Labor market informality, risk, and public insurance*

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Abstract

A large proportion of workers in developing countries are informal and are not covered by social insurance programs, including pensions and unemployment insurance (UI), depriving them of a key mechanism for mitigating risks. To address this important social issue, governments offer noncontributory benefits, such as minimum pensions. The design of these programs has implications for employment choices and savings, which can be used for self-insurance. To understand how policy can affect these life cycle choices, I develop a life cycle model of formal and informal employment as well as savings and self-employment (which requires self-funded irreversible investment). Formal employment gives access to a bundle of public insurance programs, while informal workers are covered by basic pension guarantees. I estimate the parameters of the model using longitudinal survey data linked with administrative data from Chile and exploiting policy reforms to the pension system. The estimates suggest that the role of savings as self-insurance, the presence of borrowing constraints, and job amenities are important drivers of employment decisions. I also show evidence of complementarities between pensions and UI: when individuals have access to UI to insure themselves in the short run, they are more likely to invest in pensions. In counterfactual simulations, I show how the pension design affects formality decisions.

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1 Introduction

Spending on social insurance programs accounts for a large share of private and public spending. In South America, for example, it ranges from 8% to 23% of GDP.[1] Countries provide a diverse set of programs, typically including targeted welfare transfers, unemployment insurance, and pensions. The essence of these insurance programs is to protect individuals from several shocks that give rise to earnings and consumption volatility, transferring resources across states and time. The design of social insurance involves many tradeoffs: characteristics, such as eligibility criteria, benefits structure, and links with labor market history, imply choices between the extent of insurance offered and incentives. For instance, countries may offer non-contributory minimum pensions, which offer better insurance at the expense of more expensive social security with weaker employment incentives.

A feature of the labor market in many developing countries is a high degree of informality. In Latin America, between 30% and 70% of the urban workforce is employed in the informal sector (Maloney, 2004). Informal workers do not comply with labor market regulations and do not directly contribute to social security. As a consequence, they have limited access to several social insurance programs, leaving them considerably more vulnerable to risk than those formally employed. Since the option to work informally gives an additional margin of adjustment for individuals, the existence of a large informal sector may change and amplify the tradeoffs of social insurance design. On the one hand, the existence of informal opportunities can be seen as a form of insurance. If it is easier for individuals to find an informal job or to engage in informal activities, the need for formal insurance may be reduced (Gerard and Gonzaga, 2021). On the other hand, informality may exacerbate the moral hazard associated with these insurance mechanisms. For example, as the government cannot monitor the informal sector, individuals may receive benefits and informal earnings,

[1]Data on public and private social expenditure (SOCX methodology) for the year 2018 from CEPALSTAT/ECLAC.

staying away from the formal labor market for longer (Gonzalez-Rozada and Ruffo, 2016, Gerard and Gonzaga, 2021). Similar tradeoffs are also evident over a longer horizon. More generous pension systems offer more insurance—individuals that experienced weaker labor history will access better benefits. However, this may reduce the incentives for individuals to contribute to pensions throughout their working lives. Therefore, designing a social insurance system that balances insurance and incentives in the presence of informality is particularly challenging.

This paper studies how labor market conditions, social insurance policies, and workers' characteristics shape labor decisions, including the type of employment (formal or informal), taking into account the tradeoffs between exposure to risk and insurance. I focus on the way that distinct insurance programs interact and the role of savings in providing self-insurance. Individuals may be more willing to invest in higher-return, non-liquid assets (pensions) if their short-term risk exposure is covered (unemployment insurance), decreasing the need for liquid assets. To investigate these questions, I link survey and administrative microdata from Chile. I first explore a quasi-experiment from a reform that strengthened the requirements for retirement before the normal retirement age. This exercise highlights the importance of pension rules in employment decisions. In order to investigate the dynamic incentives over the careers of individuals, I develop a life cycle model where agents decide on savings and employment in the presence of risk and social insurance. This allows me to explore counterfactual changes in the social insurance system and investigate the drivers of employment choices over the life cycle.

Chile provides an ideal setting to investigate these questions. First, it is one of the most developed countries in Latin America, with social insurance programs co-existing with high informality levels, between 28–35% of the labor force. Second, the government has experimented with social insurance programs in the last 20 years. The government tightened the requirements for retirement before the normal retirement age (in a reform in 2004),

increased the generosity of the pension system through a large reform that increased the non-contributory pension floors (in 2008), expanded access to unemployment insurance (in 2009), and increased unemployment benefits (in 2015). Third, rich microdata are available.

I use two main datasets, a longitudinal survey (*"Encuesta de Protección Social"*, EPS) and administrative data from the pension system (*"Historial Previsional de Afiliados"*, HPA). I link the two datasets at the individual level, resulting in a long-term panel, coupled with disaggregated wealth snapshots and monthly administrative data on pension contributions and pension wealth, for about 30,000 Chilean households between 1981 and 2019. Such data are rarely available in developing countries. I focus on men with at most high school education.[2] I supplement these datasets with several additional sources of information using administrative data on pension claims, unemployment benefit claims, and two labor market surveys.

Using these data, I derive three empirical findings that guide the model design and estimation. I first show how three broad categories — formal employees, informal employees, and the self-employed — account for the totality of private employment. The three sectors have different characteristics, particularly in the age profile, working hours, and workplace. A second finding relates to transitions to self-employment. I show that individuals use their own savings to fund the start of their activity and that transitions to self-employment are associated with investments in physical capital.

In the third empirical exercise, I exploit the 2004 reform in Chile, which tightened the requirements for early retirement. To be eligible for early retirement, individuals need their pensions to be above a minimum threshold, which was raised by 40%.[3] I explore the fact

[2]The restriction on men is due to the model limitation of not having an out-of-the-labor-force state. Given men's relatively higher labor force attachment, it is less problematic for this sub-sample. The restriction on individuals with at most high school degrees is to focus on a sample with relatively higher informality, for whom the tradeoff of risk and insurance may be more salient. In Section 8, I discuss extensions that would support the analysis for women and individuals with college education or more.

[3]In Sections 2 and 3, I present all the requirements for early retirement and how they were affected by the 2004 pension reform.

that the changes were discontinuously implemented in time and across cohorts to estimate the causal effects of this reform. The reform reduced early retirement by 15 percentage points, a sizable reduction from a baseline retirement probability of 25% (implying a 63% effect). Yet, it only raised the probability of individuals contributing to pensions by 4–6 percentage points. This discrepancy between individuals staying longer in the labor force but not necessarily contributing to pensions highlights the importance of taking employment decisions, including informal and self-employment, into account. The reform induced an increase in the probability of individuals working as self-employed, which can explain the low probability of pension contributions, as the self-employed do not need to pay them. I use this result directly in the model estimation, as the reform provides exogenous variation of the desirability of individuals to retire early.

While the reduced-form results are informative about the response to the more stringent requirements for early retirement, they are silent on the mechanisms driving labor decisions and the impacts of alternative social insurance changes. In order to investigate these questions, I develop a life cycle model where risk-averse agents decide on savings and employment when facing various risks. To capture job rationing and uncertainty in job search, individuals face search frictions to obtain a job in a firm, either informally or formally, which results in uncertainty on the timing and wages of job offers. Self-employed workers face, in addition, earnings volatility in every period. All working individuals might suffer separation shocks and lose their job or self-employment activity. Finally, everyone faces longevity risk, making individuals uncertain about how long they will need to finance consumption. Each of these risks is quantitatively important and connected to their labor market choices.

Agents can have up to two ways of insuring against these shocks. First, all individuals may use their savings. Second, if they are formal workers, they can rely on social insurance. While holding a formal job, workers contribute to social security, which entitles them to three social insurance programs: unemployment insurance (UI), severance payments, and

pensions. Individuals can also work informally for firms or be self-employed. If they choose either, they do not pay taxes or contribute to pensions but are entitled to a non-contributory minimum pension. I treat informal employees and self-employment as different sectors. Both of them offer different levels of amenities compared to the formal sector. In order to engage in self-employment, agents need to invest in physical capital, which is in part irreversible.[4] In the model, retirement is an endogenous choice, which is essential for capturing the impact of incentives emanating from the pension design. All decisions (consumption, savings, sector of employment, and retirement) depend on individuals' current status, including age, unemployment insurance eligibility, and, importantly, savings.

I estimate the primitives of the model using the Chilean microdata and exploiting the pension reforms in 2004 and 2008. The model replicates key characteristics of the labor market and savings behavior. It matches well the labor market allocation of the three sectors over the life cycle: namely, the hump-shaped age profile for the formal sector, the declining participation of informal employees, and the increasing participation in self-employment. I show that three mechanisms are quantitatively important for achieving this match. The first is the different job search behavior of individuals with different savings levels. Agents with the lowest wealth have fewer resources to rely on and are, therefore, more likely to accept low-wage offers, particularly from the informal sector, where offer arrival rates are higher. The model, therefore, also accounts for the observed cross-sectional correlation of wealth and informality. The second important mechanism relates to self-employment. I show how physical capital requirements and borrowing constraints are important in explaining the age profile of self-employment. Third, amenities and the option of working part-time are also important characteristics that explain the high proportion of self-employed individuals at older ages. The result also highlights the effects of unemployment insurance. Unemployed individuals have different reservation wages depending on whether they are eligible for un-

[4]The model considers both liquidity and insurance constraints for self-employment activity, consistent with the findings by Bianchi and Bobba (2013).

employment benefits.

I consider two counterfactuals. The first quantifies and decomposes the effects of the 2008 reform, which dramatically altered the pension landscape. It (i) increased the non-contributory minimum pension by 45%, and (ii) strengthened the early retirement restrictions, raising the threshold for early retirement eligibility by 23%.[5] I show that the disincentive effect, in terms of formal participation rate, caused by (i) was small and limited to individuals between 50-65, reducing formal participation by 1pp. Moreover, it was more than offset by (ii), which increased the formal participation rate by 6pp. The overall effect of the reform was to increase the proportion of individuals aged 50–65 working formally by 5pp, with no effect for individuals younger than 50 years. This exercise highlights how the government can use a combination of mechanisms of the pensions system to achieve the policy goal.

The second set of counterfactuals analyzes pension reforms recently discussed by the Chilean government (in June–August of 2022). They propose a higher minimum non-contributory pension (by 100%) and a higher contribution rate (from 10% to 16%). The two mechanisms are expected to discourage formal employment since they simultaneously increase the non-contributory pension benefits and decrease net earnings. I show that they could have moderate disincentive effects that could extend to much younger workers than what was observed with the 2008 reform. The reform would decrease the participation in the formal sector by 3.9pp over the life cycle. I also use this exercise to highlight the interactions between pensions and UI. I show that the government could, at the same time, expand the unemployment benefits in a budget-neutral way. This would reduce the negative effects of the pension reform by 1.5pp (40%). This exercise shows how the government can use more than one instrument to achieve its policy goals. Importantly, they could take advantage of the complementarities between insurance programs to offset the discouragement

[5]For an individual at the margin of eligibility.

in participation in the formal sector.

In summary, both through the reduced-form analysis of the pension reform and from the model-based counterfactual simulations, I show how social security affects employment decisions. Moreover, I show how these responses vary over the life cycle and how they may depend on the other insurance programs. Savings have an essential role. It affects the formal and informal job acceptance rates and can be used to invest in physical capital for self-employment activities. These factors, together with the amenities provided by self-employment, are key drivers for employment patterns over the life cycle.

This paper contributes to several strands of the literature. First, there is a large literature studying firms' and workers' formality decisions, mostly using a search and matching framework (Zenou, 2008, Albrecht et al., 2009, Ulyssea, 2010, Bosch and Esteban-Pretel, 2012, Lopez Garcia, 2015, Meghir et al., 2015, Albertini and Terriau, 2019, Narita, 2020, Haanwinckel and Soares, 2021, Bobba et al., 2021, 2022). Most of this work has focused on the role of firms deciding whether to comply with the labor market regulations. In these papers, workers are characterized as risk-neutral individuals who compare formal and informal offers in terms of earnings and future employment opportunities. This assumption makes it infeasible to discuss the role of risk and the value of insurance from social security in the workers' labor market decisions. A smaller set of papers introduce risk-aversion and model workers' employment decision (Pardo and Ruiz-Tagle, 2016, Conti et al., 2022, da Costa and Lobel, 2022). Compared to this work, my paper introduces the savings decision, which will be one of the key channels driving search behavior and allowing individuals to use their liquid assets as a self-insurance mechanism. Additionally, this paper also differs by accounting for heterogeneity in the informal sector, distinguishing between informal employees and self-employment. The endogenous savings decision also allows me to take into account the physical capital investments made by self-employed individuals. Closer to this paper is Herreño and Ocampo (2021), who study how workers choose between formal jobs and

self-employment in Mexico. My paper mainly differs by introducing the safety net brought by social insurance programs through unemployment insurance, severance payments, and pensions.

The effects of social security on formality decisions have also been studied in the literature. Several programs have been analyzed, including unemployment insurance and severance payment (Huneeus et al., 2012, Espino and Sanchez, 2013, Gonzalez-Rozada and Ruffo, 2016, Audoly, 2018, Gerard and Gonzaga, 2021, Britto, 2022, de Azevedo, 2022, Bloise and Santos, 2022), health insurance (Calderón-Mejía and Marinescu, 2012, Azuara and Marinescu, 2013), the 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, 2019, Joubert and Todd, 2020, Ferreira and Parente, 2020, Moreno, 2022). I make two contributions to this literature. First, I estimate the causal effects of strengthening the requirements for early retirement on retirement before the normal retirement age, pension contributions, and employment. I show how the changes reduced early retirement remarkably but did not translate to an increase in pension contributions of the same magnitude. Second, I develop a life cycle model insurance against shocks, both in the short and long run. I show the importance of considering how formal employment grants access to a bundle of social insurance programs and how they might exhibit complementarities. When individuals have access to UI to insure themselves in the short run, they are more likely to invest in pensions.

Lastly, my paper relates to the literature on self-employment in developing countries, particularly in the context of urban informality in Latin America. Most informality literature either groups self-employed individuals with informal workers or excludes them from the data. As in Narita (2020), Bobba et al. (2021, 2022), and Moreno (2022), I stress that self-employment (i) is informal and (ii) should be modeled differently from employed individuals working informally for firms. I show that self-employment and informal jobs differ over

the life cycle and have different job characteristics, mainly in terms of hours of work and workplace. The richness of my data allows me to present evidence consistent with the pre-requisite of up-front start-up costs for self-employment and the existence of significant borrowing constraints. This is important when analyzing transitions to self-employment in developing countries.

The remainder of the paper proceeds as follows. In the next section, I discuss the institutional setting of social insurance in Chile, the data, and how I classify workers working formally, informally, or as self-employed in the data. In Section 3, I estimate the causal effects of the reform that strengthened the early retirement requirements and the capital requirements to become self-employed. Sections 4 and 5 discuss the proposed life cycle model and the estimation procedure. The model estimates are presented in Section 6. In Section 7, I present a series of counterfactual analyses. The last Section concludes the paper with some final remarks.

2 Institutional Setting and Data

Chile is one of the most developed countries in Latin America. Even so, a substantial share of the labor force is informal. This section first discusses the main details of social insurance in Chile, focusing on the main programs that will be analyzed in this paper. Next, I present the data and show how I derive the sample used in the empirical part.

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 firms to administer their pension wealth. The funds are illiquid until retirement, which can take place at age 60 for women and age 65 for men. Formal workers are mandated to contribute 10% of their

earnings to the pension system up to a cap.[6] On top of the pension contributions, workers pay administration fees and contributions towards disability insurance and survival pension, which total, on average, 2.2% of wages.[7]

Upon retirement, individuals can choose from various financial options, including the purchase of annuities, which insure individuals against longevity risk.[8] Initially, individuals who contributed for more than 20 years were entitled to a minimum pension of around 85 thousand Chilean pesos.[9] Those who did not qualify for the minimum pension could receive an assistance pension that is 50% smaller. Retirement before the normal retirement age of 65 was possible if the resulting pension benefit was (a) greater than 110% of the minimum pension and (b) above 50% of the last ten-year average wage.

In 2004, the government strengthened the requirements for early retirement. After the new law, retirement before the normal retirement age was only possible if the resulting pension was (a) above 150% of the minimum pension and (b) at least 70% of the last ten-years average wage. The formula to compute the average wage was also modified, imposing a cap of at most 16 months of zero earnings to be included in the ten-years 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 important to estimate the effects of this reform.

In 2008, a large reform changed several features of the pension system. First, it abolished the 20 years requirement, replacing it with two new components. The first is a solidarity pillar, which entitles all citizens 65 or older to a minimum pension irrespectively of the contribution history. The second is a pension complement which gives the minimum

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

[7]These numbers vary monthly, 2.2% is the average value computed between 1993 and 2019 using the data on the commissions collected by the *Superintendencia de Pensiones*.

[8]For a complete characterization of the decisions upon retirement, see Bello (2019).

[9]I use the real values of Chilean pesos in August 2004, the date of the first pension reform. One thousand pesos are approximately equivalent to 1.50 US dollars.

pension as a bonus that is 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 enhanced the early retirement requirements, requiring the resulting pension to be at 80% of the PMAS, which was 23% higher than the previous requirement. Lastly, the reform made self-employment pension contributions mandatory starting in 2019. Given how difficult it is for the government to monitor self-employment activity, enforcement of this rule is challenging.[10]

Severance Payment and Minimum Wage — Severance payment has existed in Chile since 1946 and entitles all formal workers with tenure above 12 months to one month's worth of wage for each full year of tenure upon a lay-off event. In 1980 a cap of 5 months for the payment was introduced, which was later raised to 11 months (Huneeus et al., 2012). Since 1971, workers in the formal sector have been subject to a minimum wage fixed annually by Congress. The minimum wage refers to a contract of 45 weekly hours of work. The value in 2004 was 120 thousand pesos.

