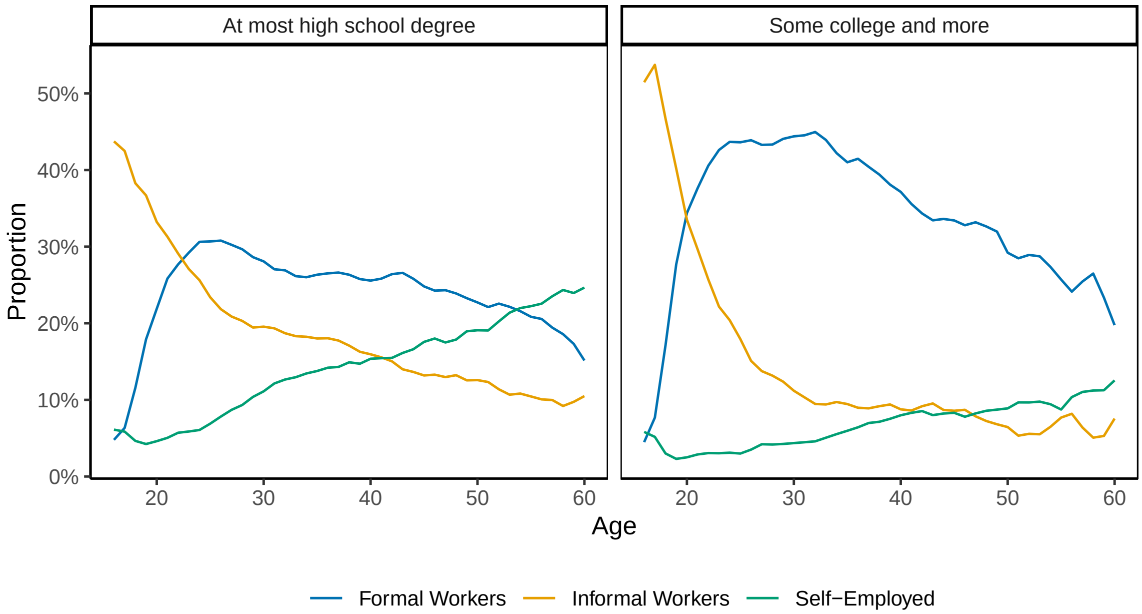
Supplemental Appendix

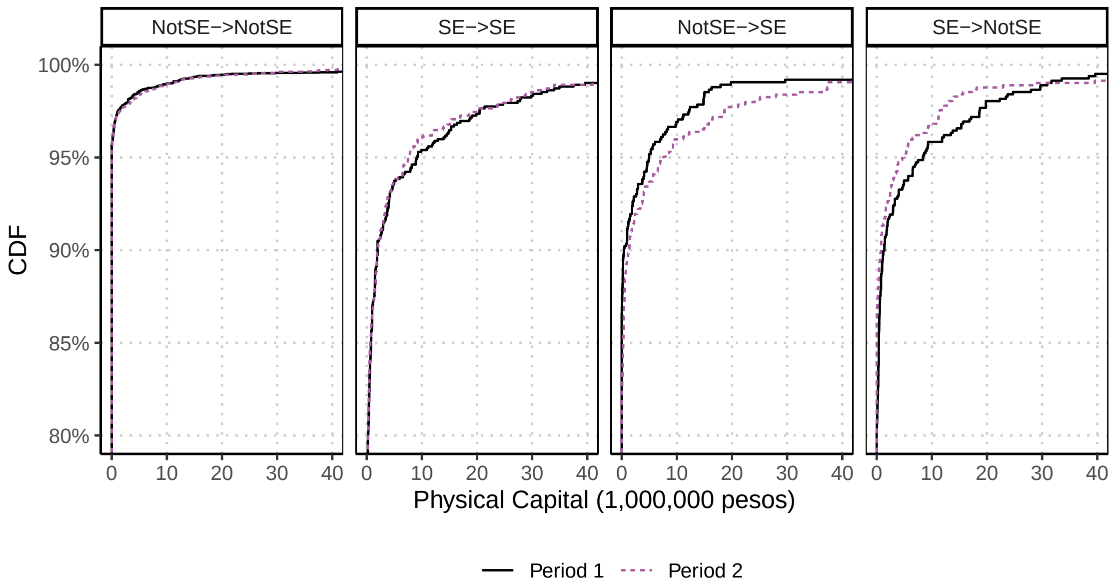
Appendix A - Appendix Tables and Figures

Figure A.1: Proportion of workers by employment type by age and education level



Notes: The figure plots the proportion of women working as formal workers (blue), informal workers (yellow), and self-employed (green) over the life cycle, separately 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. The proportions consider all individuals in the labor force. The proportions do not sum to 100% because unemployed individuals, public sector workers, and employers are not included in the graph.

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



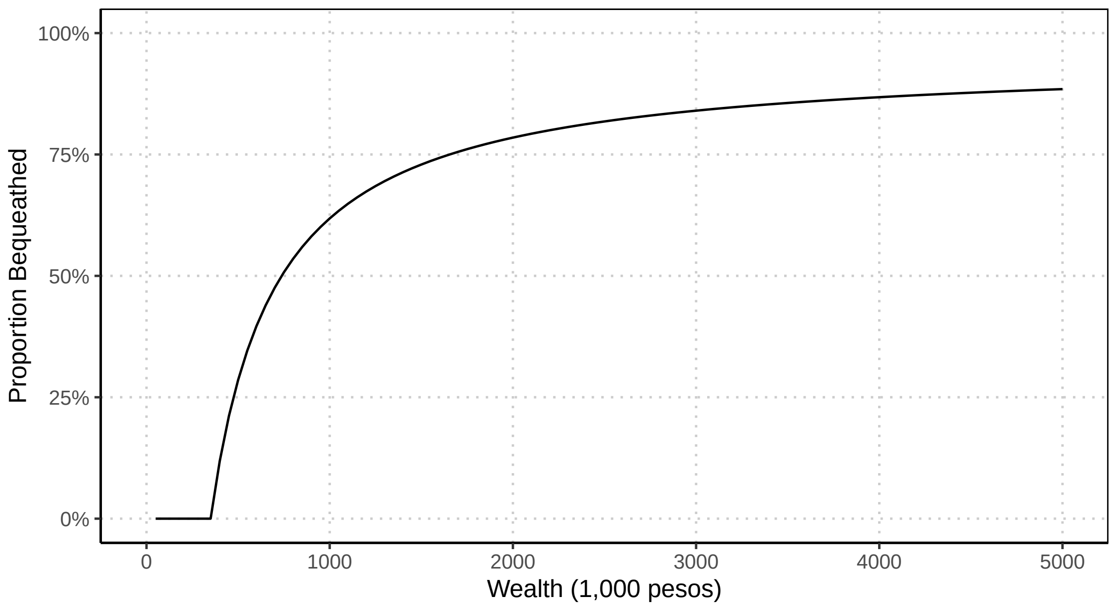
Notes: The figure shows the empirical cumulative density function (CDF) of the physical capital variable. The four panels plot the CDFs for different groups, classified as their employment status in two surveys. NotSE stands for those not self-employed. SE stands for those self-employed. $j \to j'$ stands for those in status j in the first period and j' in the second. 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%