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

[10]The 2008 reform also introduced a bonus for women equivalent to 18 monthly contributions at the minimum wage for each child. This bonus was applied retrospectively to all mothers. After the reform, women gained access to up to 50% of their husband's pension wealth in case of divorce. For this and other changes of the pension reform, check Todd and Joubert (2013).

[11]If you are a temporary worker, the employer must pay for the totality of the contribution.

they can be complemented with resources from the solidarity fund. There are limits to accessing the solidarity fund to reduce moral hazard.[12]

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. Every individual is automatically affiliated with the public health fund (*Fonasa*), but individuals may opt to transfer to a private provider, directing their contribution to the health provider.

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

Welfare Programs and Income Tax — Individuals with formal low-paying jobs and that have dependents with no earnings (spouse or children, for example) are entitled to a subsidy (*"Assignación Familiar"*, AF). The benefit amount depends on the number of dependents and the worker's 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 with marginal tax rates from 0 to 40%. In the model, I assume informal workers and self-employed individuals do not pay income tax on their labor earnings.

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 (2002, 2004, 2006, 2009, 2012, 2015, and 2019) and contains rich information on demographics, family structure, earnings, employment, and wealth. The initial sample had approximately 17,000 individuals. With

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

the refreshments in the subsequent years, around 35,000 individuals were interviewed. Since the second wave, EPS is nationally representative.[13]

The survey characterizes the labor market history for the surveyed individuals. 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. Therefore, I can reconstruct the entire labor market trajectory for most workers. The constructed 40-year-long panel allows me to compute the life cycle allocation of individuals in the types of jobs: formal, informal, or self-employment.

Using the administrative dataset, "*Historia Previsional de Afiliados*" (HPA), I can link all surveyed individuals from EPS to the pension administrative data and get 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. The combination of the two datasets yields rich longitudinal data with employment history and wealth, which are rarely available in developing countries.

I restrict the data to individuals born between 1940 and 1989. Therefore, individuals were at most 40 years old when the new pension system was introduced in 1980 and at least 30 years old when they were last observed in the wave in 2019. I restrict to men with at most high school degrees. The focus on men is due to the model limitation of not having a non-employment status. Since men exhibit relatively larger labor force attachment, I abstract away from individuals not in the labor force. I focus on individuals with at most high school education since this is the group with relatively higher levels of informality and for whom the tradeoffs of insurance and risk may be more sound.

To minimize recall bias, I only use labor market information (employment sector, work-

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

ing hours, and wages) for spells within 24 months of the reporting date. Additionally, to minimize concerns with business cycle fluctuations and changes in the minimum wage, I de-trend all the monetary values.[14] For most of the analysis, I focus on the period between 2002-2015, corresponding to the time frame after the implementation of UI and before its expansion. The only exceptions are for the earnings information, where I focus on a shorter window between 2002-2008 to minimize concerns about wage growth and increases in the minimum wage, and for retirement and wealth at old ages, where all the data up to 2019 is essential. 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*) from 2013 to 2018 to compute wages and earnings variability.[15] I use the Survey of Micro-Entrepreneurs (*Encuesta de Microempreendimento*) in 2011 to derive descriptive statistics for self-employed individuals, including their physical capital used in self-employment activity. In order to compute the parameters that regulate the pension benefits, I use the database of all pension requests and offers (*Sistema de Consutlas y Ofertas de Montos de Pensión* — SCOMP), available since 2004. 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 mortality tables computed by the Chilean pension authority (*"Superintendencia de Pensiones"*).

2.3 Definitions: Formality, Informality, and Self-Employment

In order to classify individuals into unemployment, formal job, informal job, or self-employment, I use their self-reported information from the main occupation and administrative data. If an individual reports being unemployed or self-employed, I classify them as

[14] I consider the residuals of a regression of raw labor earnings on a linear time trend.

[15] Even though the main dataset (EPS) has wage data, it is reported in spells. So for the same spell, only one wage is reported, making it difficult to compute within spell wage variation.

such. If they report to be working for firms, I use the administrative data to classify if they were working formally or informally. Spells in which there were pension contributions for at least 50% of months are classified as formal jobs, and those that do not meet this threshold as informal.[16]

Self-employment is a highly diverse category encompassing several different activities. In my data, the five most typical occupations for self-employed are: car, taxi, and van drivers (8.6%), managers of small enterprises in wholesale and retail trade (5.3%), carpenters and joiners (5.2%), field crop and vegetable growers (4.6%), and street and stall vendors (3.9%). More than 2/3 of the self-employed report working in one-employee firms.[17] After 12 months, only 3.4% will 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. Monthly, only 15.7% of self-employed individuals have pension contributions. Only one-third are registered with the tax authority, which is the absolute upper bound on formality since being registered does not imply paying taxes regularly or fully. Therefore, I will consider self-employment as informal, that is, comprising legal but unregulated activities (Ulyssea, 2010). There will be, then, two distinct informal sectors in my analysis: wage earners who work for firms without a signed labor contract (*Informal Workers*) and self-employed individuals (*Self-Employed*). For the model, I will consider that formal employees pay social security contributions, and all their income is subjected to income tax. In contrast, informal employees and self-employed will be able to hide their labor earnings and therefore pay neither social contributions nor income tax.

Table 1 shows some descriptive statistics of the data, divided by individual level, labor

[16] I get very similar classification if I instead used self-reported information from individuals on whether they have a signed labor contract.

[17] Using the Survey of Micro-Entrepreneurs with better coverage of self-employed individuals, this number is much higher. Around 91% of the self-employed report having no additional worker.

Table 1: Descriptive Statistics

Variable	Mean	Median	Min	Max	Nobs
Individual level data					
Number of monthly observations	334.4	354	52	483	6,613
Year of birth	1964	1964	1940	1989	6,613
First observed age	21.3	16	16	40	6,613
Last observed age	55.7	56	31	80	6,613
Labor market level data					
Unemployed	0.075	0	0	1	616,967
Formal Employees	0.433	0	0	1	616,967
Informal (total)	0.335	0	0	1	616,967
Informal Employees	0.132	0	0	1	616,967
Self-Employed	0.203	0	0	1	616,967
Contributing to Pensions	0.435	0	0	1	2,752,546
Hours of work (weekly)	47.5	47	10	90	482,670
Labor earnings (monthly)	178.4	154.6	12.4	603.9	179,200
Wealth data (in thousand pesos)					
Pension Wealth at age 30-35	3,225	2,706	0	13,220	6,799
Pension Wealth at age 50-55	9,853	7,379	0	51,926	12,087
Non-pension Wealth at age 30-35	7,294	3,627	-3,167	78,794	2,503
Non-pension Wealth at age 50-55	11,575	7,234	-2,864	107,791	3,545

Notes: Data from the EPS and HPA, for the sample of men born between 1940 and 1989 with at most high school education. The monetary values are in thousands of Chilean pesos in 2004, which is approximately 1.5 US dollars. The columns show, respectively, the mean, median, minimum, maximum, and number of valid observations for each variable. Pension wealth, non-pension wealth, and hours are winsorized at the 1% level. Labor market information, including labor earnings, are only considered for spells reported within 18 months of reporting, are detrended, and the bottom and top 1.5% are discarded.

market level, and wealth information. All monetary values are considered in real terms, being displayed in thousands of Chilean pesos in August of 2004, when the 2004 reform was implemented. One thousand pesos are equivalent to approximately 1.50 US dollars. We can see that around 43% of individuals in the labor force are formally employed, around 13% are working for firms informally, and 20% as self-employed. In any given month, only 43% of individuals are making pension contributions.

3 Empirical Findings

This section explores three empirical findings that are important to 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 individuals). I show how they differ in age profile, hours of work, and workplace. I then show my estimated causal effects of the 2004 reform on early retirement patterns, pension contribution, and employment. This evidence will be used later in the model as some exogenous variation of the policy environment. The last exercise shows how self-employment activity is associated with investments in physical capital.

3.1 Key features of each sector of employment

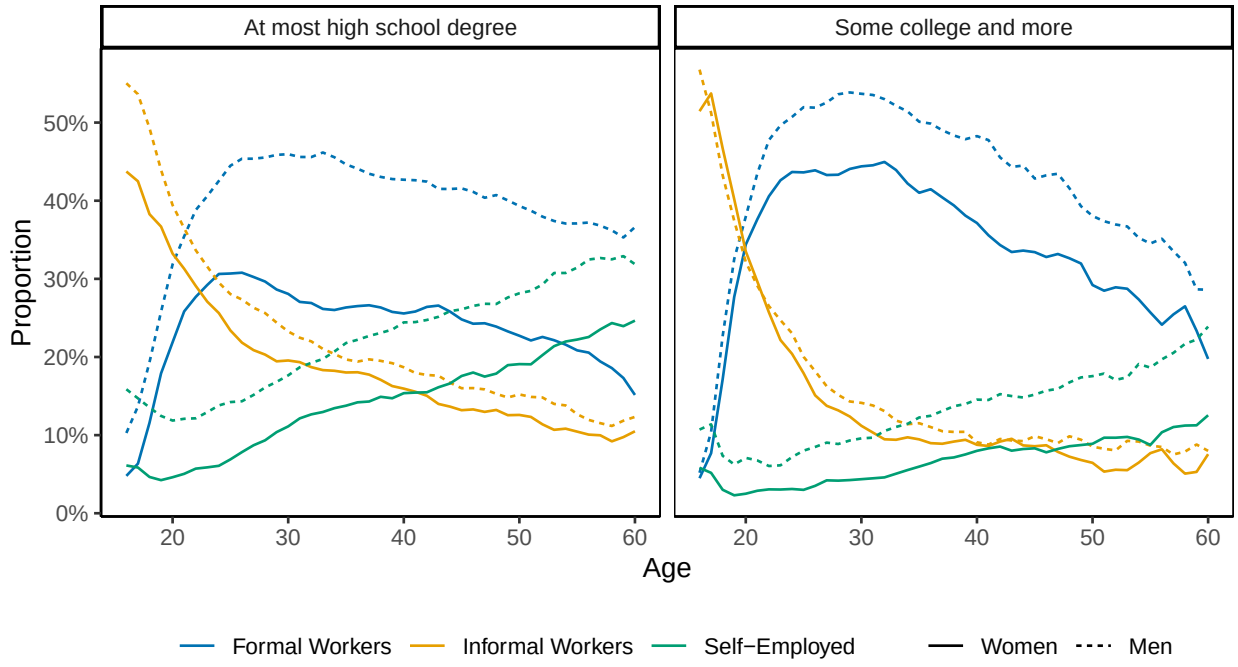
Different age profiles for formal, informal, and self-employment

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

Different work arrangements

The self-employed have different work arrangements than both formal and informal employees. Table 2 below shows the distribution of hours and places of work for formal workers, informal workers, and self-employed. Along these two dimensions, informal workers

Figure 1: Proportion of workers in each sector over the life cycle



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

have more flexibility than formal employees. However, the difference is more striking when compared with the self-employed. Among the self-employed, 22% work less than 35 hours, while only 1.8% formal workers do the same. While more than 70% of formal employees work at the firm site, only 14.2% among the self-employed do the same. The proportion of self-employed individuals working from home is nine times larger than formal employees.

3.2 Effects of the 2004 reform on early retirement, pensions, and employment

In 2004, the Chilean government strengthened the requirements for early retirement. Individuals can retire before the normal retirement age if their resulting pension is above (i) a

Table 2: 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. Work place			
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%

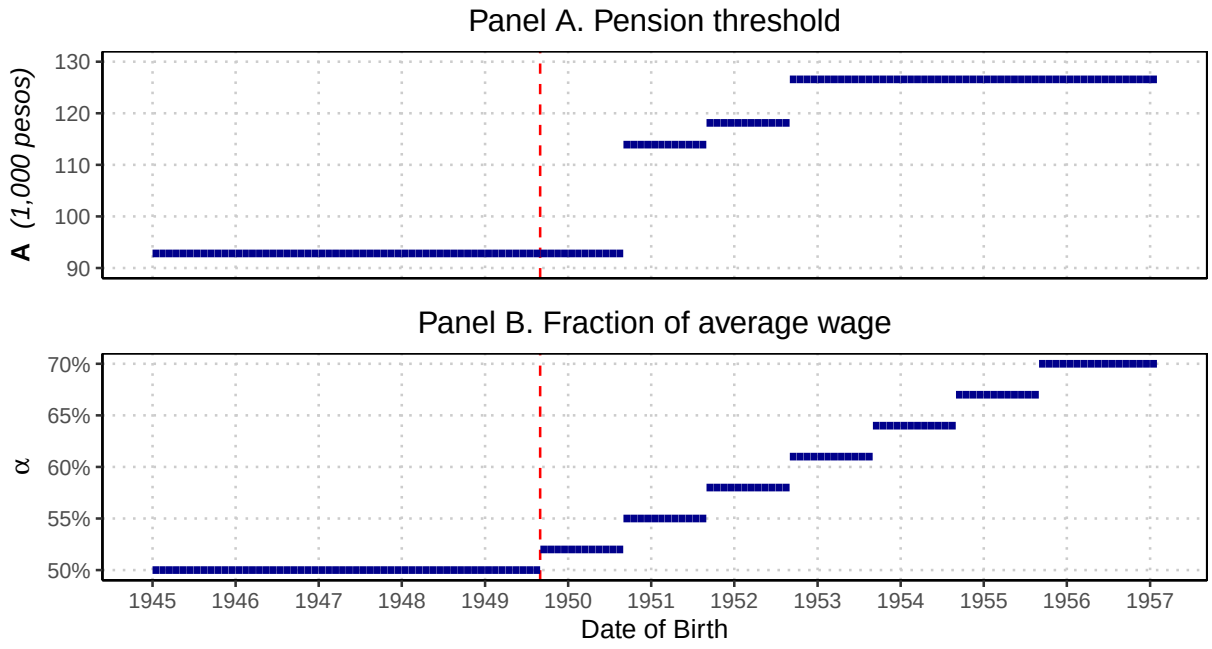
Notes: EPS data. The table shows the distribution of hours of work (panel A) and work place (panel B) for formal workers, informal workers and self-employed individuals. In each panel, the columns sum to 100%.

pension threshold A and (ii) a fraction α of their previous average wages. The threshold and the fraction α were raised. Individuals born before August 19th, 1949, were exempted from the new rules. The new values were gradually implemented following the reform, making individuals of different cohorts experience different criteria to retire early. Appendix C shows the exact dates for each requirement.

Figure 2 below presents the two eligibility criteria for individuals to retire at age 55 if they were born between 1945 and 1957. The top panel shows the absolute threshold. Before the reform, the resulting pension needed to be 110% of the minimum pension (93 thousand pesos), which was gradually raised to 150% (126 thousand pesos). The bottom panel shows the required fraction of the average wage, which started at 50% and was raised to 70%. Due

to the gradual increase of the requirements, individuals born right after August 1949 do not experience very different requirements. However, individuals born in the following years, in 1951 and 1952, started experiencing more stringent criteria.

Figure 2: Criteria for Early Retirement at age 55

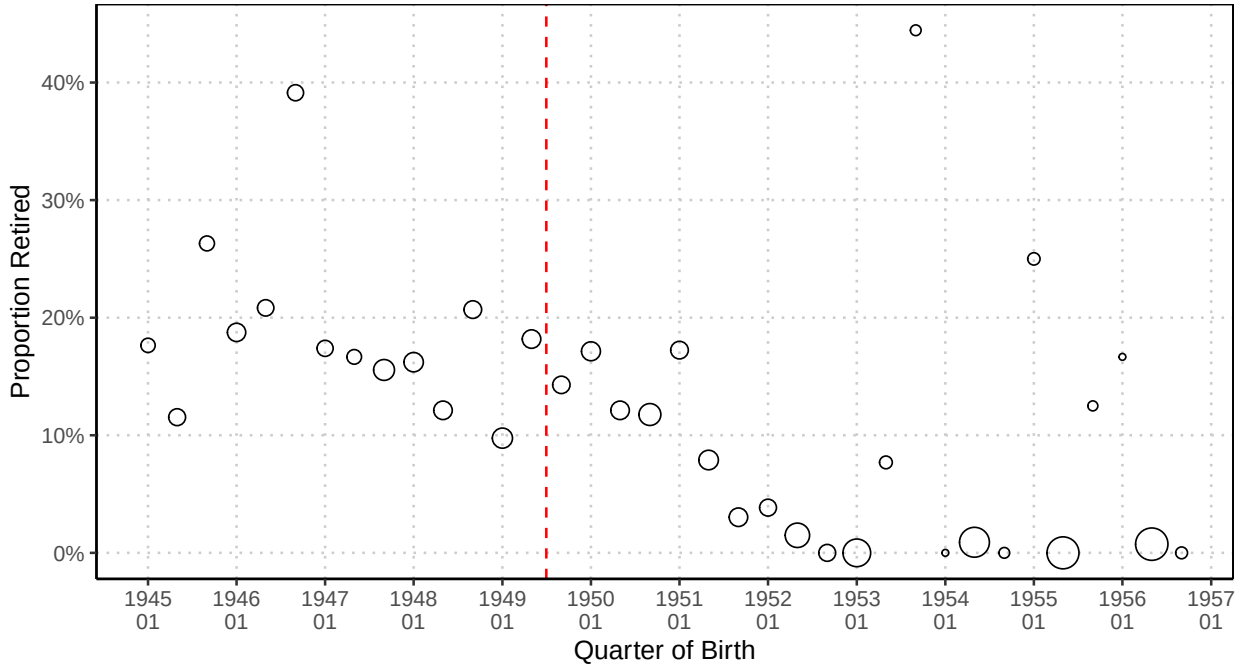


Notes: The figure shows the requirements for early retirement in Chile based on the month of birth. The top panel shows the pension threshold A measured in thousand pesos and the bottom panel the fraction α of the average wage going from 50% to 70%. Both requirements are presented when these individuals are 55 years of age.

Figure 3 below shows the proportion of individuals who were at 55 by quarter of birth. Among individuals born before the reform threshold, around 18% retired before age 55. We observe a slight reduction for those born right after the reform threshold, which is consistent with the small gradual increase in the criteria for early retirement. The proportion of retired individuals at age 55 quickly falls to near zero as the more stringent requirements take place for cohorts born after 1952.

More generally, in Figure 4, I show the proportion of individuals retired by age and by cohorts. To enhance precision, I group individuals born in intervals of 3 years, respecting

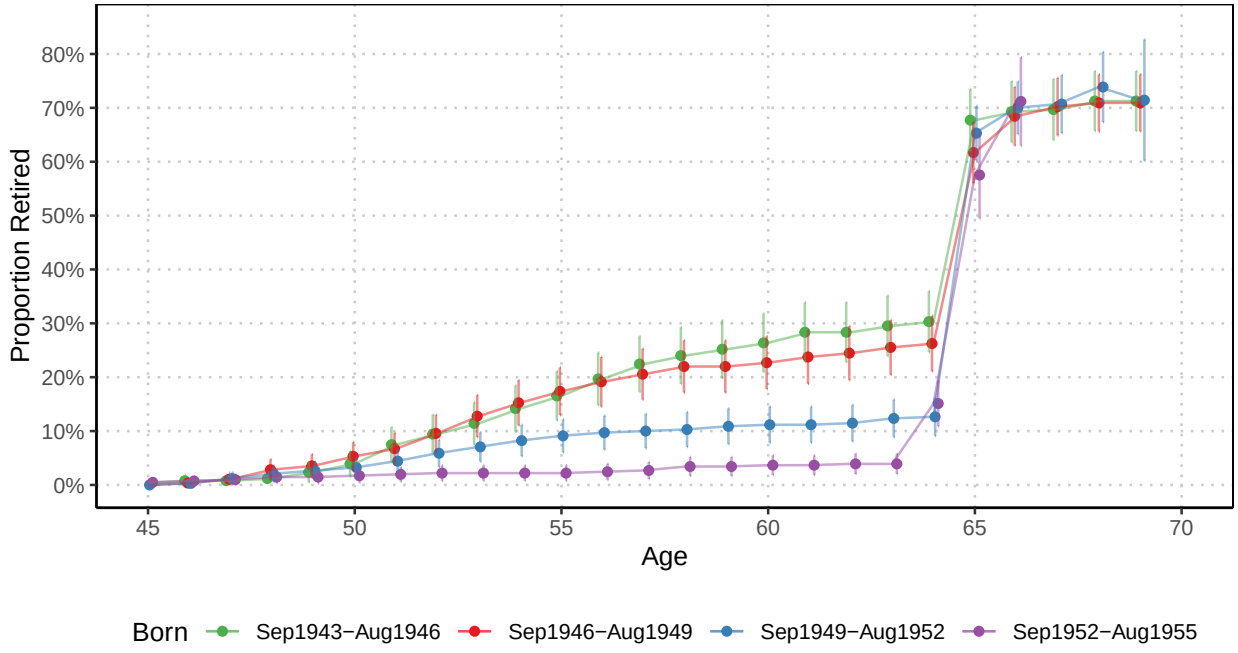
Figure 3: Proportion retired at age 55 by quarter of birth



Notes: The figure shows the proportion of individuals retired by age 55 by quarter of birth. The data uses EPS and HPA. The size of the circle is proportional to the number of individuals born in that quarter-year in the survey. The vertical red line represents the threshold introduced by the 2004 reform. Only individuals born after August 1949 experienced more stringent requirements to retire before the normal retirement age.

the pension reform threshold in August 1949. Comparing the 1946–1949 (red) cohort with the following cohort born in 1949–1952 (blue), we can see the large effects of the reform. The retirement gap between ages 55 and 64 is from 8 to 15 percentage points. Interestingly, we can see that this difference is entirely driven by early retirement behavior. There is no difference after the normal retirement age of 65. 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 plots the cohort born in 1943-1946 (green) that was unaffected. We can see that they follow similar trends as the 1946–1949 cohort. The small observed differences starting at age 57–58 could be driven by different trends making individuals retire at older ages or the effects of the 2008 reform, which also affected early retirement requirements and incentives.

Figure 4: Proportion Retired by Age and Cohort



Notes: The figure shows the proportion of individuals retired for each age between 45 and 70. I group individuals in windows of three-years, respecting the cutoff of August 1949 implemented by the 2004 reform. 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 those born between September 1946 and August 1949, blue for the cohort September 1949–August 1952, and purple for those born in September 1952–August 1955. Data from EPS and HPA.

I summarize these results in a regression comparing individuals born three years before the threshold established by the reform, between September 1946 and August 1949 (control), with those born in the following three years (treated). For those born after the threshold, I separate those born one year after the chosen date, which experienced a modest increase in the requirements, from those born after September 1950, who faced more stringent requirements. The results are presented in Table 3 below.

In the first column, we can see that while 15.5% of individuals from the control group retired before age 55, those in the first treated group were 1.7pp less likely to be retired. This estimate is much larger and statistically significant for those in the second group; they are 9.3pp less likely to be retired. The second column shows the same results for being retired at

Table 3: Effects of the 2004 reform

Outcome:	Retired				Contributing		Formal	Informal	Self-Employed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(Intercept)	0.155	0.246	0.636		0.382				
	(0.022)	(0.031)	(0.033)		(0.027)				
T1 (Sep1949–Aug1950)	-0.017	-0.062	0.018	-0.040	0.018	0.028	0.005	-0.007	-0.003
	(0.036)	(0.052)	(0.094)	(0.038)	(0.050)	(0.048)	(0.042)	(0.019)	(0.032)
T2 (Sep1950–Aug1952)	-0.093	-0.155	0.012	-0.105	0.064	0.044	0.052	0.003	0.045
	(0.028)	(0.037)	(0.060)	(0.032)	(0.046)	(0.037)	(0.039)	(0.016)	(0.030)
Age Fixed-Effects	-	-	-	Yes	-	Yes	Yes	Yes	Yes
Age Range	55	63	66	[50-63]	63	[50-63]	[50-63]	[50-63]	[50-63]
Observations	7,584	7,584	7,584	56,105	7,584	56,105	56,105	56,105	56,105

Notes: The table presents the results from the regressions comparing the control cohort, individuals born between Sep1946–Aug1949 (the intercept), with two treated cohorts: T1 for those born between Sep1949–Aug1950 and T2 Sept1950–Aug1952. All the outcomes are binary variables: in the first four columns, an indicator for retirement status; in the fifth and sixth columns, an indicator for making pension contributions; and in the last three columns, indicators for working as a formal employee, informal employee, or self-employed. Clustered standard errors at the month of birth are presented in parentheses. As the results in columns 4, and 6–9 pool ages from 50 to 63, age fixed effects are included.

age 63, where we still can see that individuals in the second group were 15.5pp (or 63%)less likely to be retired. In the third column, I present a placebo exercise. The reform did not modify any rule for retirement after the normal retirement age of 65. It is reassuring that the three groups do not present differential retirement patterns at age 66.[18] In the fourth column, I pool all the data between 50 and 63 years of age. We can see that along this time window, individuals in the second group are 10.5pp less likely to be retired. In the fifth and sixth columns, I show the effects on the probability of making pension contributions. We can see that in the two samples (restricted to those at 63 or pooling all years), the effect is less than half of the estimated effect on retirement. The results in the next three columns show why: while the reform increased the probability of someone not retiring being in the formal sector by 5.2pp, it also increased the probability of being self-employed by the same magnitude. These results are not surprising and highlight the importance of taking informality decisions into account. As we saw in the previous subsection, a substantial share of individuals who work as self-employed in old age do not make pension contributions.

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

3.3 Self-Employment requires investment

When starting a new self-employment activity, individuals may need resources to buy the necessary equipment and merchandise, adapt the workplace, pay for marketing expenses, and keep funding the business while acquiring a new customer base. To investigate this, I turn to the survey of microentrepreneurs, which asks respondents about the source of resources they used to start their self-employment activity. Table 4 presents the results. Almost 82% report using mainly their own savings and family and friends' resources. Only 10% use either public or private credit. A very small proportion of individuals, less than 5%, report not needing any investment to be self-employed.

Table 4: Source of resources to start self-employment activity

Source	Percentage
Own Savings	67.4%
Family and Friends	14.3%
Public Institutions	5.1%
Private Institutions	4.9%
Other	3.6%
No resources needed	4.6%

Notes: Data from the Survey of Microentrepreneurs 2011. Each individual selected one category. Restricted to men with at most high school degree.

From the most typical self-employment occupations, we can already see the importance of physical capital, for example, vehicles (for drivers), tools and machinery (for carpentry or agriculture), and merchandise (for 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. In order to do so, I group individ-

uals 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 became self-employed between the two surveys. $G = 10$ and $G = 11$ are defined similarly. Interested in comparing the proportion of individuals in each group who reports holding any positive amount 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 physical capital for each group g. Table 5 shows the results. We can see that for the groups that remained not self-employed or self-employed in between the two surveys, there is no difference in the proportion of individuals holding physical capital. However, for the group that transitioned into self-employment, the individuals are 3.2 percentage points 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 4.8pp.[19] These numbers are not larger because, as mentioned above, I can only identify physical capital in the main survey for large investments. A proportion of 18.1% of self-employed individuals holds positive amounts of physical capital in these categories capturing large investments, in contrast with 2.9% in the formal sector. In the microentrepreneur survey, there are more granular measures of assets used in production. There, 77% of self-employed individuals report assets with a positive market value that are used in their activity. This evidence corroborates the above evidence showing how self-employed individuals invest in physical capital at the onset of their self-employment activity.

[19] In the appendix figure A.1, I show the cumulative density function for this variable for the four groups, where we can see no changes for groups 00 and 11 and outwards and inwards shifts for groups 01 and 11, respectively.

Table 5: Transitions to and from self-employment and physical capital

Group		Coefficient
Group 00	(NotSE→NotSE)	-0.0002
(s.e.)		(0.0017)
Group 11	(SE→SE)	0.0021
(s.e.)		(0.0100)
Group 01	(NotSE→SE)	0.0335***
(s.e.)		(0.0117)
Group 10	(SE→NotSE)	-0.0451***
(s.e.)		(0.0121)
Group Fixed Effects		Yes
N Obs		27,926

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-employment) in two consecutive surveys. SE stands for self-employed. The regression controls for group fixed effects (the average for each group in the first period) and the standard errors are clustered at the individual level.

3.4 Summary of empirical findings

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

4 Model

The model is populated by risk-averse individuals who decide their consumption, savings, and employment. In terms of employment, they 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 at the offered wage. If not, they continue in their status quo. Becoming self-employed is always an option, but it requires an up-front investment, which is, in part, irreversible. Self-employment earnings are volatile. Workers in the formal sector pay social security contributions and taxes and are entitled to unemployment insurance, severance payment, and pensions. Agents decide endogenously when to retire and claim pension benefits. I now present each part of the model. Appendix D shows the exact formulae for the value functions and social insurance.

Timing

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

Types

Individuals are heterogeneous in three dimensions: birth year (their cohort), ability (general and entrepreneurial), and initial wealth. The three dimensions are orthogonal. All

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

cohorts are the same except for the age they experience the two pension reforms (in 2004 and 2008). All the reforms come as surprises for the individuals.[21] Each individual is endowed with a general ability g and an entrepreneurial ability e. General ability impacts their productivity when working for firms, formally or informally. Entrepreneurial ability controls their productivity when engaging in self-employment activity. 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

In terms of the labor market, individuals can be in four different states. Agents can work for a salary — formally (F) or informally (I), be self-employed (S), or unemployed (U). From now on, I will 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 arrival rate, and each offer has an attached wage. The offers can be accepted or rejected by the worker. Offers are drawn from different distributions for the formal and informal sectors. When working formally, individuals pay social security contributions and taxes and are entitled to unemployment insurance in case of separation.

Moving to self-employment is always an option provided that individuals pay the up-front investment X. This investment captures the acquisition of tools, equipment, and vehicles required for self-employment activity. 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. The formal and informal sectors only offer full-time jobs, while self-employed individuals can decide to work part-time or full-time. This specification

[21] As the data only start in 2002, I do not consider the UI introduction. I also abstract away from the expansion of UI in 2009 as it was for temporary contracts, which are not the focus of this project. I do not distinguish between temporary or permanent contracts. For simplicity, I consider that all changes implemented in the 2004 and 2008 reforms happened instantaneously. That is, there was no phase-in.

is motivated by the facts about the distribution of work hours by sector presented earlier. Importantly, labor earnings from the informal and self-employment sectors are not taxed or subject to social security contributions. Table 6 summarizes the differences across the three sectors.

Table 6: Sectors in the model

	Formal	**Informal**	**Self-employment**
Entry	Receive offer	Receive offer	Pay up-front investment
Wage	Accepted offer (constant within job spell)	Accepted offer (constant within job spell)	AR(1) process (volatile)
Hours	Full-time	Full-time	Full or part-time
Upon Exit	Unemployment Insurance & Severance Payment	-	Recoup fraction investment
Social Security	Yes	No	No

Labor Supply, Consumption, and Savings Decision

Individuals of type θ start a given period at age a, with unemployment status n and pension wealth given by p. They bring k as assets from the last period and are employed in sector j with wage w. They decide the number of hours to supply h and consequently the number of hours for leisure ℓ, given the stock of hours per period $\bar{L}$. Agents also decide consumption and the amount of assets to leave for the next period, respecting the budget and borrowing constraints. The available resources are the assets from the last period, $k(1+r)$, and the net earnings from this period. The function $Y(\theta, j, w, h, k, b)$ obtains the net earnings from sector j, netting the 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 for that

period. I denote the value function for this period as $V_a(\theta, n, p, k, j, w)$.

$$V_a(\theta, n, p, k, j, w) = \max_{\tilde{k}, h, c, \ell} \left\{ u_j(c, \ell) + \beta \Big((1 - m_a)\mathbb{E}[V_{a+1}(\theta, n', p', k', j', w')] + m_a b(\tilde{k}) \Big) \right\}$$

$$\begin{aligned} \text{s.t.} \quad & c + \tilde{k} = k + Y(\theta, j, w, h, k, b) \\ & \ell = \bar{L} - h \\ & \underline{B} \leq \tilde{k} \leq k + Y(\theta, j, w, h, k, b) \end{aligned} \tag{2}$$

The per-period utility function will be given by a CRRA function on a composite of consumption and leisure, with weights ν and $(1 - \nu)$, respectively.[22] 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.

$$u_j(c, \ell) = \frac{\phi_j \left(c^\nu \ell^{1-\nu}\right)^{1-\gamma} - 1}{1 - \gamma} \tag{3}$$

While deciding $(\tilde{k}, h, c, \ell)$, individuals take into account the continuation values at age $a + 1$. An individual dies with probability m_a and bequeaths the remaining wealth yielding him the utility $b(\tilde{k})$. I use a common specification from the bequest function as in French and Jones (2011), O'Dea (2018), De Nardi et al. (2021) with bequest weight ψ and bequest shifter $\overline{K}$.

$$b(k) = \psi \frac{\left(\overline{K} + k\right)^{1-\gamma} - 1}{1 - \gamma} \tag{4}$$

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

[22] This formulation implies that the relative coefficient of risk aversion will be given by

$$-\frac{c u_c''(c, l)}{u_c'(c, l)} = -(\nu(1 - \gamma) - 1)$$

shocks and the labor market transitions from period to period.

Labor market shocks and transitions

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

I now show the exact formula of $\mathbb{E}[V_{a+1}(\theta, n', p', k', j', w')]$ for someone that is currently unemployed, that is, $j = U$. To help with the notation, I will define as $\tilde{V}_{a+1}$ the best decision of this agent in case he does not receive any offer, which will be the decision to remain unemployed, to go to self-employment, or to retire (if $a \geq a_{\min}^{\text{Ret}}$).[23]

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

Notice that when deciding to go to self-employment, this individual needs to pay the upfront investment X, and he does 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 expectation for the unemployed individual at age a.

$$\begin{aligned}\mathbb{E}_U[V_{a+1}(\theta, n', p', k', j', w')] = & (1 - \lambda_U^F)(1 - \lambda_U^I)\tilde{V}_{a+1}^U + \\ & \tilde{\lambda_U^F} \int \max \left\{ \tilde{V}_{a+1}^U, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w}) \right\} dW^F(\tilde{w}) + \\ & \tilde{\lambda_U^I} \int \max \left\{ \tilde{V}_{a+1}^U, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w}) \right\} dW^I(\tilde{w})\end{aligned} \tag{6}$$

[23] The value function after retirement ($V_a^{Ret}(.)$) is detailed below.

He does not receive any offer with probability $(1-\lambda_U^F)(1-\lambda_U^I)$. If that is the case, he chooses between moving to self-employment or remaining unemployed. If he receives a formal offer (with probability $\tilde{\lambda}_U^F$), he can decide between moving to the formal sector or his best choice. Notice 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.[24]

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 engage in self-employment activity. The other difference is that in his best choice in the absence of labor market choices, he now has four options, remaining in the same job, quitting and moving to unemployment, going to self-employment, or retiring (if that is already possible). Let this best choice be given by

$$\begin{aligned}\tilde{V}_{a+1}^F := \max\Bigg\{ & V_{a+1}(\theta, n', p', \tilde{k}, F, w), V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \\ & \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), V_{a+1}^{\text{Ret}}(\theta, \tilde{k}, y^P, q)\Bigg\}\end{aligned} \tag{7}$$

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

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

[24]For computational purposes, I do not allow simultaneous offers from the formal and informal sectors. If that is the case, the formal offer is observed with probability ϵ. Therefore, $\tilde{\lambda}_j^F = \lambda_j^F(1 - \lambda_j^I + \lambda_j^I\epsilon)$ and $\tilde{\lambda}_j^I = \lambda_j^I(1 - \lambda_j^F + \lambda_j^F(1-\epsilon))$.