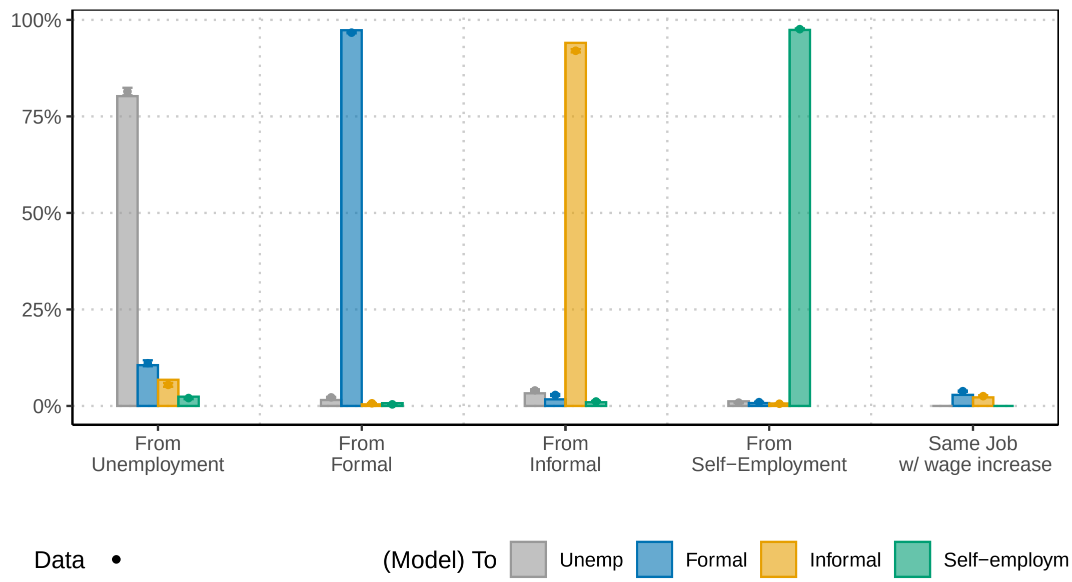
Notes: The table shows the distribution of hours of work (panel A) and workplace (panel B) for formal workers, informal workers, and self-employed individuals. In each panel, the columns sum to 100%.

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



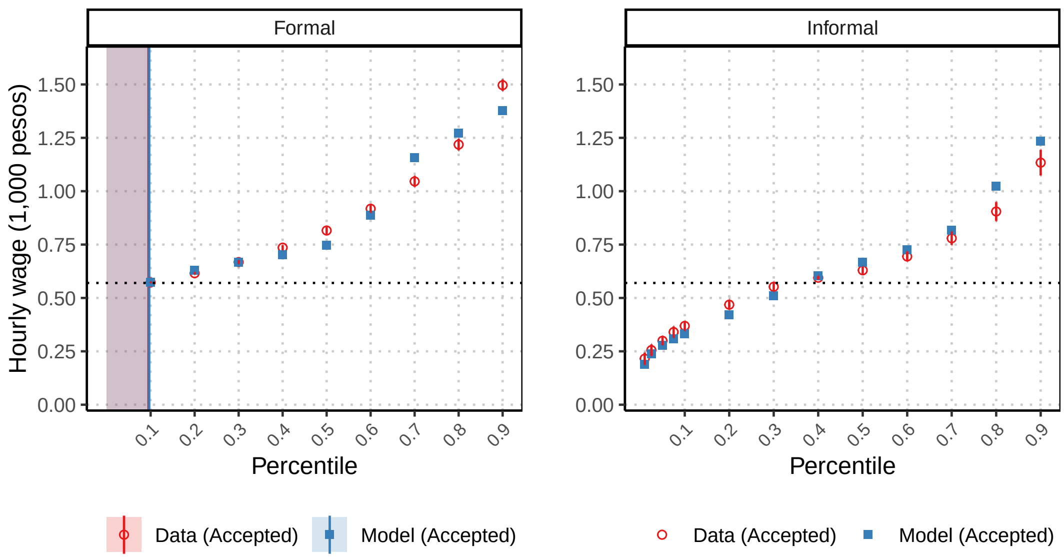
Notes: The figure shows the proportion of wealth bequeathed in the last period of life, when individuals face death with certainty. The function takes into account the interest rate (r), the discount rate (β), the coefficient of risk-aversion (γ), the consumption weight (ν), the bequest weight (ψ) and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

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



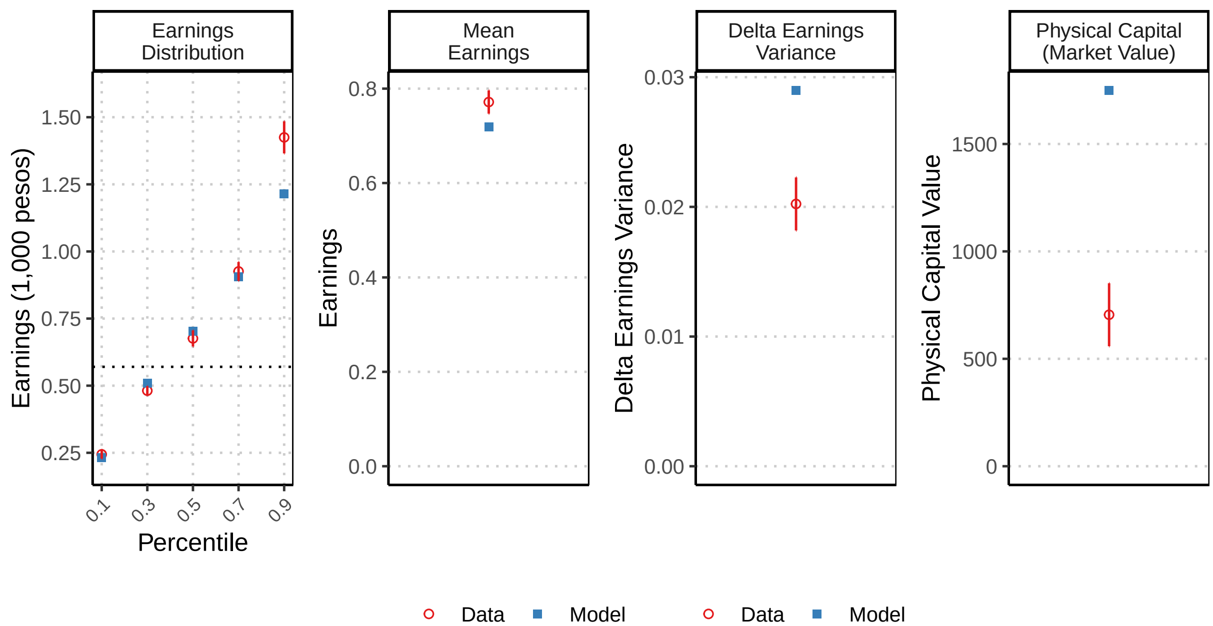
Notes: The figure shows the transition rates in the data and simulated in the model. The colors highlight the destination sector (gray for unemployment, blue for formal, yellow for informal, and green for self-employment). The sector of origin is on the x-axis. The first four groups are for individuals 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 (accepted wages)



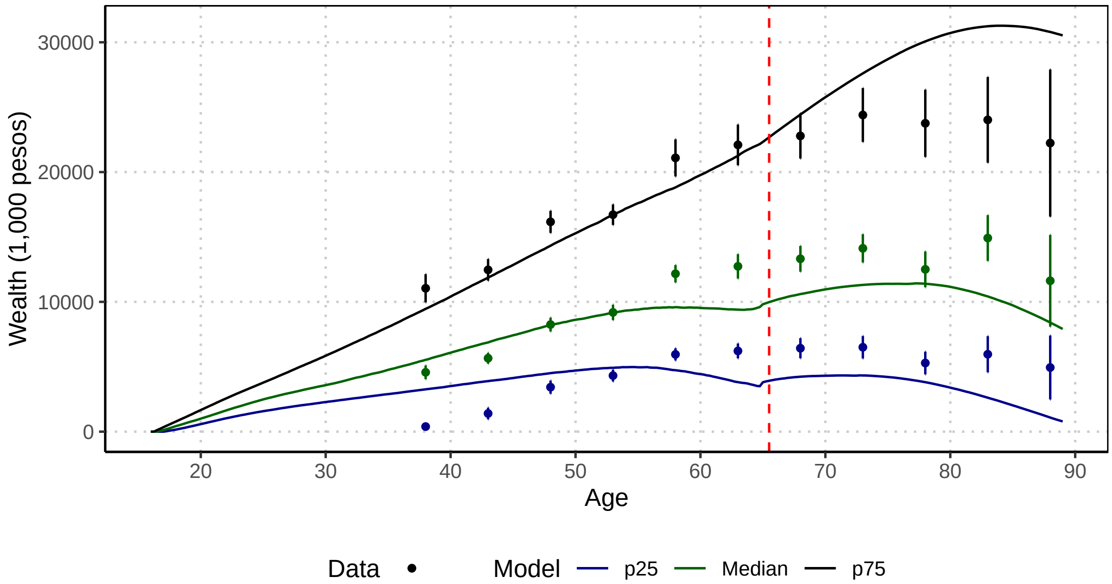
Notes: The figure shows percentiles of the earnings distribution (accepted wages) for the formal and informal sectors, in the data and simulated in the model. The red circles show each percentile in the data, together with the 95% confidence interval. The blue squares show the equivalent percentiles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

Figure A.6: Self-employment earnings



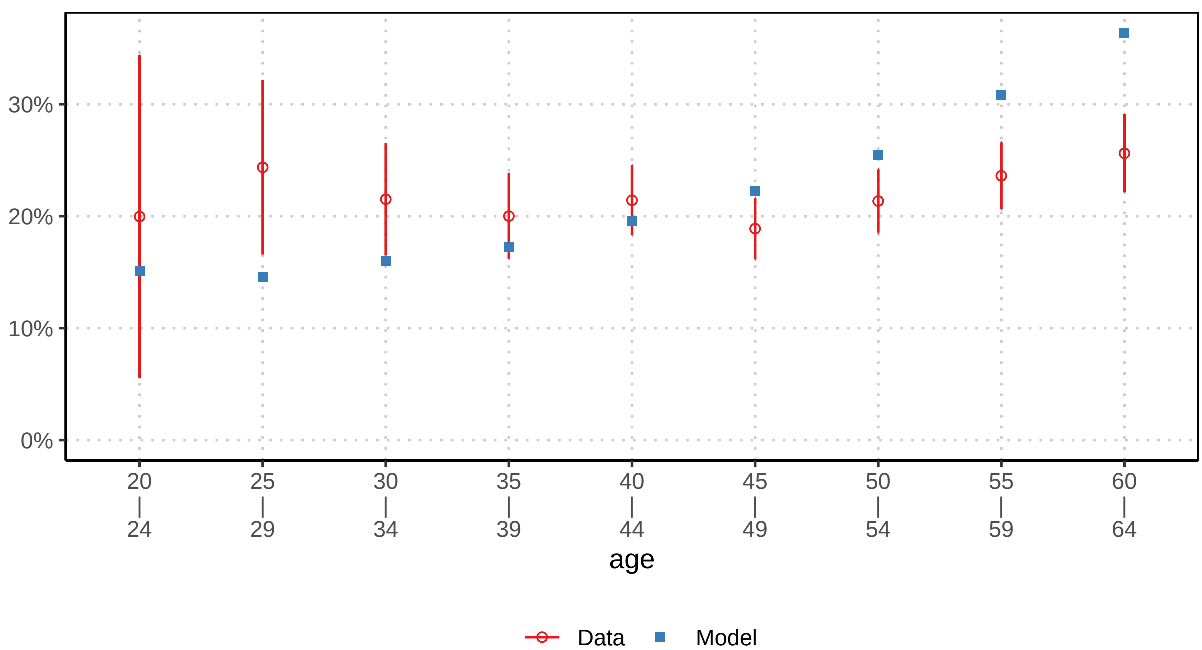
Notes: The figure shows moments of the earnings distribution for self-employed individuals in the data and simulated in the model. The red circles show each moment in the data, together with the 95% confidence interval. The blue squares show the equivalent moments in the model. The first panel shows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

Figure A.7: Wealth over the life cycle



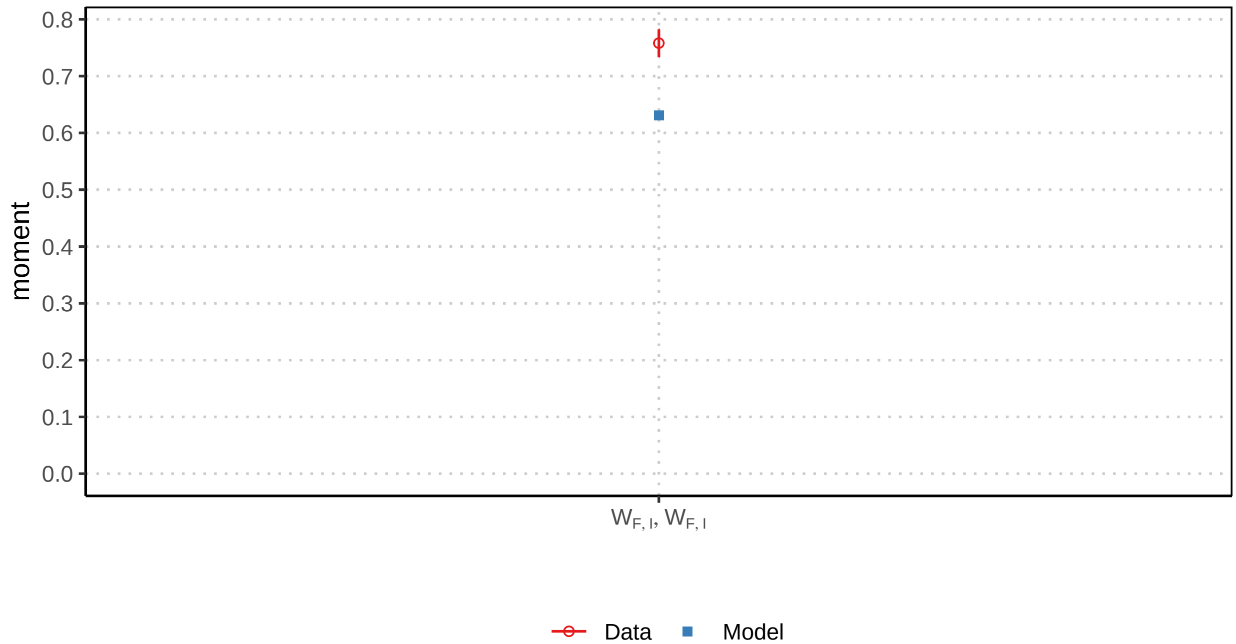
Notes: The figure shows the median (green), 25th percentile (blue), and 75th percentile (**black**) wealth over the life cycle in the data and in the model. The dots are the moments in the data, together with the 95% confidence intervals. The solid lines are the same moments in the model.