(8)

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 $SP(w)$.

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.

$$\begin{aligned}\tilde{V}^I_{a+1} \coloneqq \max\Bigg\{ & V_{a+1}(\theta, n', p', \tilde{k}, I, w), V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \\ & \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\Bigg\}\end{aligned} \tag{9}$$

and

$$\begin{aligned}&\mathbb{E}_I[V_{a+1}(\theta, n', p', k', j', w')] = \\ &\quad \delta_I \max\Bigg\{V_{a+1}(\theta, n', p', \tilde{k}, U, 0), \int V_{a+1}(\theta, n', p', \tilde{k} - X, S, \tilde{w}) dW^S(\tilde{w}), \\ &\qquad V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\Bigg\} + \\ &\quad (1 - \delta_I)\Bigg[(1 - \lambda^F_I)(1 - \lambda^I_I)\tilde{V}^I_{a+1} + \\ &\quad \tilde{\lambda^F_I} \int \max\Bigg\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, F, \tilde{w})\Bigg\} dW^F(\tilde{w}) + \\ &\quad \tilde{\lambda^I_I} \int \max\Bigg\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k}, I, \tilde{w})\Bigg\} dW^I(\tilde{w})\Bigg]\end{aligned} \tag{10}$$

For self-employed individuals, the choice in the absence of labor market choices 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.

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

and

$$\begin{aligned}
\mathbb{E}_S[V_{a+1}(\theta, n', p', k', j', w')] = \\
&\delta_S \max\left\{V_{a+1}(\theta, n', p', \tilde{k} + \pi X, U, 0), V^{\text{Ret}}_{a+1}(\theta, \tilde{k}, y^P, q)\right\} + \\
&(1-\delta_S)\Bigg[(1-\lambda^F_S)(1-\lambda^I_S)\tilde{V}^S_{a+1} + \\
&\tilde{\lambda^F_S}\int \max\left\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, F, \tilde{w})\right\} dW^F(\tilde{w}) + \\
&\tilde{\lambda^I_S}\int \max\left\{\tilde{V}^I_{a+1}, V_{a+1}(\theta, n', p', \tilde{k} + \pi X, I, \tilde{w})\right\} dW^I(\tilde{w})\Bigg]
\end{aligned} \tag{12}$$

Notice 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, whether they decided to be self-employed and paid the initial investment (X), and whether they exited self-employment and recouped a fraction of the investment.

$$k' = \tilde{k} + SP(w)\mathbb{1}\{j = F \text{ and fired}\} - X\mathbb{1}\{j \neq S, j' = S\} + \pi X\mathbb{1}\{j = S, j' \neq S\} \tag{13}$$

Once again, the borrowing constraint is imposed, implying that moving to self-employment is an option if and only if $\tilde{k} + SP(w)\mathbb{1}\{j = F \text{ and fired}\} \geq X$. Now, I turn to explain how social insurance evolves from period a to $a+1$.

Unemployment Insurance

At each point in time, individuals are in UI status $n \in \{0, 1, 2, ..., n_{\max}\}$. When $n = 0$, no payment is received. In this state, agents are either formally employed or have already exhausted their UI benefits. When individuals are laid off from the formal sector, they move to $n = n_{\max}$ and will receive their UI benefits next period.[25] If individuals remain not formally employed, they move to $n' = n - 1$. When individuals accept a formal offer, they

[25]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 (amenity) from the formal sector that is not modeled explicitly.

move to $n = 0$, which is an absorbing state. In summary, the evolution of n will be given by:

$$n' = \begin{cases} n_{\max} & \text{, if } j = F \text{ and fired} \\ n - 1 & \text{, if } n > 1 \text{ and } j' \neq F \\ 0 & \text{, if } j' = F \text{ or } n \leq 1 \end{cases} \tag{14}$$

The value of UI, given by $b(n, p, a)$, 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 (50% in the first month, 45% in the second, and so on). In reality, the UI benefits are a function of the individuals' UI accounts and wages. In the model, I approximate both the available funds and the previous wages through their pension wealth and age.[26] Since the government cannot monitor informal jobs and self-employment, I allow individuals to continue receiving unemployment benefits even if they work in these sectors.

Pension contributions and retirement

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

$$p' = p(1 + r^P) + 0.10w\mathbb{1}\{j = F\} \tag{15}$$

Individuals endogenously decide whether to retire. In the model, the decisions of

[26]The model already contains three continuous state variables: liquid wealth, pension wealth, and wages. It is computationally infeasible to include either the UI funds or the previous wage as new state variables. Notice 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.

claiming pension benefits and retiring, that is, exiting the labor market, are intertwined. There is no re-entry after claiming the benefits, making retirement a permanent choice. Individuals can claim early retirement after age $a^{\text{Ret}}_{\min}$ and the normal retirement age is a^{Ret}. All individuals that did not retire at age $a^{\text{Ret}}_{\max}$ will claim benefits at this age. Individuals choose whether to retire at the same time as making employment decisions, that is, after observing all the labor market shocks. The pension benefit formula is:

$$y^p = \omega(\theta, a, p) \tag{16}$$

The pension wealth p will be fully annuitized, considering the age a individual is claiming benefits. 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, $y^p \geq \max\{A, \alpha\bar{w}\}$[27]. I denote by q whether the individual retired before the normal retirement age ($q = 1$). The net income function is $Y^{\text{Ret}}(y^p, q, \theta, a, k)$. I define this function formally 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 how long individuals will survive.

$$\begin{aligned} V^{\text{Ret}}_a(\theta, k, y^p, q) = \max_{k', c} \Bigg\{ u_j(c, \ell) + \beta \Big((1 - m_a) V^{\text{Ret}}_{a+1}(\theta, k', y^p, q) + m_a b(k') \Big) \Bigg\} \\ \text{s.t.} \quad c + k' = k + Y^{\text{Ret}}(y^p, q, \theta, a, k) \\ \ell = \bar{L} \\ \underline{B} \leq k' \leq k + Y^{\text{Ret}}(y^p, q, \theta, a, k) \end{aligned} \tag{17}$$

[27] 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 $\bar{w}$ will be computed using the pension wealth stock and age.

Firms

Since this paper focuses on the tradeoffs that workers experience while making employment decisions, firms are modeled in a simplified way. 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. For this analysis, I will always keep the wage distributions and arrival rates fixed.

5 Estimation

Estimation proceeds in two steps. In the first step, 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 the remaining parameters, which are a mixture of preference and technology parameters, using the methods of simulated moments. Before detailing the two steps, I first show how I parametrize the wage and earnings distributions and the initial wealth distribution.

5.1 Parametrization of wage 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. Additionally, it has the main advantage of having a closed support, making it easier to capture bunching at the minimum wage. For each offer distribution, there will be two parameters capturing the support $(\underline{w}, \overline{w})$ and two

scale parameters (ζ_1, ζ_2).

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

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

$$\begin{aligned} w_0 &= \mu + \varepsilon_0 \\ w_t &= (1-\rho)\mu + \rho w_{t-1} + \varepsilon_t, \forall t > 0 \\ \varepsilon_t &\sim N(0, \sigma^2) \end{aligned} \tag{18}$$

I assume the initial wealth is drawn from a truncated normal distribution

$$k_0 = \max\{0, k_0^*\}, \quad k_0^* \sim N(\mu_{k_0}, \sigma_{k_0}) \tag{19}$$

5.2 Estimation — First Step

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

Types - Types are defined by their cohort, ability vector, and initial wealth. The three dimensions are independent. Cohorts run from 1940 to 1989. I assume there are two sub-types regarding ability: type 1 (g_1, e_1), and type 2 (g_2, e_2). I use the normalization that $g_1 = 1$. For the initial wealth distribution, I set μ_{k_0} to zero and σ_{k_0} to 2,500. With this parametrization, approximately 50% of individuals start their lives in the simulation with

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

no wealth, which is consistent with the observed wealth for individuals between 16 and 20 years of age. Unfortunately, there is a very limited number of observations with wealth data for individuals at young ages.[29]

Social Security - Formal employees pay as social security contributions 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 also pay 2.5% as administration fees and disability insurance.[30] Informal employees and self-employed individuals do not pay contributions. Retired individuals continue to 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 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 2021.[31] I obtain an average annual (risk-free) return of 7.3%. For the general interest rate, since, in the data, most of the non-pension wealth comes from houses, I will consider the housing returns in Chile between 2002 and 2020. The average annual return is 4.5%.

Pension Benefits - In order 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

[29] There are only 7 observations for individuals aged 16–18, and 44 for those aged 19–20.

[30] This number depends on the pension administrator, and it varies over time. 2.5% is the average value paid across all pension funds between 1993 and 2019, weighted by the number of beneficiaries in each fund.

[31] 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).

cost is 43.2%. 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 20%.

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.[32]

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 the pension wealth and age to compute the average wage workers experienced in their working life. From the administrative data of the UI system, I approximate available resources as a function of wages.[33] 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, comprised of 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, child tax credit (*Assignación Familiar*, AF) and a welfare transfer (*Subsidio Unico Familiar*, SUF). These programs have 3-4 levels of benefits depending on family earnings. I implement a linear version of the benefits where those with 0 earnings receive the maximum benefits (4 thousand pesos for AF and SUF). This value is then withdrawn with a given implicit tax rate that offsets the benefits for the defined thresholds of the programs (360 thousand pesos).[34] I consider the real brackets of the income tax schedule. There are

[32]The R-squared of this prediction is 0.44 for my sample.

[33]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.

[34]For SUF, there is no statutory maximum. I defined the 360 thousand pesos.

eight brackets, with marginal tax rates from 0 to 40%. I assume that informal employees and self-employed individuals can hide their earnings from the government. Therefore they do not pay taxes on their labor earnings.

Earnings - For the formal and informal wage distributions, I set the minimum and maximum of the support as the empirically observed minimum and maximum of the observed wage distribution, separately for each sector. To compute self-employment earnings, I rely on the data from National Employment Survey, which better captures within-spell volatility. To compute the persistence parameter (ρ), I take advantage of the fact that:

$$\rho = \frac{\text{Cov}(Y_t, Y_{t-2})}{\text{Cov}(Y_t, Y_{t-1})} \tag{20}$$

This allows me to use all observations from any period of the self-employment spell and does not require estimating the innovation variance. I set ρ directly as the empirical counterpart of equation 20, which implies a quarterly correlation of 0.91 (or an annual correlation of 0.68). Since the entrepreneurial abilities, e_1 and e_2 will be estimated, I cannot separately identify the mean of the self-employment earnings distribution that I set to 1.

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).

5.3 Estimation — Second Step

In the second step, I estimate all the remaining parameters using the simulated method of moments. Let ξ represent the vector of parameters to be estimated in this stage. The estimation procedure will minimize the following criteria function:

$$M(\xi)'\Sigma_m M(\xi) \tag{21}$$

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.[35] The details of the implementation of this estimation are presented in Appendix E.

The model does not allow for a closed-form solution, so formal identification of each parameter is infeasible. However, each estimated parameter is closer-linked to some specific moments from the data. We confirm these links with the sensitivity analysis proposed by Andrews et al. (2017), which presents the connections between moments and parameters transparently. All the parameters and the connected moments are presented in Table 7.

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

The other utility parameter to be estimated is the consumption weight in the per-period utility function (ν). This parameter captures the relative importance of consumption and leisure for individuals. Two sets of moments help estimate this parameter: the proportion of self-employed individuals working part-time and the differential retirement trends generated by the 2004 reform. The reform captures exactly the willingness of individuals to retire early, forgoing a future income stream by not staying longer in the labor force. The last two preference parameters are the amenities for the informal and self-employment sectors.[36] These parameters will rely heavily on the life cycle patterns for the three sectors. Particularly, the increasing proportion of individuals switching to self-employment over the life cycle would

[35] Σ_m is estimated using a bootstrap procedure with 1,000 replications.

[36] I normalize the amenities for the formal sector ϕ_F to be 1. 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.

imply higher amenities in this sector.

Table 7: Second step parameters

Parameter	Description	Most informative moments
Preference Parameters		
β	Discount factor	Wealth profile
ν	Consumption weight	Pension reform on early retirement
$\psi, \bar{K}$	Bequest weight and shifter	Old-age wealth profiles
ϕ_j	Amenities for informal/self-employment	Sector allocation over life cycle
Technology Parameters		
δ_j	Destruction rates	Transitions from j to unemployment
$\lambda_j^{j'}$	Arrival rates	Transitions from j to formal/informal
ζ_1^F, ζ_2^F	Shape parameters (formal wage distribution)	Formal wage distribution percentiles
ζ_1^I, ζ_2^I	Shape parameters (informal wage distribution)	Informal wage distribution percentiles
σ	Variance of self-employment earnings	Self-employment earnings distribution
X	Start-up cost for self-employment	Life-cycle transitions to self-employment
π	Recouped fraction of initial investment	Average value for physical capital
g_2,e_1,e_2	General and entrepreneurial abilities	Correlation of wages, self-emp earnings
$p(\theta_2)$	Proportion of sub-type two	Proportion never self-employed

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

The arrival and destruction rates can be inferred from the empirical transitions for each sector. Indeed, as we can see in the sensitivity matrix, there is a tight link between the transitions from sector j to j' and the corresponding arrival (or destruction if $j' = U$) rate. All transitions for the pairs jj' are included, omitting one category for j to avoid collinearity in the variance-covariance matrix. I also include the proportion of individuals that stayed employed in the formal or informal sector with wage increases to inform the on-the-job arrival rates for the same sector (λ_F^F and λ_I^I).

For the wage distributions for the formal and informal sectors, I estimate the two shape parameters for the beta distribution of each sector. They will be closely linked to the percentiles of the wage distributions. I include all deciles from 10-90% in addition to the percentiles 1%, 2.5%, 5%, and 7.5%, to better capture the bottom of the distribution.

For the self-employment earnings, I estimate the variance of the innovation shocks. To provide information for this parameter, I use as moments the ventiles of the self-employment distribution, the mean earnings, and the variance of annual wage differences. For the general and entrepreneurial abilities, I include as moments the correlation of wages of individuals that lost their jobs (involuntarily) and found jobs after 1-year in the same or other sectors. The within-sector correlation informs each ability, while the across-sector correlation informs the covariance of these two abilities.

The last set of parameters is related to self-employment: investment cost to be self-employed, the fraction that can be recouped at the exit, and the proportion of each type. The investment cost X is informed mainly by the life cycle proportion of self-employed. The fraction of initial investment that can be recouped is identified directly from the self-reported value for physical capital used in the self-employment activity.[37] Lastly, the proportion of type two individuals is informed by the observed proportion of individuals that are never self-employed.

6 Results

Table 8 presents the estimates for the parameters estimated in the second step with their computed standard errors. The discount rate β estimate is 0.93, slightly smaller than the typical estimates in life cycle models. The estimate for the consumption weight in the utility function ν is 0.41, which lies in the typical range for this parameter. It implies a coefficient of relative risk aversion of 1.81. The bequest shifter and weight have no interpretability on their own. They imply a marginal propensity to consume in the last period of life (with certain death) of 0.7% (out of their total wealth). In the Appendix Figure A.2, I show the amount left as bequest as a function of wealth in the last period of life, following De Nardi et al. (2021).

[37]The average physical capital value is computed using the microentrepreneur survey, where individuals report the market value of the assets they use in the self-employment activity.

Table 8: Parameters estimated in the second step

Preference	β	ν	ψ	$\bar{K}$	ϕ_I	ϕ_S
estimate	0.935	0.407	9,883.3	113,631.8	1.090	0.986
(s.e.)	(0.001)	(0.003)	(3,108.3)	(22,957.6)	(0.011)	(0.007)
Destruction Rates	δ_F	δ_I	δ_S			
estimate	0.030	0.003	0.010			
(s.e.)	(0.001)	(0.000)	(0.001)			
Formal Arrival Rates	$\lambda_{U,F}$	$\lambda_{F,F}$	$\lambda_{I,F}$	$\lambda_{S,F}$		
estimate	0.181	0.161	0.054	0.249		
(s.e.)	(0.008)	(0.012)	(0.001)	(0.027)		
Informal Arrival Rates	$\lambda_{U,I}$	$\lambda_{F,I}$	$\lambda_{I,I}$	$\lambda_{S,I}$		
estimate	0.991	0.850	0.374	0.713		
(s.e.)	(0.048)	(0.082)	(0.021)	(0.152)		
Wage (Shape)	ζ_1^F	ζ_2^F	ζ_1^I	ζ_2^I		
estimate	2.252	39.827	1.906	38.433		
(s.e.)	(0.084)	(1.340)	(0.113)	(1.230)		
Self-Employment	σ	X	α			
estimate	0.062	2,594.4	0.023			
(s.e.)	(0.003)	(63.1)	(0.007)			
Ability Types	g_2	e_1	e_2	$p(\theta_2)$		
estimate	1.711	0.725	0.495	0.570		
(s.e.)	(0.016)	(0.013)	(0.631)	(0.007)		

Notes: The table presents the estimates for each of 28 parameters estimated in the second step through the method of simulated moments. The estimates for the standard error are in parenthesis and they were computed using the numerical derivative for the criteria function.