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



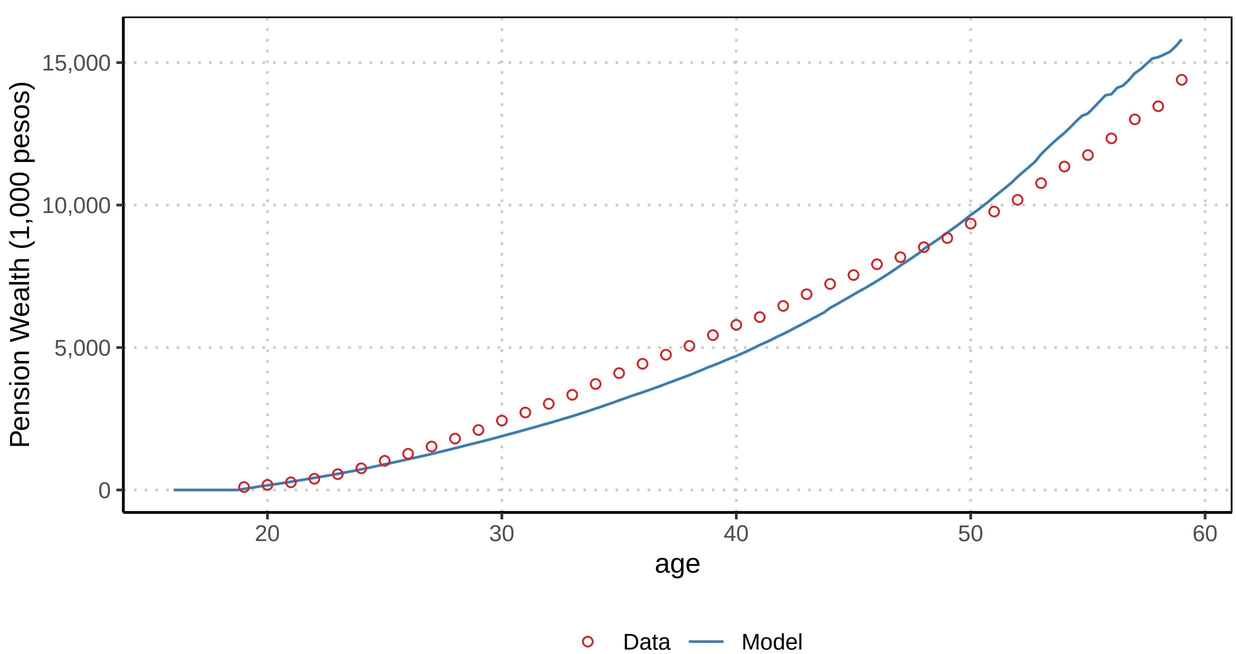
Notes: The figure shows the percentage of self-employed individuals working part-time in the data (red circles, with the 95% confidence interval) and in the model (blue squares).

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



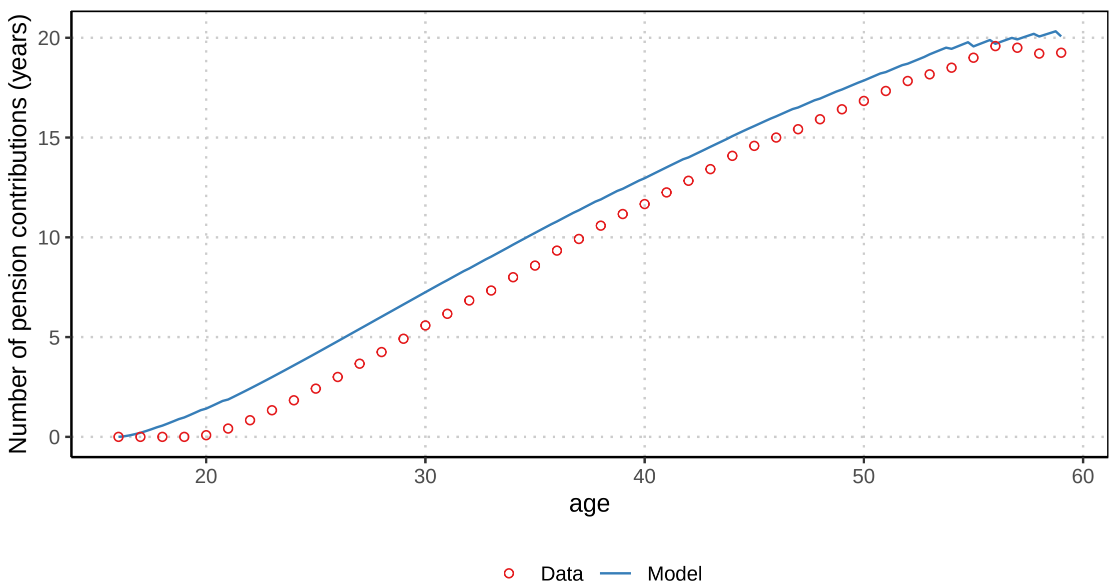
Notes: The figure plots the within-individual correlation of wages, combining formal and informal jobs in the data (red circle, with the 95% confidence interval) and in the model (blue square).

Figure A.10: Untargeted moment: Pension Wealth



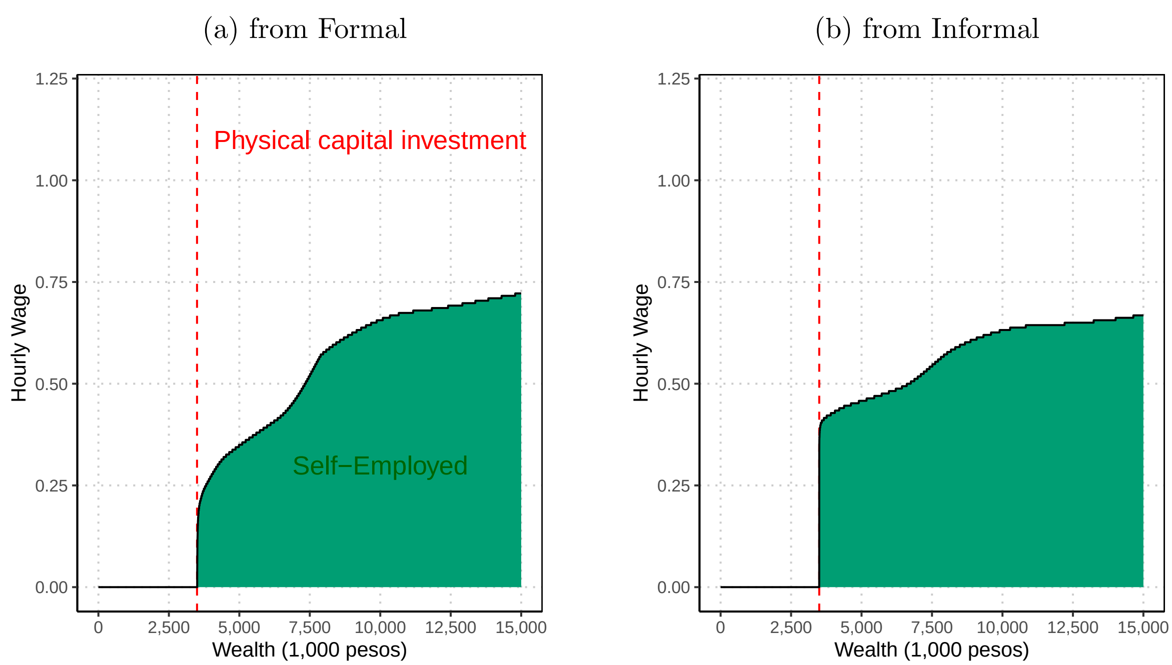
Notes: The figure shows untargeted moments, the average pension wealth (in thousand Chilean pesos) over the life cycle, in the data (red circles) and simulated in the model (blue).