The last two preference parameters are the amenities for the informal sector and self-employment. Table 9 presents one way of interpreting these parameters as comparing the consumption equivalent to yield the same *per-period* utility of someone working in the formal sector.[38] We can see that, to achieve the same utility as a formal worker, an unemployed individual could consume only 50.1% of the formal worker's consumption. The unemployed individual could consume 49.1% less because he derives utility from having more leisure. Analogously, an informal worker would require 11.1% more consumption and the self-employed individual 1.7% less. These numbers imply negative amenities for the informal

[38]That is, considering only $u_j(c, \ell)$ and not their continuation values.

sector and positive amenities for self-employment. 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.

Table 9: Value of leisure and amenities

Sector	Formal	Unemployed	Informal	Self-employed
Consumption Equivalent	1.000 *(baseline)*	0.501	1.111	0.983

Notes: The table presents the consumption equivalent to yield the same utility as a formal worker working full-time. These numbers refer solely to the per period utility function $u_j(c, \ell)$ and do not take into account continuation values. To have the same utility as a formal worker, an unemployed individual would have to consume only 50.1%, of the amount consumed by the formal worker. Analogously, an informal worker needs to consume 11.1% more and a self-employed 1.7% less. The values depend on the estimates of the consumption weight (ν) and amenities (ϕ_I, ϕ_S).

The next set of estimates relates to search frictions. The quarterly destruction probabilities for formal, informal, and self-employed workers are 0.030, 0.003, and 0.010, respectively. For each sector, I estimate two arrival rates: the probabilities of receiving offers from the formal and informal sectors. We can see that, in any state, the informal arrival rates are always higher than the formal. Figure A.3 shows how the model matches well the transition rates, which are intrinsically connected to these parameters. It is worth noting that the model allows the possibility of voluntary quitting, which occurs with frequency 0.025%, 0.524%, and 0.176%, respectively, for formal workers, informal workers, and self-employed.

Using the model estimates, we can compute the average monthly earnings for someone working full-time in the three sectors. The average labor earnings are 180.16, 114.12, and 154.10 thousand pesos for the formal, informal and self-employed, respectively. That implies a formal-informal gap of 36.6%. The average earnings in self-employment are close to the earnings of formal workers, being 14.5% lower. Figures A.4 and A.5 show the labor earnings distributions. We can see that the model produces a good match for the three distributions. These numbers are the average earnings for those that accept jobs in the formal sector, considering how the two types sort into each sector.

In terms of the sub-types (ability), we can see that sub-type two has comparative and absolute advantages in working for firms, with a general ability of 1.71 and an entrepreneurial ability of 0.495. Sub-type one has a general ability of 1.000 (normalized) and an entrepreneurial ability of 0.725. This result implies that these abilities are negatively correlated. Sub-type one has a comparative advantage on self-employment, and it accounts for the totality of individuals engaging in self-employment activity.[39] The proportion of individuals of sub-type two is 57.0%.

For the self-employment sector, there are two additional parameters. The start-up cost X is estimated at 2,594.40 thousand pesos or around 17 monthly wages. I estimate that only 2.3% of this initial investment can be recouped at self-employment exit.

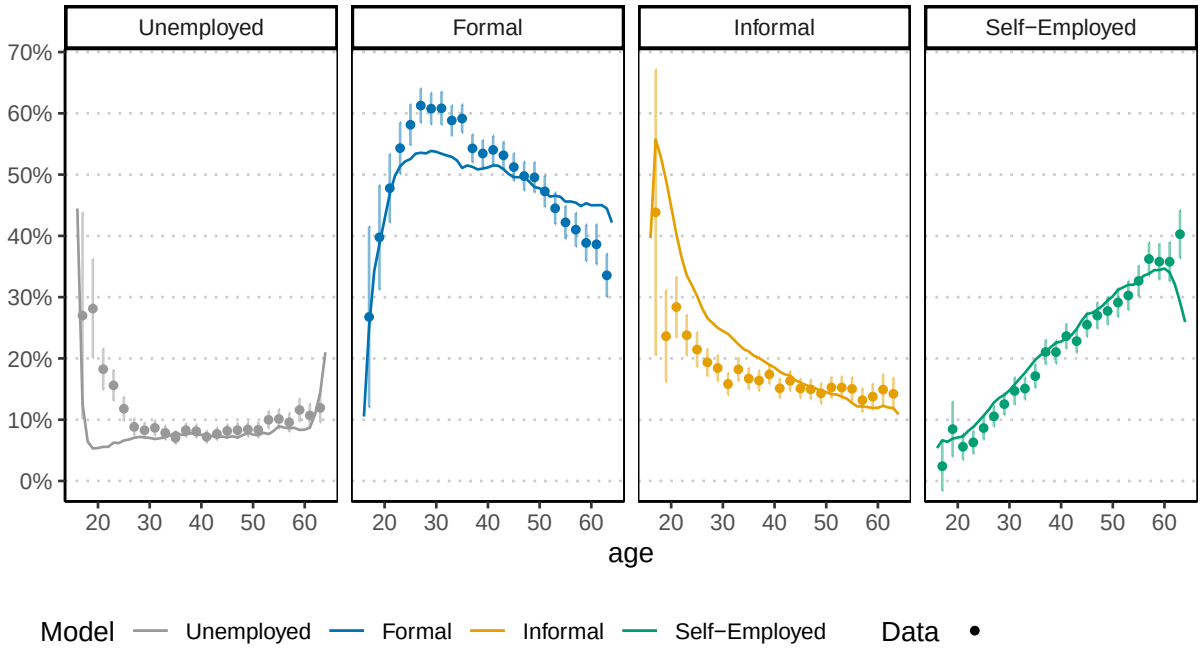
The model can replicate well the life cycle allocation across the three sectors. Figure 5 shows how the model replicates the main trends of labor market allocation well, with two exceptions. First, it slightly overstates the proportion of young individuals in the informal sector at the expense of estimating a lower rate of unemployed individuals. Second, it shows a flatter age profile for individuals in the formal sector between ages 30–65 than what is observed.

One of the interesting channels of the model is that job search depends on available resources. Figure 6 shows how the reservation wage for the informal sector depends on wealth and unemployment status for an unemployed individual.[40] We can see that unemployed individuals with low wealth and who do not receive unemployment insurance have significantly low reservation wages. They would accept offers paying around 25 thousand pesos monthly. The same individual with more wealth would have reservation wages three times higher. The figure clearly shows the value that UI brings to unemployed individuals

[39]That is why e_2 is estimated with great imprecision, individuals belonging to the second sub-type are never self-employed, and therefore their self-employment earnings are not observed.

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

Figure 5: Life cycle employment trends

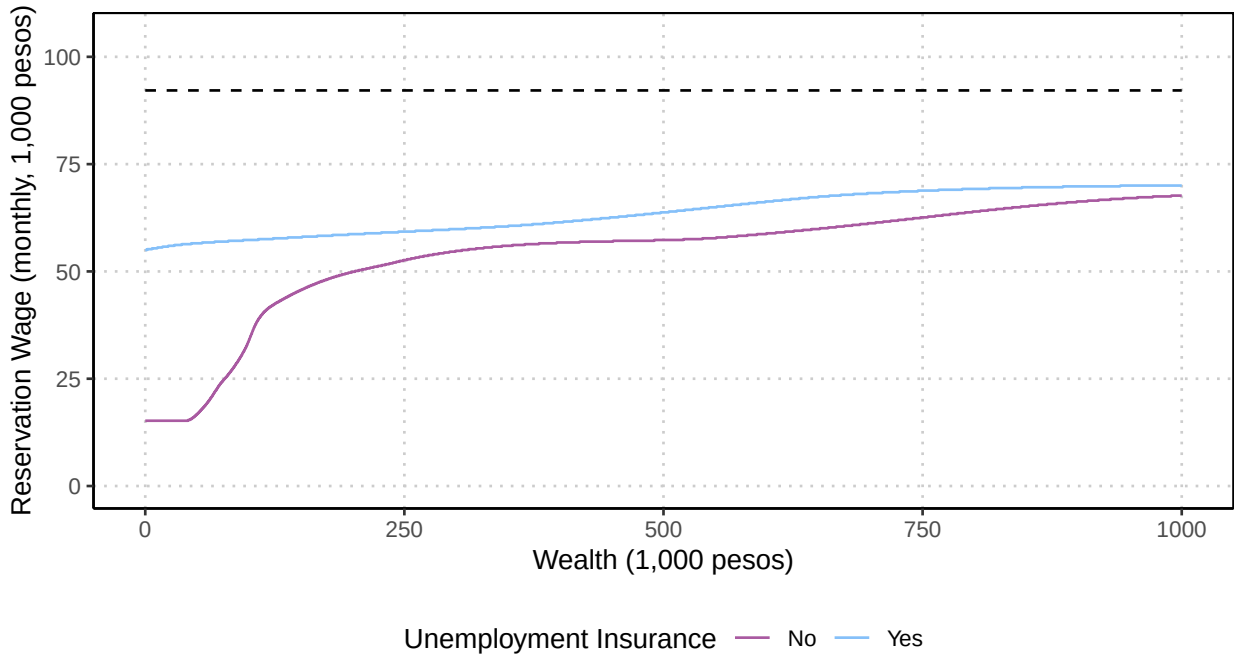


Notes: The graph shows the proportion of individuals in each sector (unemployment, formal, informal, and self-employment) over the life cycle. The dots represent each moment computed in the data, with the 95% confidence intervals. The lines are equivalent moments in the model.

without savings. They would reject low-wage offers from the informal sector if entitled to UI benefits. For individuals without liquid assets, the reservation wage with UI is more than two times higher.

Lastly, I show the model performance on targeted and non-targeted moments. Figure 7 shows the match of the retirement patterns for individuals born five years before and after August 1949, which was the exemption threshold for the 2004 reform. We can see that the results replicate well the retirement patterns of these two cohorts, particularly the jump at the normal retirement age (65) and the lower retirement rates before 65 for the cohort affected by the reform. The model does not capture some early retirement for individuals between 50-58 in both cohorts. This is likely due to special retirement rules for those employed in hazardous occupations. These special rules are firm-occupation specific; therefore, it is difficult to account for them in the data and the model.

Figure 6: Reservation wages for the informal sector

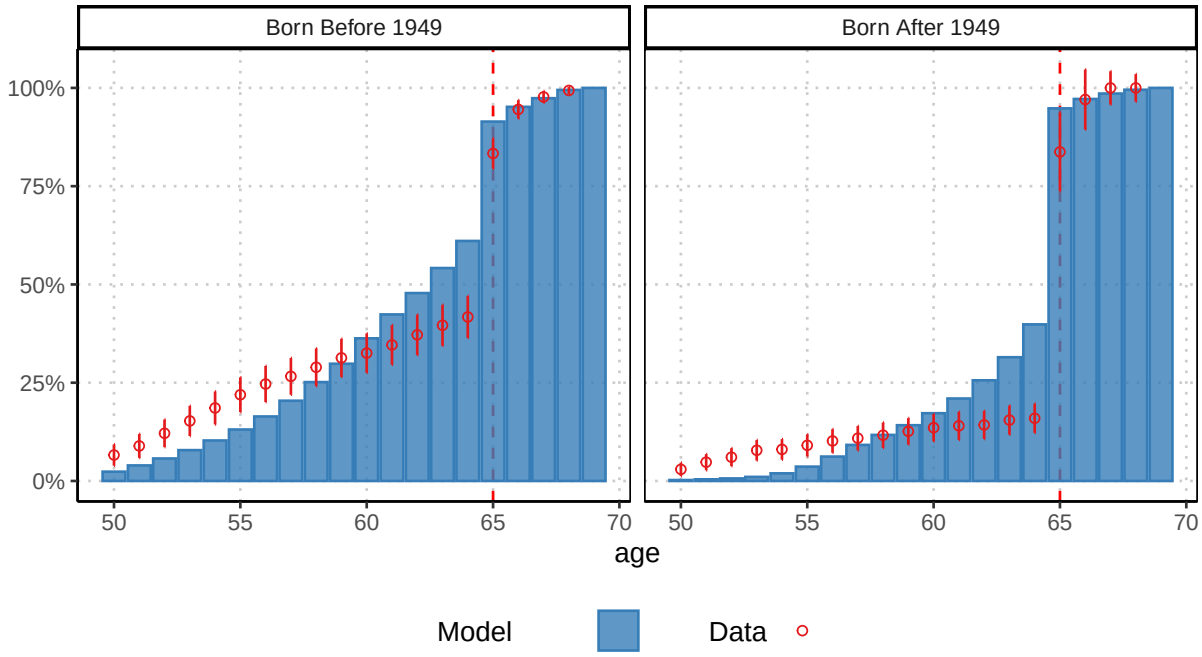


Notes: The figure shows the reservation wages for offers in the informal sector as a function of liquid wealth. The reservation wage is computed for a given individual that is 20 years old, of the entrepreneur type, before the pension reforms and with low pension wealth stock. The purple line shows the reservation wages for someone not entitled to unemployment insurance (UI), and the blue line for someone entitled to UI. The reservation wage depends on all 28 estimated parameters. The dashed black line shows the level of the minimum wage from the formal sector.

Figure A.6 shows the match of liquid wealth moments. The level and age profile are matched well, except for the post-retirement behavior for the individuals in the 75th percentile. One of the reasons is that wealth is imprecisely estimated. Consequently, the wealth moments receive less weight in the MSM procedure, particularly those for old ages, in the interval 70–89.

Figure A.7 shows the fit on the proportion of individuals working part-time as self-employed over the life cycle, which the model captures well. Figures A.9 and A.10 show the model performance on non-targeted moments, specifically the average pension wealth and the number of pension contributions by age. The model fits these non-targeted parameters extremely well.

Figure 7: 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.

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 seem to be present. The main exception is the bequest parameters with a looser link with the wealth moments than anticipated, likely due to the lower precision of these moments.

7 Counterfactuals

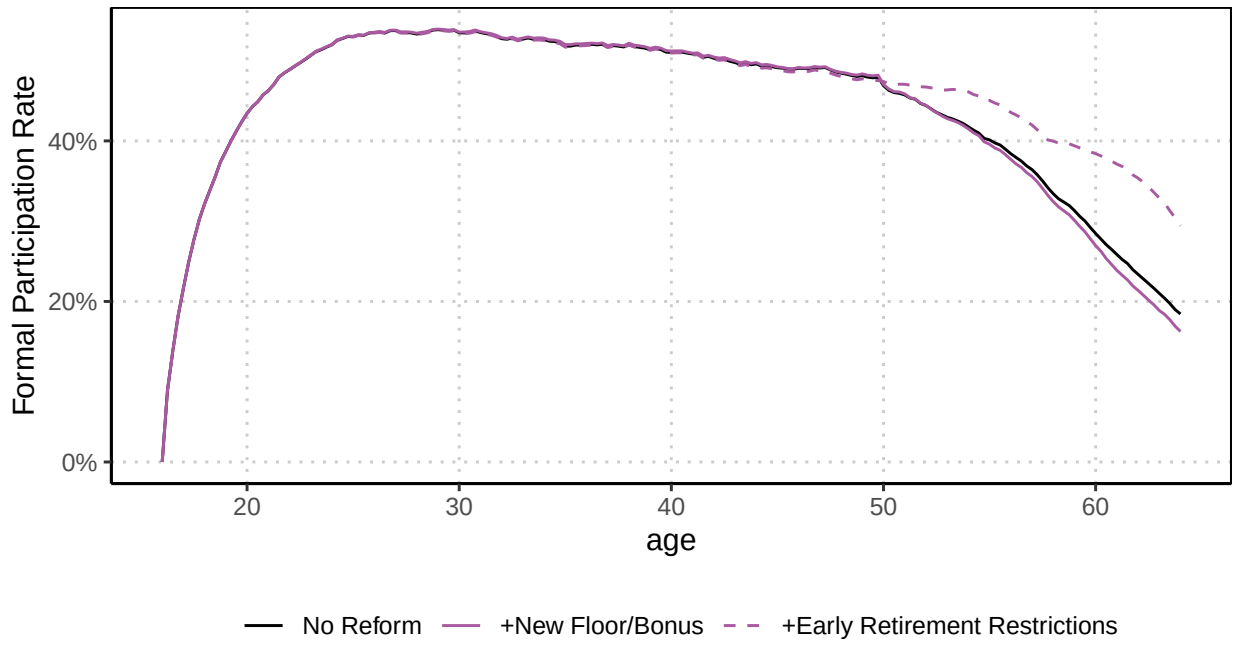
In this section, I use the model to generate and evaluate counterfactual policies and their impact on the allocation of individuals across sectors. The first exercise decomposes the effect of the pension reform implemented in 2008. The second evaluates alternative pension

reforms that the government is currently discussing. I then move to the discussion of the interaction effects of unemployment insurance and pensions.

7.1 Decomposing the 2008 pension reform

The 2008 pension reform implemented two main changes for men. It increased the system's generosity by introducing a minimum pension benefit (PBS) to which an individual without pension wealth would be entitled at retirement. The value of the PBS was treated as a bonus to all retirees, being withdrawn with an implicit tax rate of 30%. The reform also raised further the requirements for retirement before the normal retirement age. It increased the pension threshold value (A) by 23%. I use the model to decompose the effect of these two components.

Figure 8: Decomposition of the 2008 Pension Reform



Notes: The figure plots the proportion of individuals in the formal sector over the life cycle. The numbers use simulated data from the model. The **black** line shows the baseline economy, in the absence of the 2008 reform. The solid purple line shows the economy with only the increased minimum pension and bonus introduced by the 2008 reform. The dashed purple line adds the second component of the 2008 reform, the more stringent requirements for early retirement.

Figure 8 presents the decomposition exercise. The graph shows the proportion of individuals in the formal sector over the life cycle. The black line shows the baseline economy before the 2008 reform. The solid purple lines show that introducing the new floor for pension benefits has disincentive effects. It reduces the formal participation rate by 2.1pp near retirement, 1.5pp at age 60, and 0.5pp at age 55. This is expected, given that the reform loosened the link between pension benefits and contributions. These results are consistent with the findings of Attanasio et al. (2011).[41] However, the disincentive was small and limited to individuals between 50-65. When we consider the second component of the reform, the more stringent requirements for early retirement, it almost offsets the disincentive effects. For individuals younger than 50, formality rates go up. In terms of formal participation, the total reform had positive effects. These results show how governments can use different margins of pension regulation. Importantly, together with the strong results from the 2004 reform, they show how changing the early retirement rules can have large effects.

7.2 Proposed pension reform

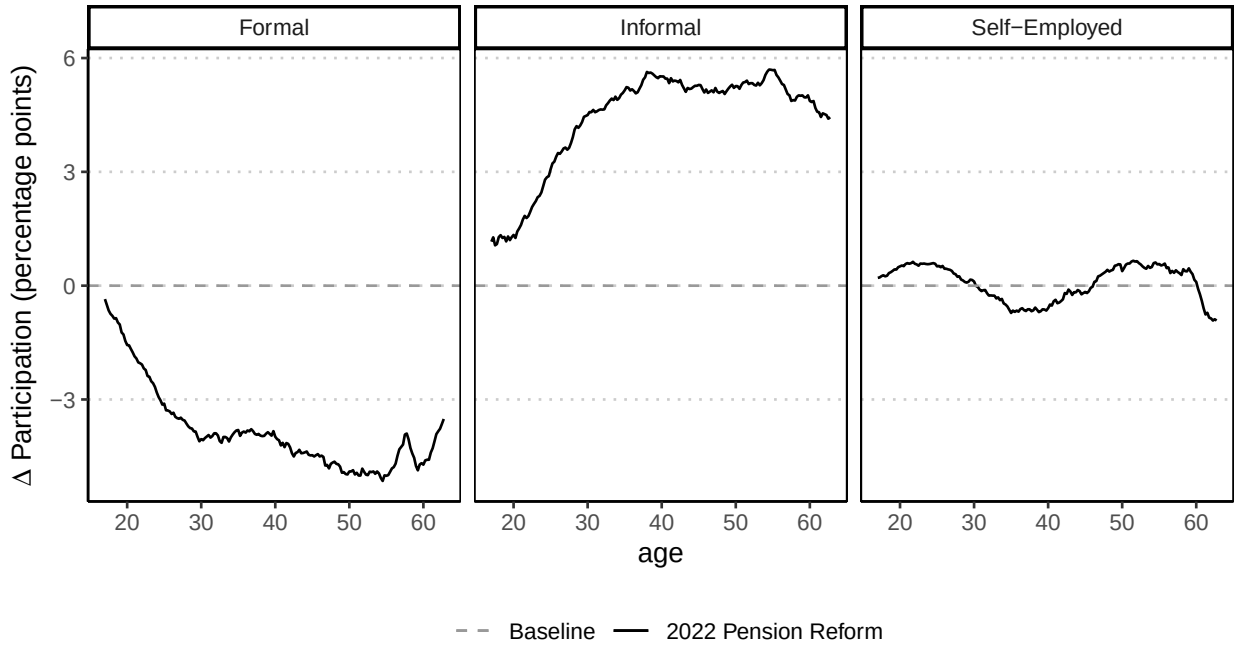
Between June and August of 2022, the Chilean government announced that it was studying a large pension reform. While the details of the reforms were not made public, the main characteristics announced were: (i) increasing the minimum pension to 250 thousand pesos and (ii) increasing the pension contributions from 10% to 16%. There was a debate whether the extra 6% would go towards the individual accounts or to a new common public fund[42]. I implement these changes in the model and assess the results in the allocation of individuals in the three sectors.

Figure 9 shows the results for the reform if the extra 6% of contributions go to the

[41] In their paper, the second pillar raising the early retirement restrictions was not yet in place.

[42] Details of the announcements can be checked on `https://web.archive.org/web/20220915214634/https://www.emol.com/noticias/Economia/2022/06/01/1062756/presidente-reforma-previsional-cuenta-publica.html`, `https://web.archive.org/web/20220915214835/https://www.emol.com/noticias/Economia/2022/07/25/1067970/reforma-pensiones-6-gobierno.html` and many other media outlets.

Figure 9: 2022 proposed pension reform (common funds)

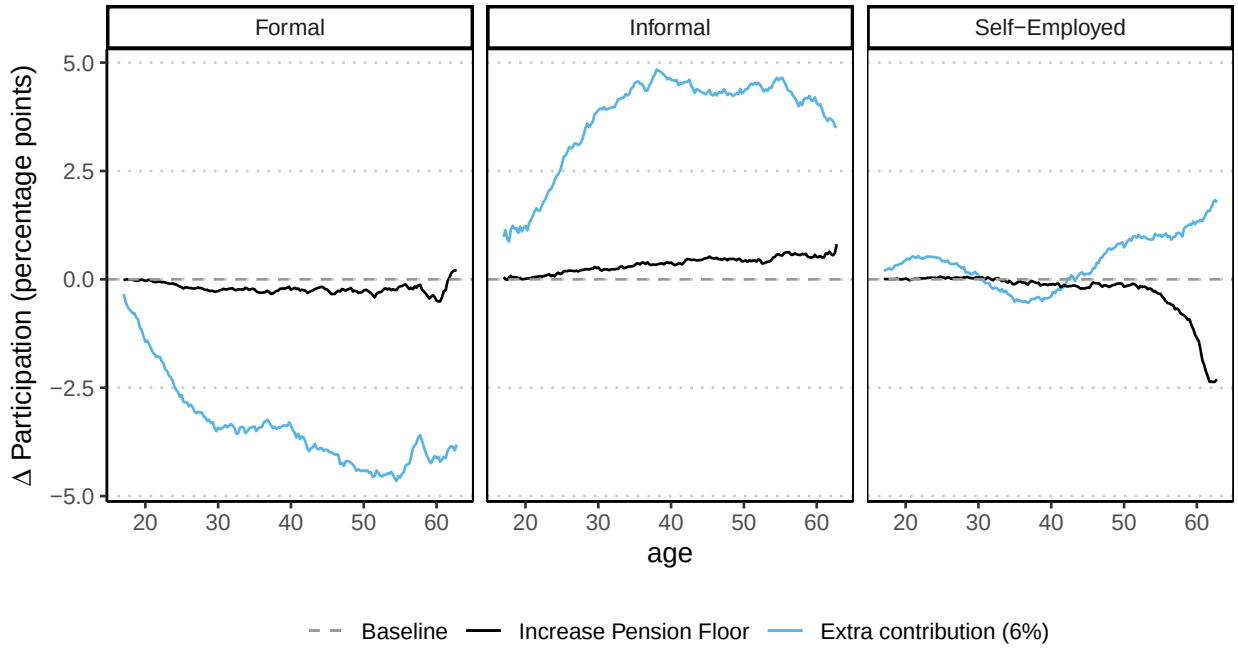


Notes: The figure shows the difference, in percentage points, in the proportion of individuals in the formal, informal, and self-employed with the introduction of the 2022 pension reform.

common funds. I assume the government uses these extra resources to finance the pension minimum for those whose resulting benefit would be smaller than 250 thousand pesos. We can see an increase in informality, as informal employees and no change in self-employment. Formal participation rates fall by more than 3pp over the life cycle. These effects are comprised of both the increase in the minimum pension and the extra contribution of 6%. Figure 10 decomposes this effect into the two components. We can see that the increase in the contributory rate drives the entire effect.

In figure 11, I show the same policy reform with the extra 6% going to the individual accounts. The effects are similar up to age 50. However, we can see that with the extra 6%, individuals would be more likely to meet the requirements for early retirement and retire early, reducing the formal (and total labor force participation) at old age.

Figure 10: 2022 proposed pension reform (common funds) — decomposition

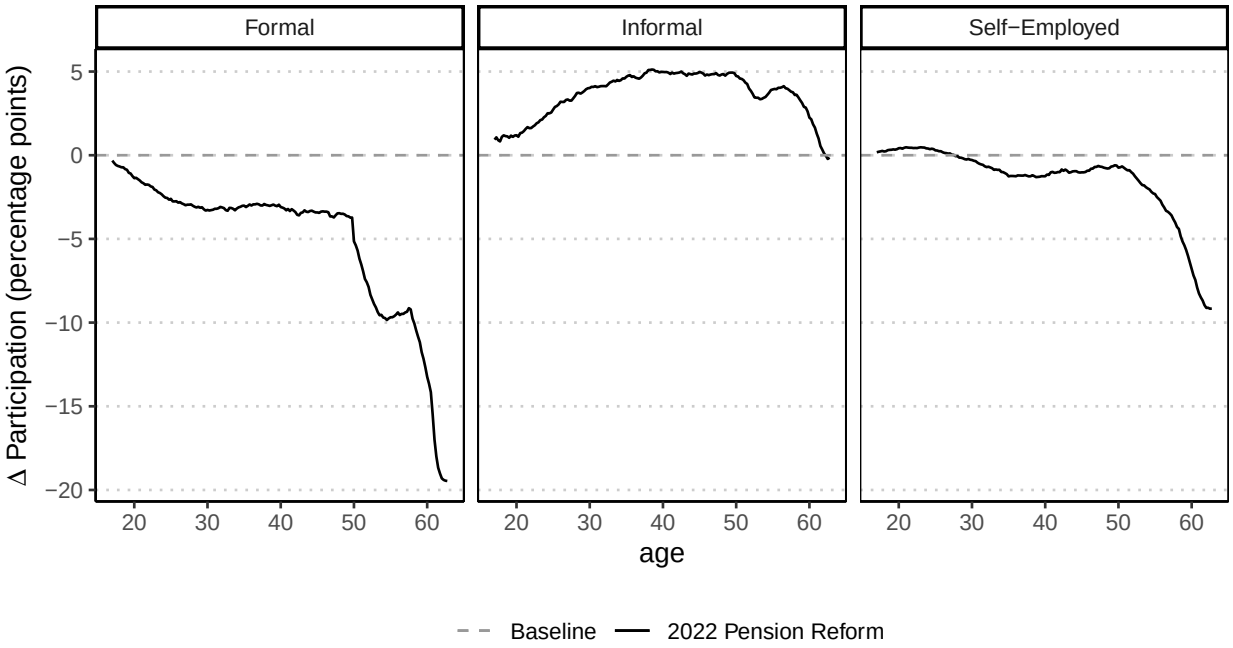


Notes: The figure shows the difference, in percentage points, in the proportion of individuals in the formal, informal, and self-employed with the introduction of the 2022 pension reform. The **black** line shows the effect just from the increase in the minimum pension. The blue line shows the effects of increasing the pension contribution rate from 10% to 16%.

7.3 Interactions between unemployment insurance and pensions

One of the advantages of this model is to analyze different forms of insurance tied to participation in the formal sector. If individuals are well covered against short-term shocks through insurance, they may be more likely to invest in high-return tax-favored illiquid investments like pensions. I test if that is the case, given the institutional settings in Chile by simulating marginal changes in both systems. Table 10 show the results of this exercise. In the first row, I show that increasing the unemployment benefits by 10% would increase formal participation rates by 0.25pp. In the second row, I show that increasing the pension benefits by 10% (keeping the same contribution history) would increase formal participation rates by 0.06pp. However, when I apply these two changes together, I obtain an increase of 0.35pp, which is 13% larger than the sum of the individual effects. This is robust to several

Figure 11: 2022 proposed pension reform (individual funds)



Notes: The figure shows the difference, in percentage points, in the proportion of individuals in the formal, informal, and self-employed with the introduction of the 2022 pension reform with the extra 6% going to the individual accounts.

changes in unemployment benefits and pensions.

Table 10: Complementarities between pensions and unemployment insurance

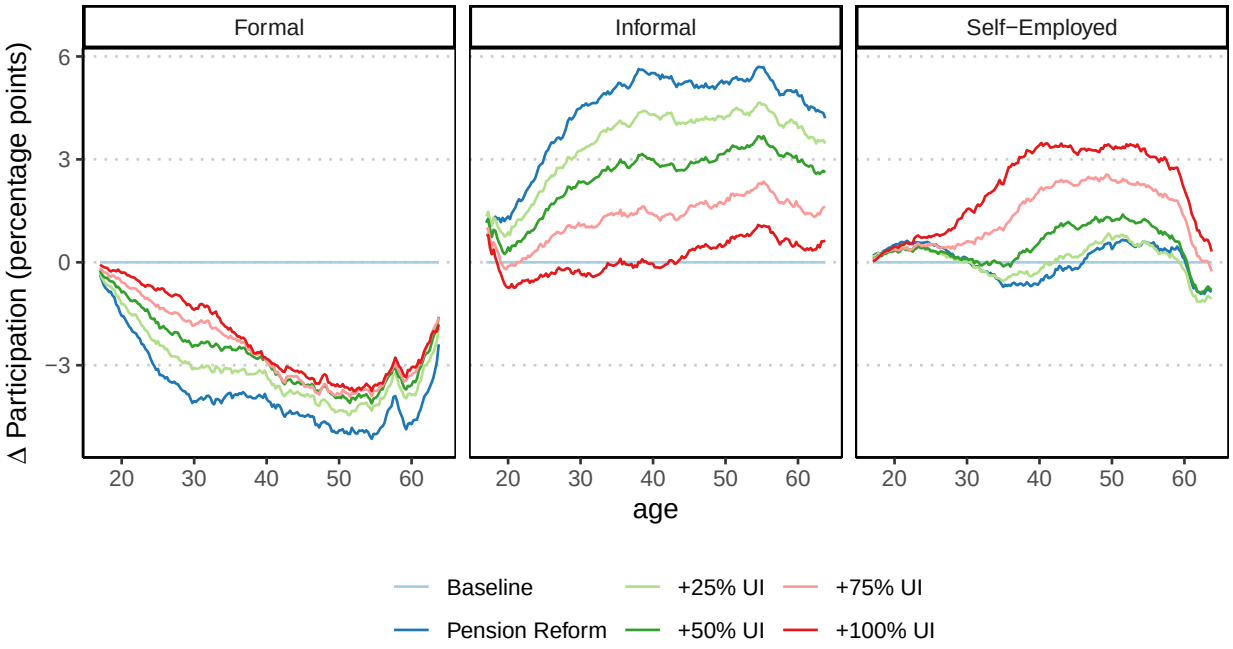
Change	Δ Formal participation rate (pp)
Increase in UI	0.25
Increase in Pensions	0.06
Increase in both	0.34

Notes: The table shows the difference in the proportion of individuals in the formal sector (in percentage points) by marginal changes in the unemployment insurance, pensions, and both.

Another way of showing these interaction effects is by simulating the 2022 pension reform simultaneously with the government increasing unemployment benefits. Figure 12 shows what would be the effect of the same reform being implemented with a budget-neutral expansion of unemployment benefits by 25%, 50%, 75%, and 100%. We can see that this

expansion would reduce the negative effects of the pension reform by almost half in terms of participation in the formal sector. Interestingly, we can see opposite effects in the informal and self-employment sectors. This is driven by the liquidity effects of increasing unemployment benefits "leaking' to self-employment since it allows individuals to pay the physical capital investment.

Figure 12: 2022 proposed pension reform (common funds) — with UI expansion



Notes: The figure shows the difference, in percentage points, in the proportion of individuals in the formal, informal, and self-employment sectors with the introduction of the 2022 pension reform. The darker blue line shows the effects of the pension reform of 2022 and the next two green and red colors the same reform in addition to the expansion in the unemployment benefits by 25%, 50%, 75%, and 100%

8 Conclusion

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

I develop a model where risk-averse individuals decide 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 payment, and pensions. My findings show how it is essential to allow the job search to depend on savings. Poor and rich individuals have different job search behavior. This is the main driver of two facts from the data: (i) young workers are more likely to be working informally, and (ii) the correlation between informality and poverty. Using the model to run counterfactuals, I show how it is important to consider interactions across social insurance programs.

One important extension of this paper is to endogenize labor force participation, allowing the analysis of men and women in a unified framework. This is particularly interesting in the context of Chile since several aspects of the pension reform in 2008 affected men and women differently. What provides additional variation in the policy environment. Expanding the analysis to include human capital accumulation is another fruitful direction, which would allow the extension to individuals with some college education or more. Another direction of future research is to identify these interaction effects in different insurance mechanisms, in other settings, and by exploring different strategies.