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



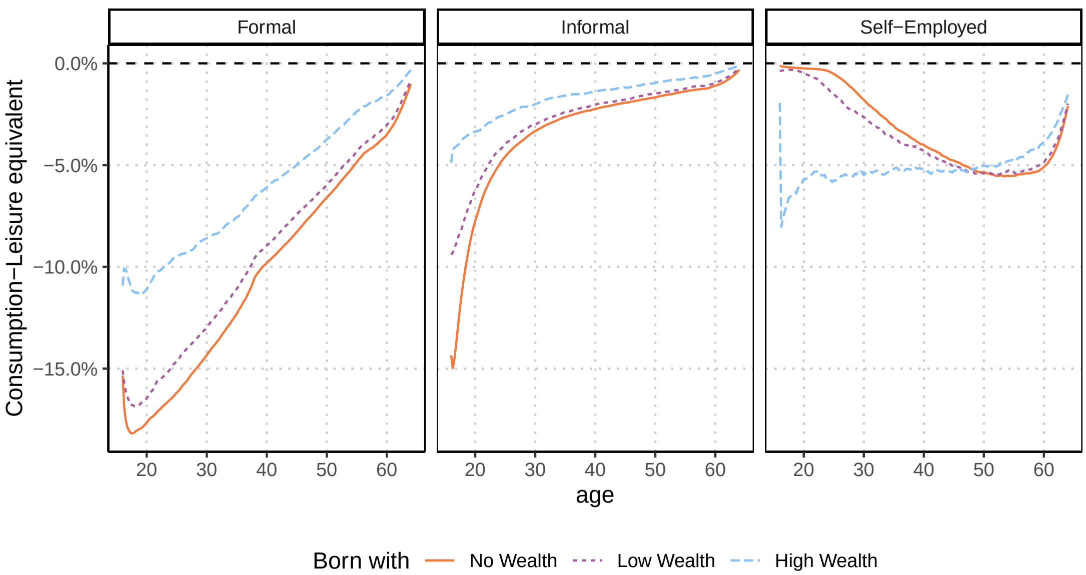
Notes: The figure shows untargeted moments, the average number of years of pension contributions over the life cycle, in the data (red circles) and simulated in the model (blue).

Figure A.12: Transitions to self-employment



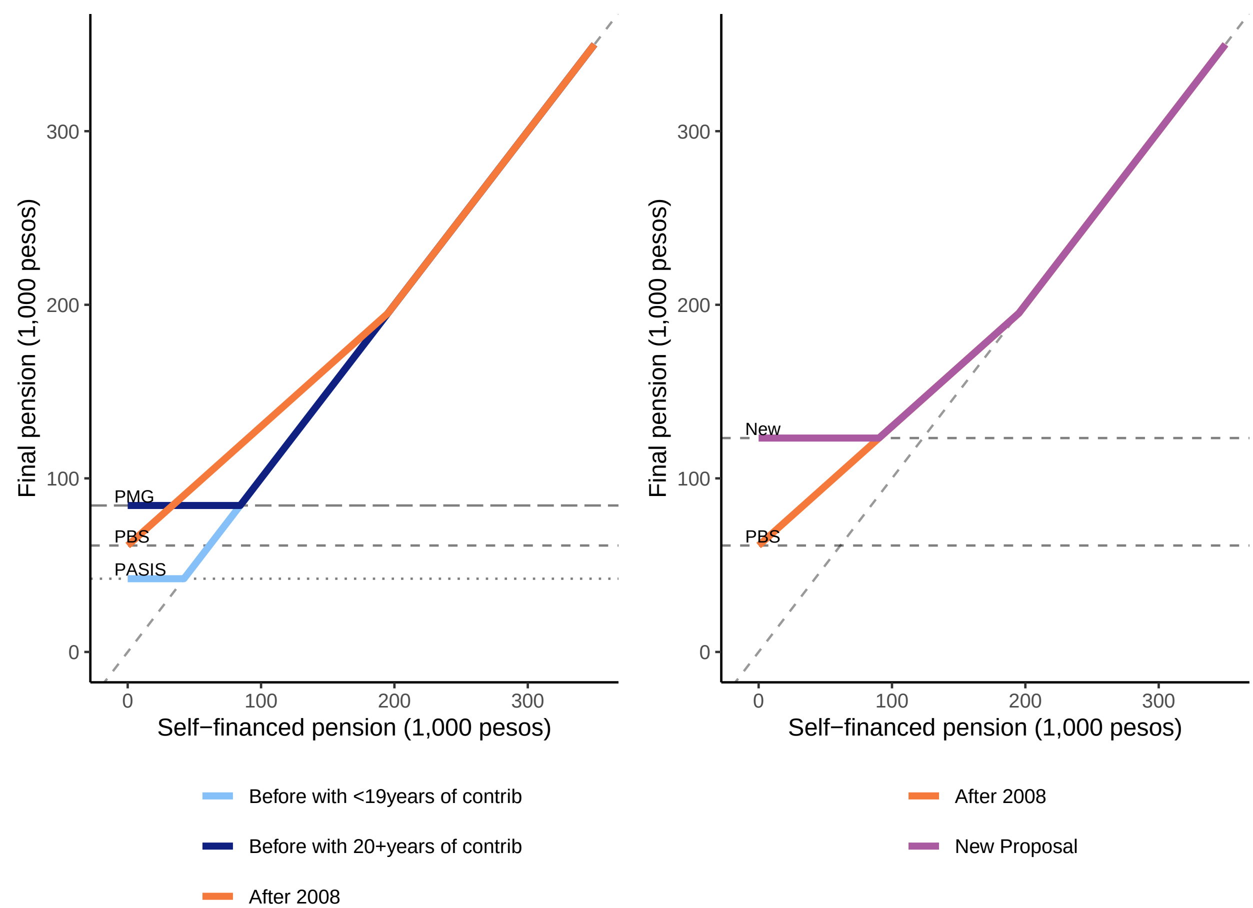
Notes: The figure shows the decisions to transition into self-employment from formal (left panel) and informal employment (right plot), as a function of wealth (x-axis) and hourly wages (y-axis). The green area denotes the combinations of wage and wealth at which individuals would prefer to move to self-employment. The vertical dashed line exhibits the initial physical capital investment required. The plot represents the decisions of an individual aged 20 years 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) by age. The three curves show the losses for individuals born with no wealth (orange), low wealth (purple), and high wealth (blue).

Figure A.14: Resulting Pension Benefits



(a) 2008 Pension Reform

(b) Change in minimum pension

Notes: The figures plot the relationship between individual self-financed pension, annuitizing their entire pension wealth upon retirement and the final pension received under different pension regimes. In the left plot, 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. The orange curve plots the final pension after the 2008 reform. In the right plot, the orange is the same final pension formula after the 2008 pension, and the purple curve is the final pension formula if an increase in the minimum pension was implemented.

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 Microemprendimiento	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 Montos 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 across 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 overlapped, I kept the one whose reporting date 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 then 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 in 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 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. This implies that I am not considering self-employment earnings for the first six months of activity.

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.