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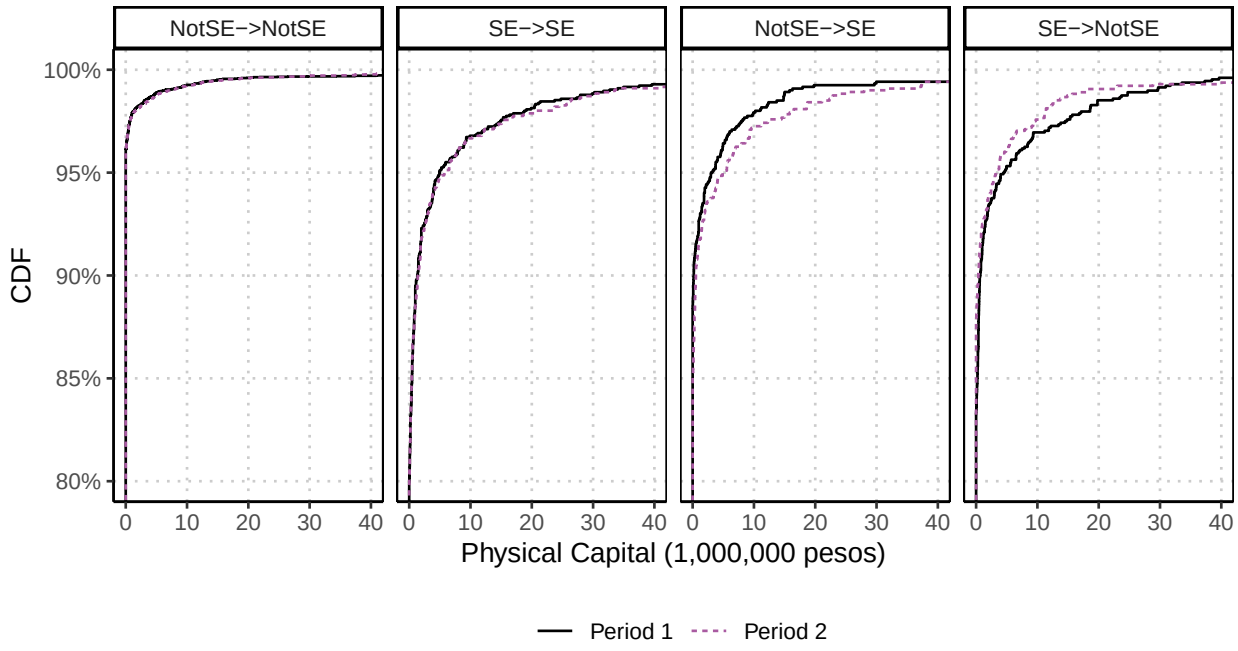
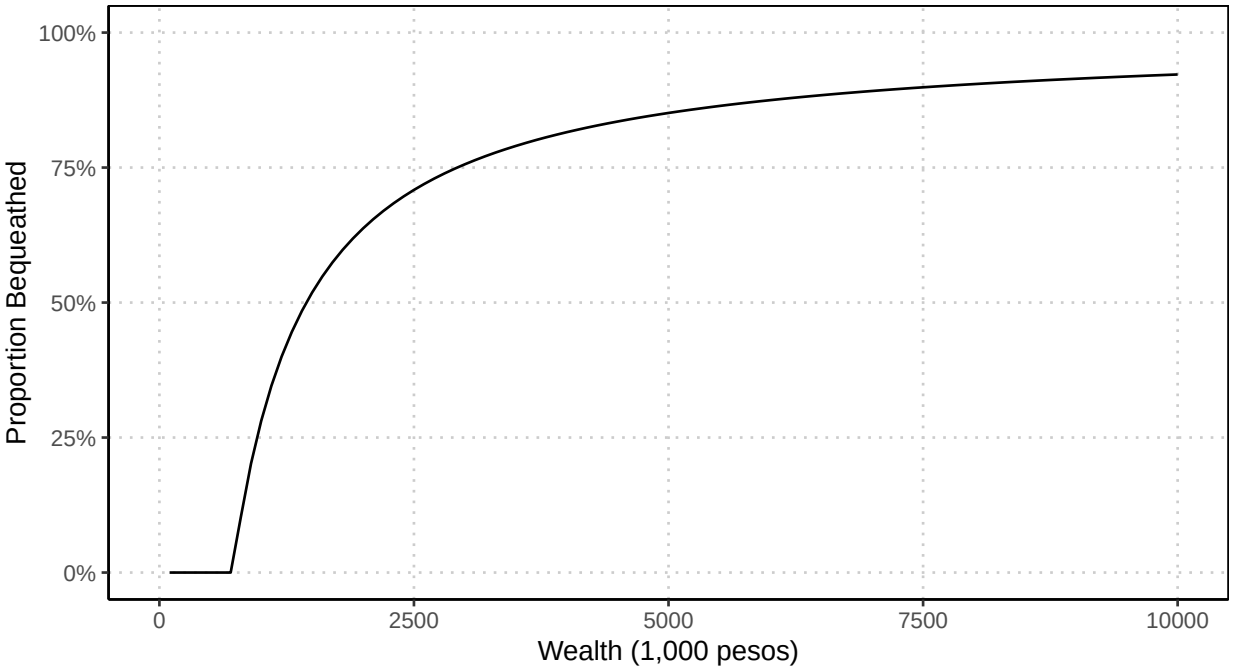
Appendix A - Appendix Tables and Figures

Figure A.1: Self-Employment and wealth allocated to physical capital



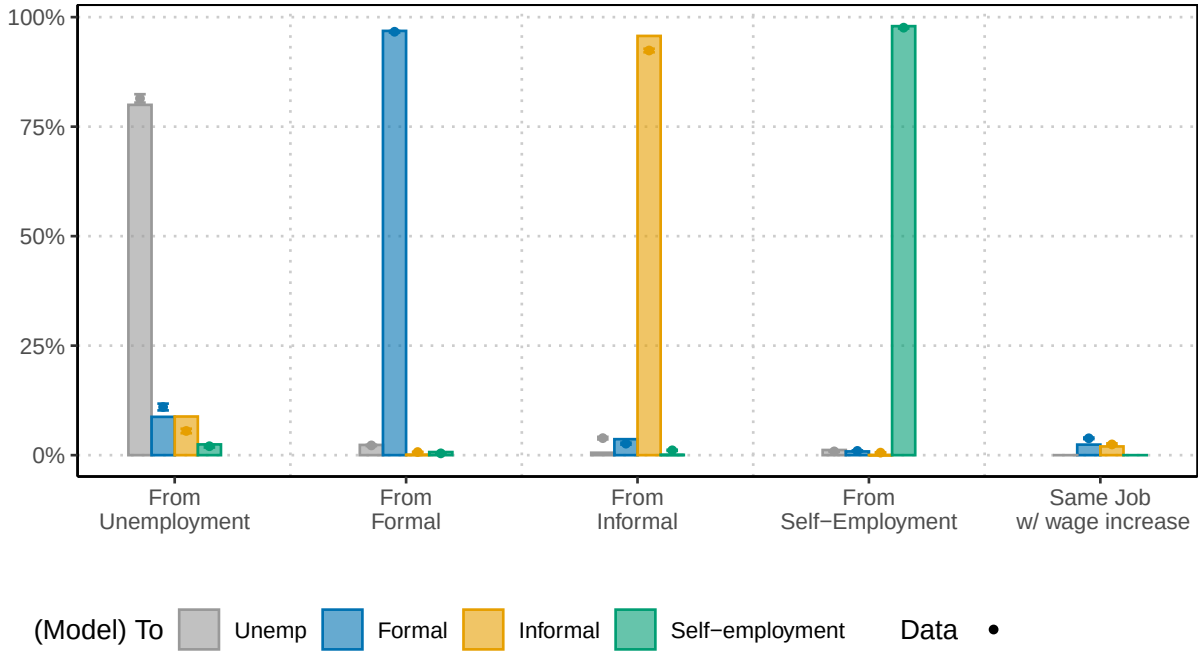
Notes: Data from EPS, main sample. The figure shows the empirical cumulative density function (CDF) of the physical capital variable. The four panels plot the CDFs for different groups, classified as their employment status in two surveys. NotSE stands for those not self-employed. SE stands for those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

Figure A.2: Proportion of wealth bequest as a function of wealth



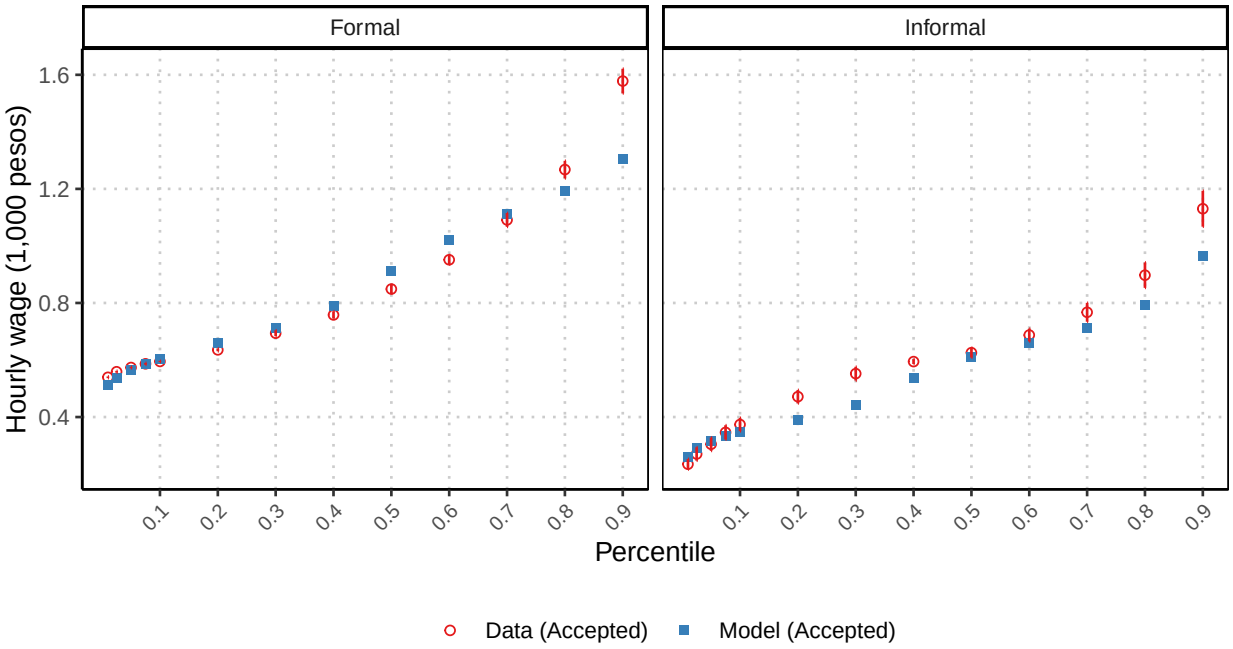
Notes: The figure shows the proportion of wealth bequeathed in the last period of life, when individuals face death with certainty. The function takes into account the interest rate (r), the discount rate (β), the coefficient of risk-aversion (γ), the consumption weight (ν), the bequest weight (ψ) and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

Figure A.3: Transitions in the model and in the data



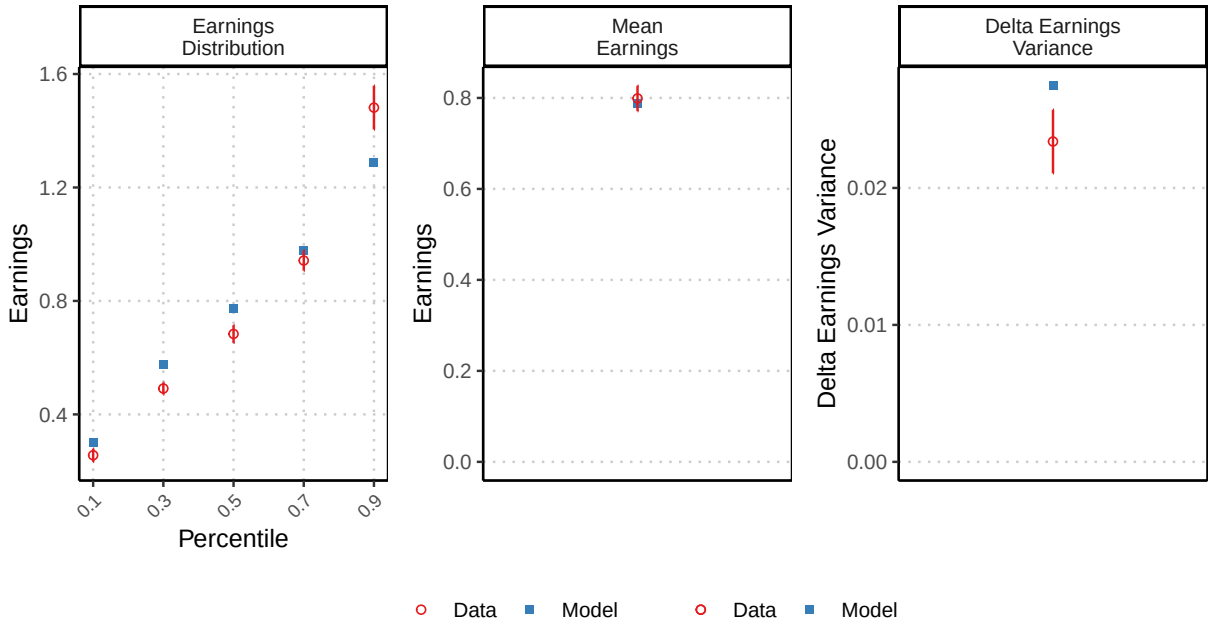
Notes: The figure shows the transitions rates in the data and simulated in the model. The colors highlight the destination sector (gray for unemployment, blue for formal, yellow for informal, and green for self-employment). The sector of origin is on the x-axis. The first four groups are for individuals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

Figure A.4: Formal and informal wage distributions (offered and accepted)



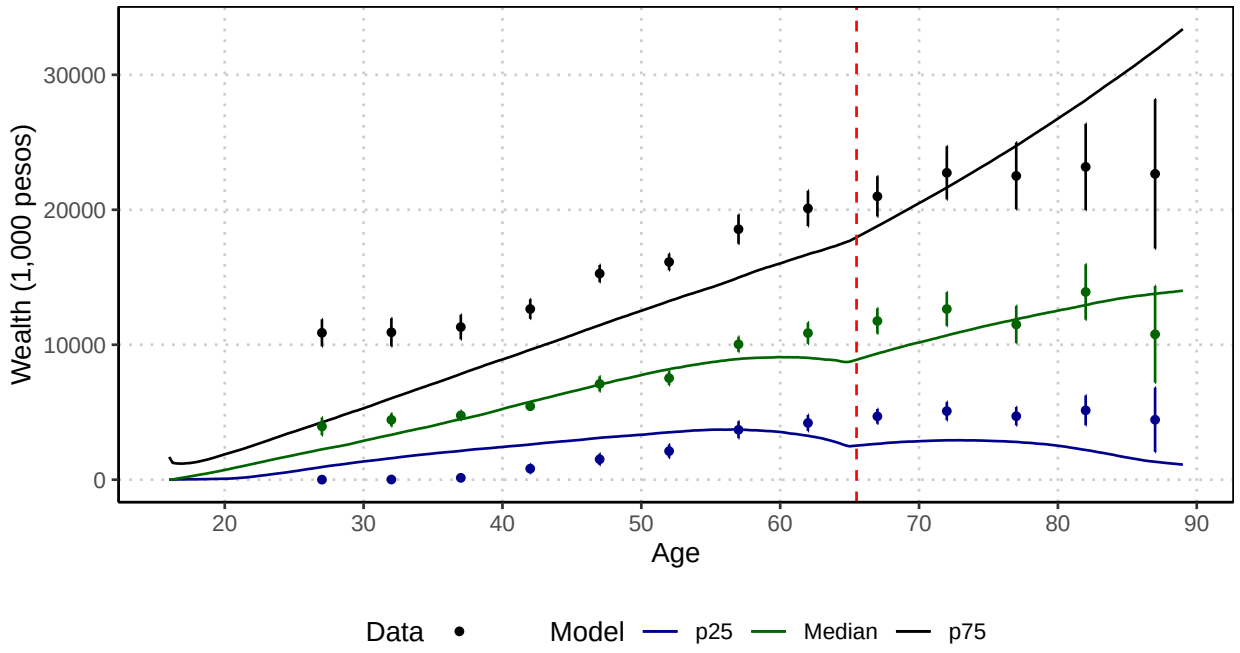
Notes: The figure shows percentiles of the earnings distribution for the formal and informal sectors, in the data and simulated in the model. The red circles show each percentile in the data, together with the 95% confidence interval. The blue squares show the equivalent percentiles in the model. Both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

Figure A.5: Self-employment earnings



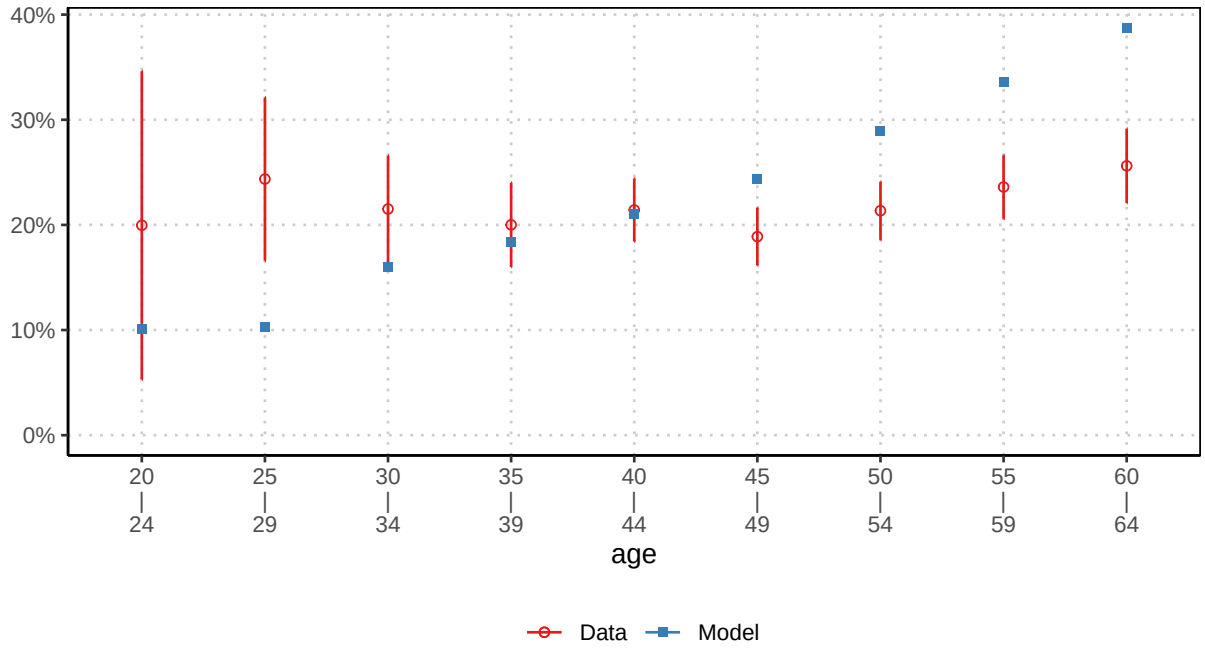
Notes: The figure shows moments of the earnings distribution for self-employed individuals in the data and simulated in the model. The red circles show each moment in the data, together with the 95% confidence interval. The blue squares show the equivalent moments in the model. The first panel shows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