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

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 ($\bar{w}$). Therefore early retirement is possible, if and only if:

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

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 $\bar{w}$. The table below shows how these changes were gradually implemented.

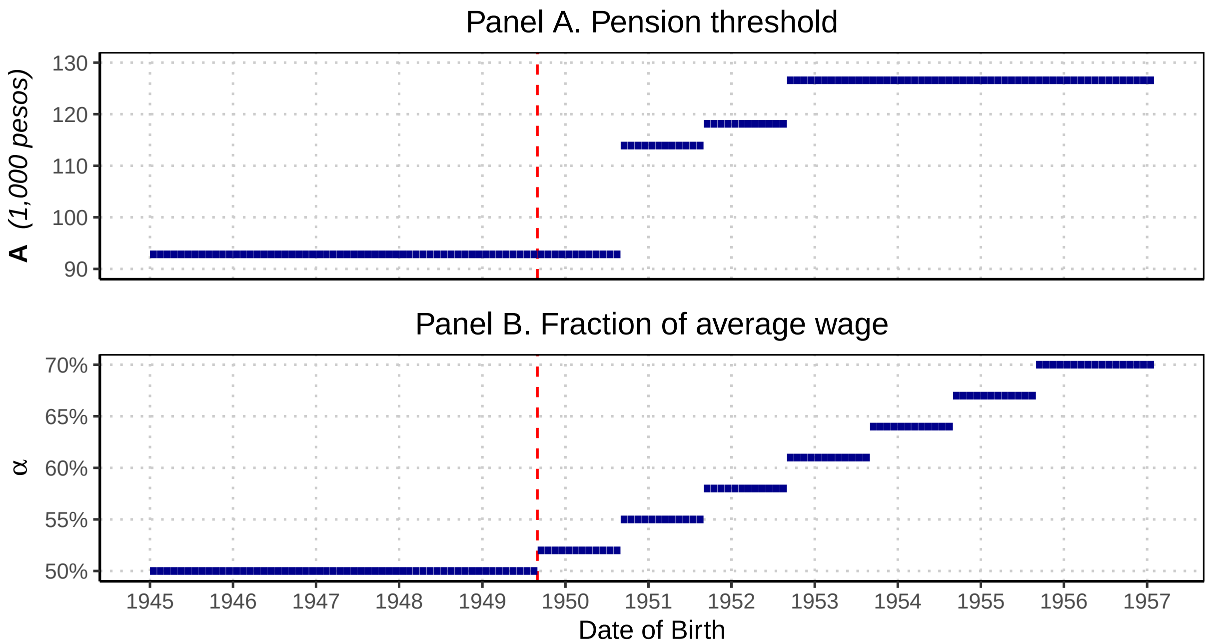
Table A.3: Early retirement requirements

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.

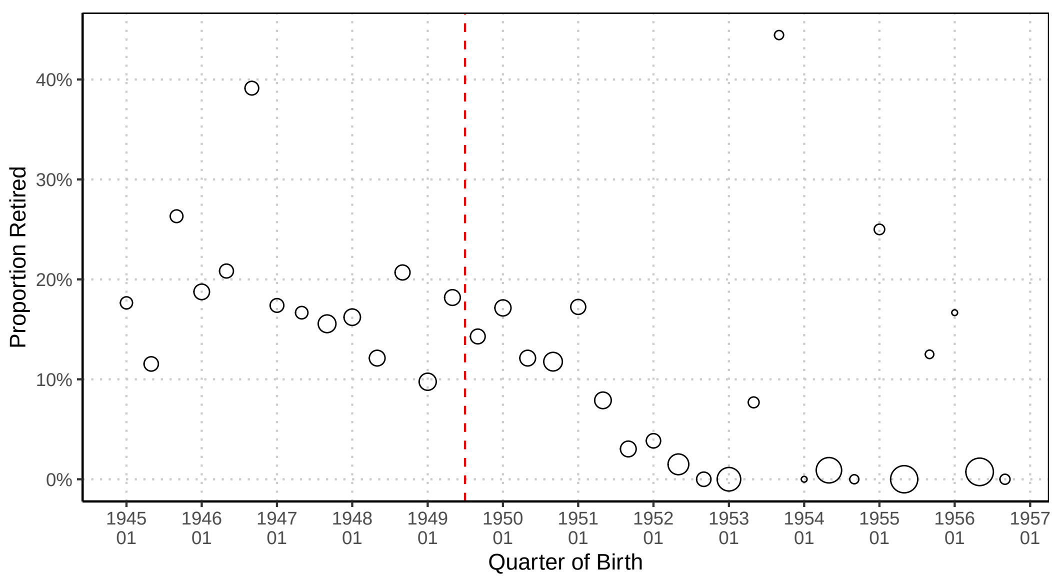
[a] Change introduced by the pension reform in 2008.

Figure A.15: 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 A.16: 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.

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 $Y(\theta, j, w, h, k, b)$.

$$Y(\theta, j, w, h, k, b) = \begin{cases} \Upsilon\Big(rk + SUF(k)\Big) + b & \text{, if } j = U \\ \Upsilon\Big(rk + g(\theta)wh(1-\tau) + AF(g(\theta)wh)\Big) & \text{, if } j = F \\ \Upsilon\Big(rk + SUF(k)\Big) + b + g(\theta)wh & \text{, if } j = I \\ \Upsilon\Big(rk + SUF(k)\Big) + b + e(\theta)wh & \text{, if } j = S \end{cases} \tag{8}$$

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 that total labor earnings are 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 depends on the baseline pension y^P, the policy environment to be determined by θ (cohort) and a (age), and the assets k.

$$Y^{\text{Ret}}(y^P, \theta, a, k) = \Upsilon\Big(rk + \tilde{y}^P(1 - \tau_H) + SUF(k)\Big), \tag{9}$$

where

$$\tilde{y}^P = \begin{cases} y^P & \text{, if year} < 2008 \text{ or } a < 65 \\ y^P(1 + PBS(1 - \frac{y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 0 \\ y^P(1 + PBS(1 - \frac{\vartheta y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 1 \end{cases} \tag{10}$$

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. If individuals retired before the normal retirement, their bonus is smaller, represented in this formula by $\vartheta > 1$.

D.2 Value function for working in the informal sector

$$\begin{aligned}\tilde{V}^{I}_{a+1} := \max\Bigg\{ & V_{a+1}(\theta, n', p', \tilde{k}, I, w), V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \\ & \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^{S}(\tilde{w}), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^{P}, q)\Bigg\}\end{aligned} \tag{11}$$

and

$$\begin{aligned}&\mathbb{E}_I[V_{a+1}(\theta, n', p', k', j', w')] = \\ &\qquad \delta_I \max\Bigg\{V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^{S}(\tilde{w}), \\ &\qquad\qquad V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^{P}, q)\Bigg\} + \\ &\qquad (1 - \delta_I)\Bigg[(1 - \lambda^{F}_{I})(1 - \lambda^{I}_{I})\tilde{V}^{I}_{a+1} + \\ &\qquad \lambda^{F}_{I}(1 - \lambda^{I}_{I}) \int \max\Big\{\tilde{V}^{I}_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w})\Big\} dW^{F}(\tilde{w}) + \\ &\qquad \lambda^{I}_{I}(1 - \lambda^{F}_{I}) \int \max\Big\{\tilde{V}^{I}_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w})\Big\} dW^{I}(\tilde{w}) + \\ &\qquad \lambda^{I}_{I}\lambda^{F}_{I} \int\int \max\Big\{\tilde{V}^{I}_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}), V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{\tilde{w}})\Big\} dW^{F}(\tilde{w}) dW^{I}(\tilde{\tilde{w}})\Bigg]\end{aligned} \tag{12}$$

D.3 Value function for self-employed

$$\begin{aligned}\tilde{V}^{S}_{a+1} := \max\Bigg\{ & \int V_{a+1}(\theta, n', p', \tilde{k}, S, \tilde{w}) dW^{S}_{w}(\tilde{w}), \\ & V_{a+1}(\theta, n', p', \tilde{k} + \pi X, U, 0), V^{\text{Ret}}_{a+1}(\theta, \tilde{k} + \pi X, y^{P}, q)\Bigg\}\end{aligned} \tag{13}$$

and

$$
\begin{aligned}
&\mathbb{E}_S[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\qquad \delta_S \max\left\{V_{a+1}(\theta, n', p', \tilde{k} + \pi X, U, 0), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\right\} + \\
&\qquad (1-\delta_S)\Bigg[(1-\lambda^F_S)(1-\lambda^I_S)\tilde{V}^S_{a+1} + \\
&\qquad \lambda^F_S(1-\lambda^I_S)\int \max\left\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, F, \tilde{w})\right\} dW^F(\tilde{w}) + \\
&\qquad \lambda^I_S(1-\lambda^F_S)\int \max\left\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, I, \tilde{w})\right\} dW^I(\tilde{w}) + \\
&\qquad \lambda^I_S\lambda^F_S \int\int \max\Big\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, F, \tilde{w}), \\
&\qquad\qquad V_{a+1}(\theta, n', p', \tilde{k} + \pi X, I, \tilde{\tilde{w}})\Big\} dW^F(\tilde{w}) dW^I(\tilde{\tilde{w}})\Bigg]
\end{aligned}
\tag{14}
$$

D.4 Optimization problem after retirement

$$
\begin{aligned}
V^{\text{Ret}}_a(\theta, k, y^p, q) = \max_{k',c}&\left\{u_j(c,\ell) + \beta\Big((1-m_a)V^{\text{Ret}}_{a+1}(\theta, k', y^p, q) + m_a b(k')\Big)\right\} \\
\text{s.t.} \quad & c + k' = k + Y^{\text{Ret}}(y^p, q, \theta, a, k) \\
& \ell = \bar{L} \\
& \underline{B} \le k' \le k + Y^{\text{Ret}}(y^p, q, \theta, a, k)
\end{aligned}
\tag{15}
$$

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 earnings) and the beta distribution (for formal and informal wage distributions). I use linear interpolation in one,

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	12	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	$n \in \{0, 1, 2\}$

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. This increases the coverage of the low levels of wealth and pension wealth, where the utility function exhibits more curvature.

The optimization algorithm solves for 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 (Powell'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 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.17–A.20). In the x-axis, there are the 212 moments used in the estimation, separated into 11 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 Appendix Figure A.17 we can see that the moments most affecting 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
G05	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
G11	Employment shares cohorts before/after 1949

Figure A.17: Sensitivity Matrix - I

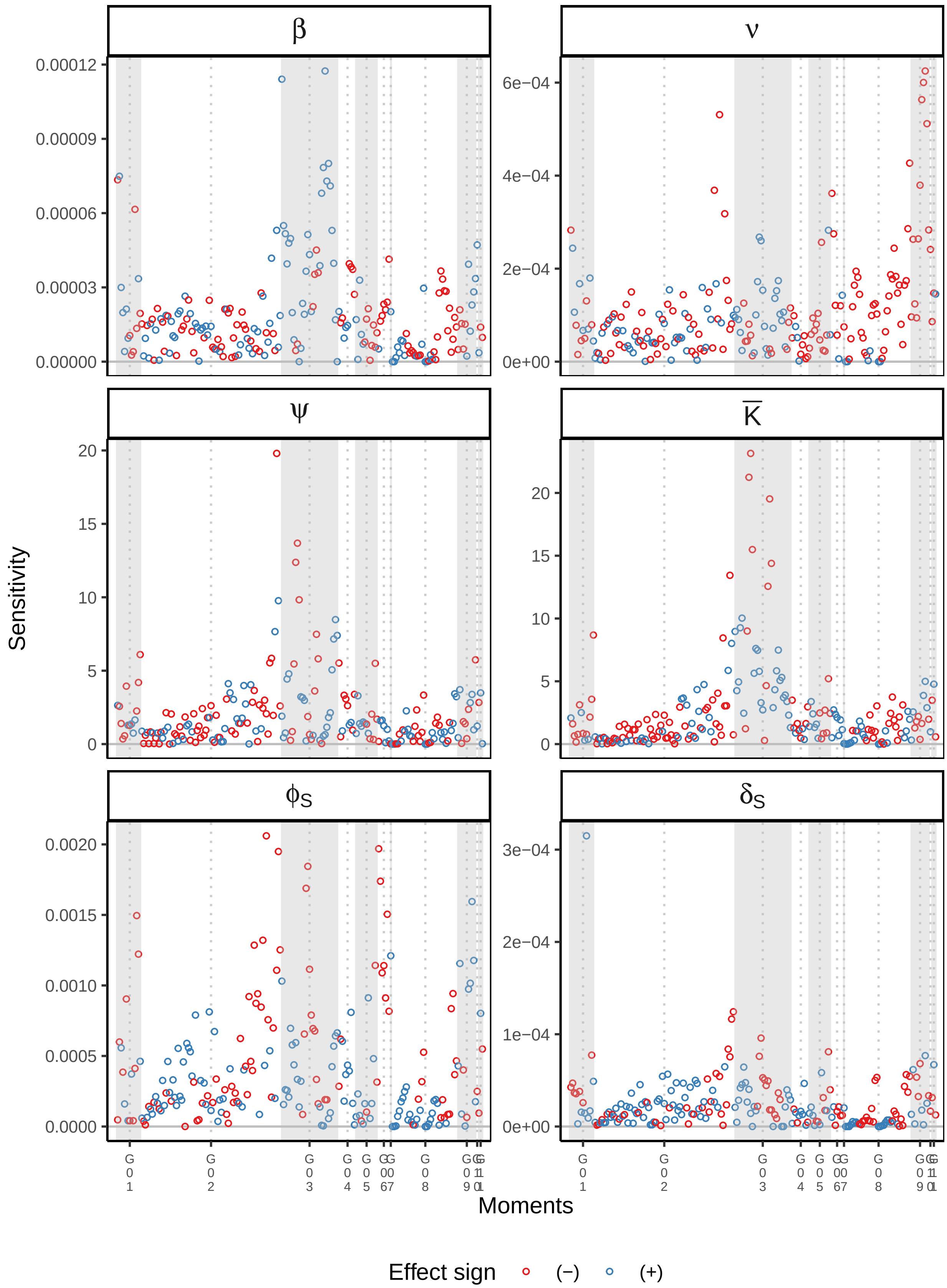


Figure A.18: Sensitivity Matrix - II

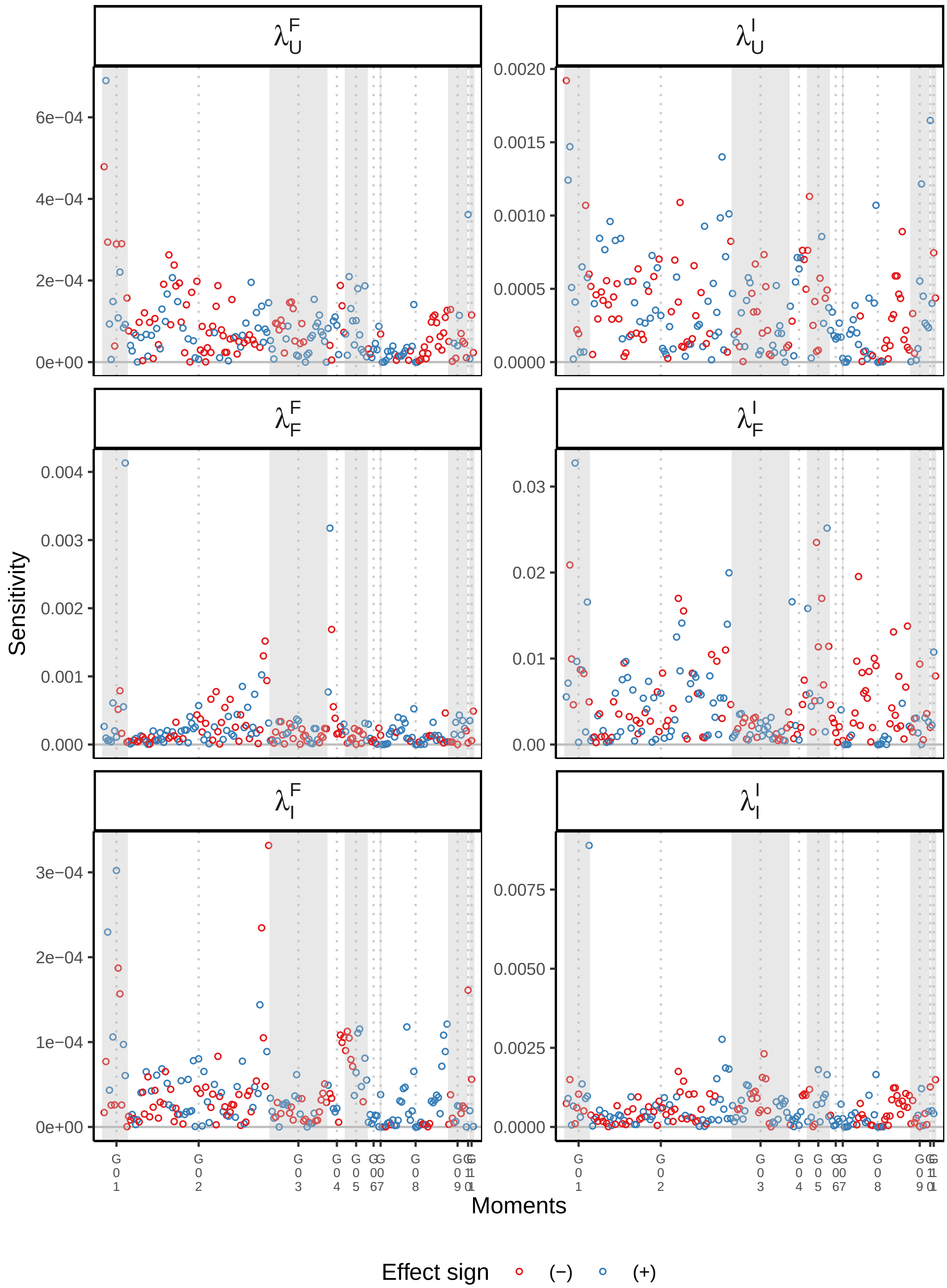


Figure A.19: Sensitivity Matrix - III

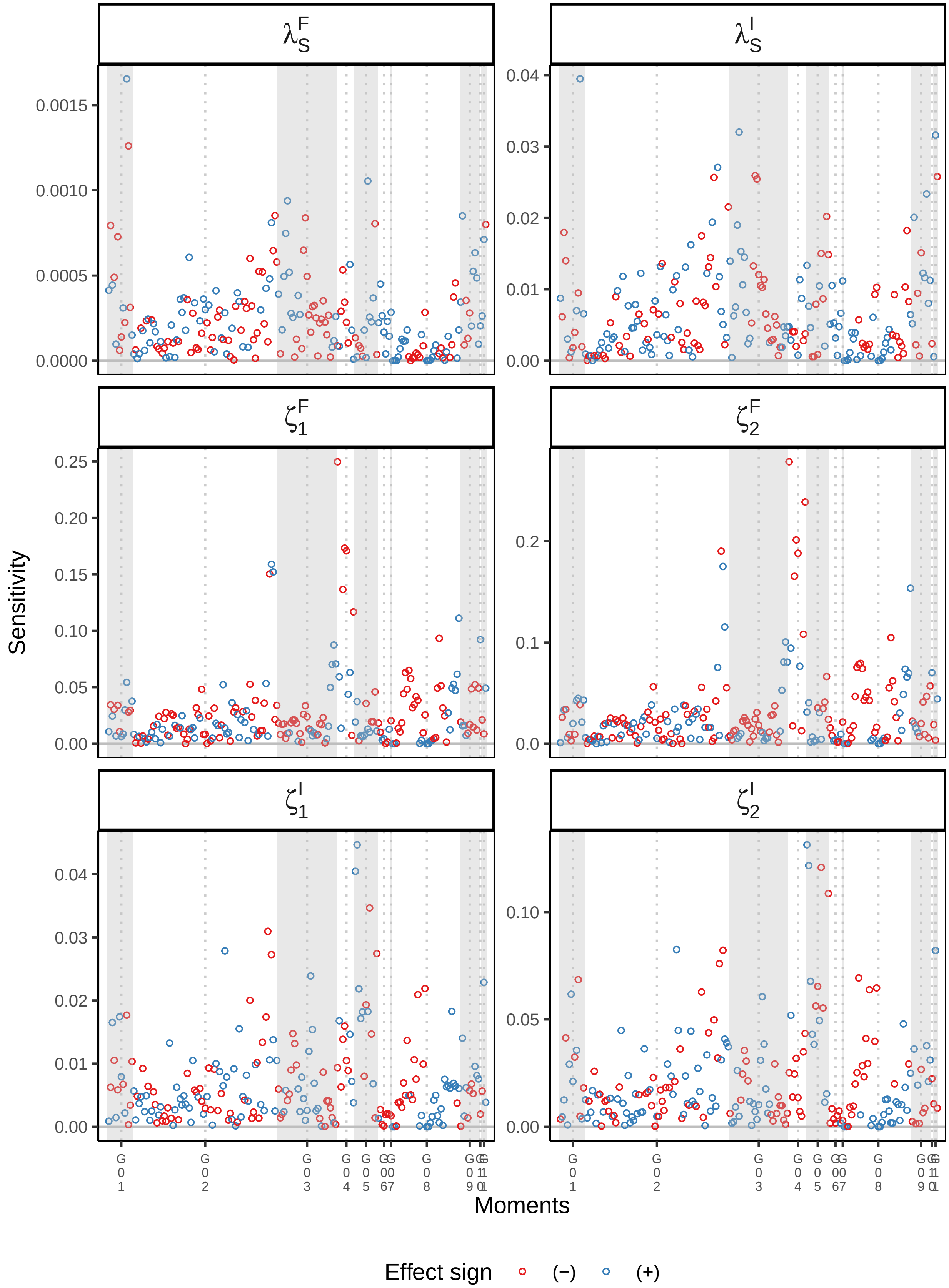


Figure A.20: Sensitivity Matrix - IV