Figure A.6: Wealth over the life cycle



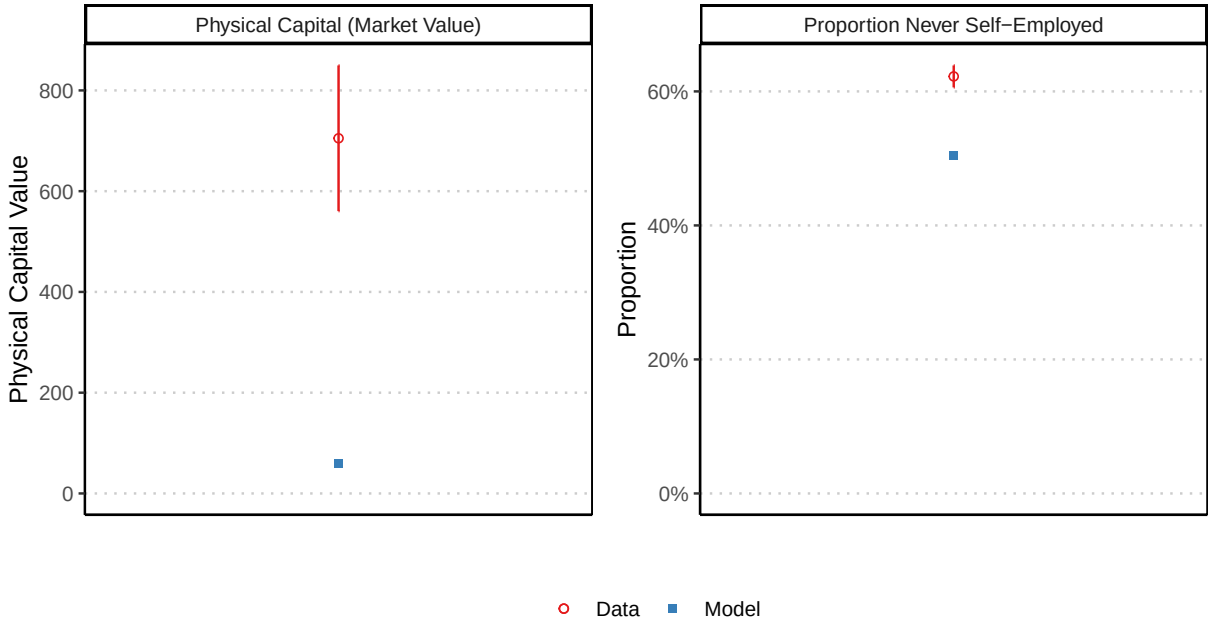
Notes: The figure shows the median (green), 25th percentile (blue), and 75th percentile (**black**) wealth over the life cycle in the data and in the model. The dots are the moments in the data, together with the 95% confidence intervals. The solid lines are the same moments in the model.

Figure A.7: Proportion of self-employed working part-time



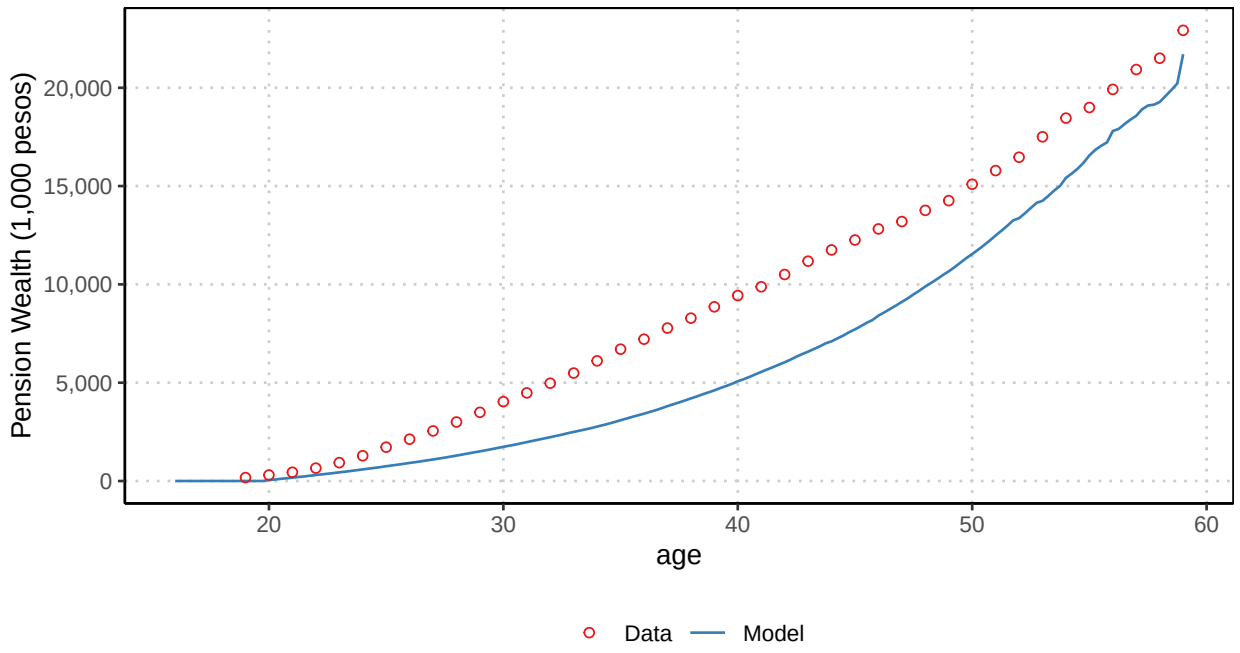
Notes: The figure shows the percentage of self-employed individuals working part-time in the data (red circles, with the 95% confidence interval) and in the model (blue squares).

Figure A.8: Self-employment physical capital and proportion never self-employed



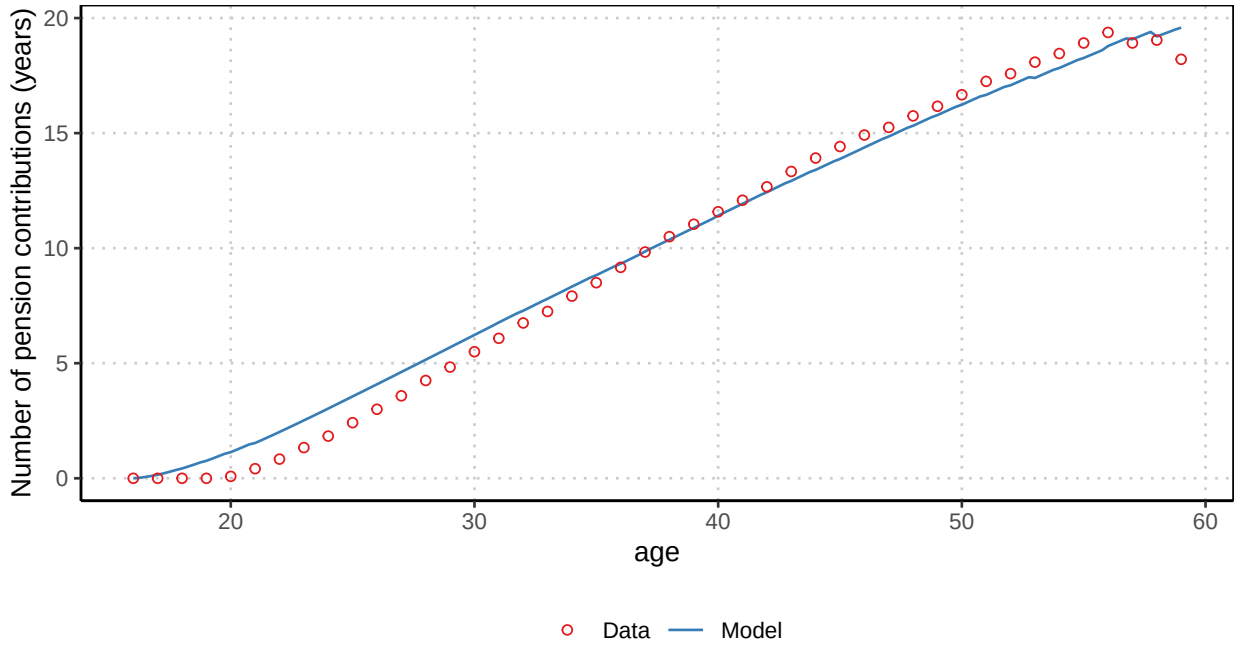
Notes: The figure shows moments in the data (red circles, together with the 95% confidence intervals) and simulated in the model (blue squares). The first plot shows the average value of physical capital that can be recouped at self-employment exit. The plot on the right shows the proportion of individuals that were never self-employed over the life cycle.

Figure A.9: 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.10: 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).

Appendix B - Data cleaning

B.1 Data description and source

Table A.1 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.1: Data sources — microdata

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

On top of the microdata detailed in Table A.1, 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 Pen-*

siones, 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 discard individuals with inconsistent gender or year of birth over the EPS waves (256 observations).

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

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

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

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

for all individuals in the formal, informal, or self-employment sectors, working between 10 and 60 hours. w_{it} is computed as the hourly wage, trimming the bottom and top 2%. I also discard information from the formal sector that results in an hourly wage below 90% of the minimum wage. The trend is also defined as zero value ($t = 0$) in August 2004.

For most of the analysis, I restrict the sample to individuals born between 1940 and

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

For retirement patterns, I use data up to 2019 to capture retirement at ages 65-70 for the cohort born in 1950–1954. I use wealth moments for ages 70–89, therefore, only for these moments, I use individuals born between 1915-1949. All labor market information only uses data recorded at most two years after the reported event. For the earnings information, to minimize concerns with wage growth and minimum wage increases, I only use data from a short interval from 2002–2008.

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.[43] 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 that reported working as self-employed in two surveys, where the reporting was less than 12 months apart, and the spell duration was greater than 18 months in the second report. That implies that I am not considering self-employment earnings for the first six months of business.

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

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

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

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 their number of enrolled individuals. To obtain the average return on the pension funds, I use data from Sistema de Pensiones on the monthly returns for each pension type. There are five funds, A–E, where A is the safest and E the riskiest. I use data in the interval 1982–2019. I first obtain monthly returns by getting the weighted average of each fund's return. The weights are the amount of resources in each fund.

Appendix C - 2004 Reform

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

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

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

Table A.2: Early retirement requirements

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

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

Appendix D - Model specifications

D.1 Net income function

When in the labor market, the net income function for an individual of type θ, working in sector j, earning w, working h hours, bringing k as assets, and with unemployment benefits given by b, is $Y(\theta, j, w, h, k, b)$.

$$Y(\theta, j, w, h, k, b) = \begin{cases} \Upsilon\Big(rk + SUF(k)\Big) + b & \text{, if } j = U \\ \Upsilon\Big(rk + g(\theta)wh + AF(wh) - \tau wh\Big) & \text{, if } j = F \\ \Upsilon\Big(rk + SUF(k)\Big) + b + g(\theta)wh & \text{, if } j = I \\ \Upsilon\Big(rk + SUF(k)\Big) + b + e(\theta)wh & \text{, if } j = S \end{cases} \tag{22}$$

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

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

$$Y^{\text{Ret}}(y^P, \theta, a, k) = \Upsilon\Big(rk + \tilde{y}^P(1 - \tau_H) + SUF(k)\Big) \tag{23}$$

,where

$$\tilde{y}^P = \begin{cases} y^P & \text{, if year} < 2008 \text{ or } a < 65 \\ y^P(1 + PBS(1 - \frac{y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 0 \\ y^P(1 + PBS(1 - \frac{\vartheta y^P}{PMAS})) & \text{, if year} \geq 2008, a \geq 65, q = 1 \end{cases} \tag{24}$$

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.

Appendix E - Estimation

E.1 State Space

Table A.3 below presents the 10 state variables and how they are implemented in the numerical estimation.

Table A.3: State space

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

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, two, and three dimensions to approximate the value for the three continuous variables.

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

I compute numerical derivatives only to compute the standard errors and the sensitivity matrix proposed by Andrews et al. (2017). To do that, I compute numerical derivatives using

two symmetrical deviations around each estimated parameter, with a step size of 2.5%.

Appendix F - Sensitivity Matrix

I compute the sensitivity matrix proposed by Andrews et al. (2017). I plot the results for each parameter in the collection of graphs below (Figures A.11–A.15). In the x-axis, there are the 218 moments used in the estimation, separated into 11 groups, which are described in Table A.4 below. Each circle reads as the impact of changing one standard deviation of that given moment on the estimated parameter. The color codes whether the impact is positive or negative. For instance, in the first plot of figure A.11 we can see that the moments that most affect the estimation of the discount rate β are those associated with the wealth moments.

Table A.4: Groups of moments

Group	Description
G01	Transitions from j to j'
G02	Age profile for each sector
G03	Wealth age-profile
G04	Formal earnings distribution
G04	Informal earnings distribution
G06	Self-employed earnings
G07	Physical capital
G08	Retirement before/after 1949
G09	Proportion working part-time over life cycle
G10	Proportion never self-employed
G11	Wage correlations

Figure A.11: Sensitivity Matrix - I

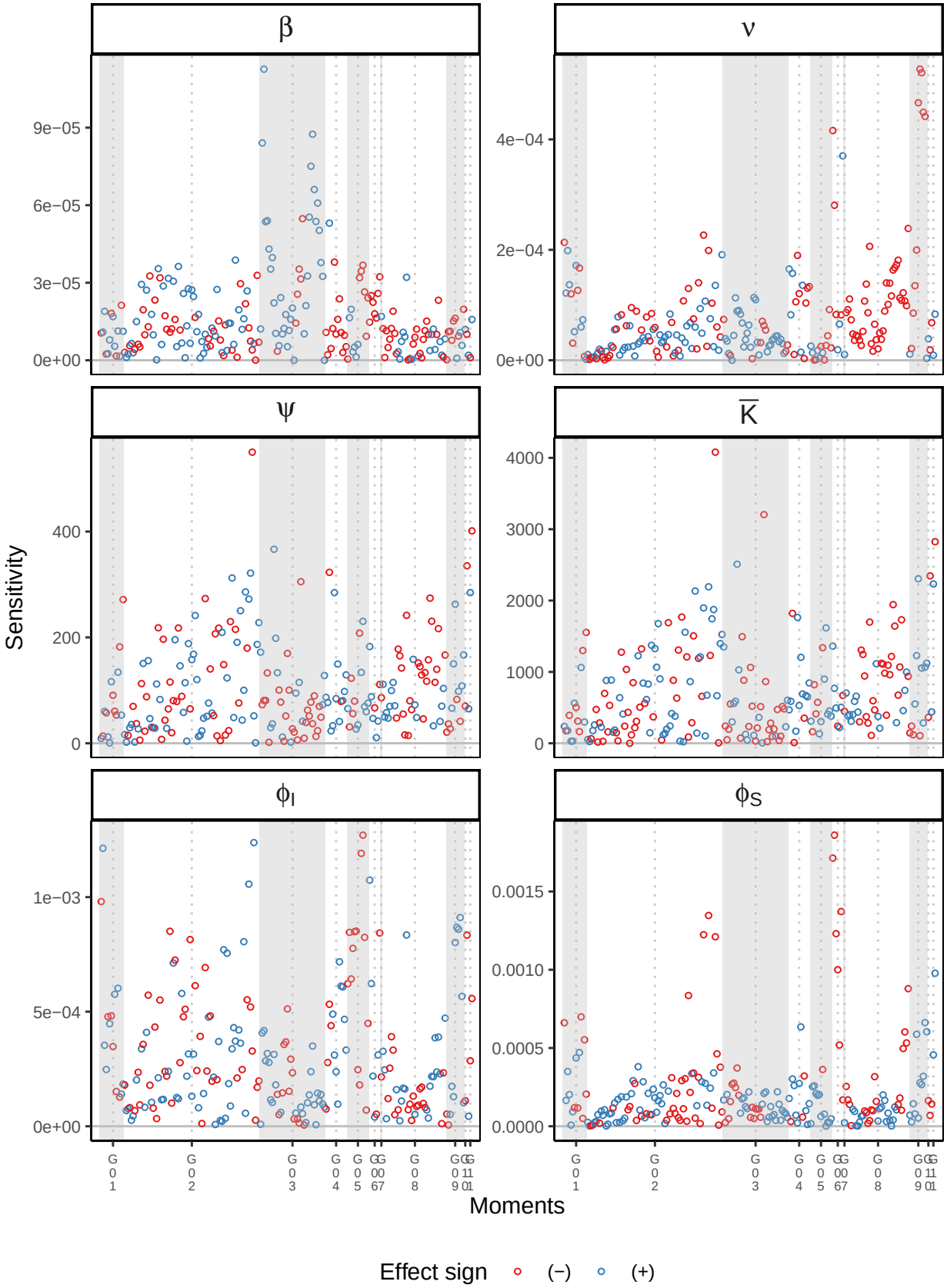


Figure A.12: Sensitivity Matrix - II

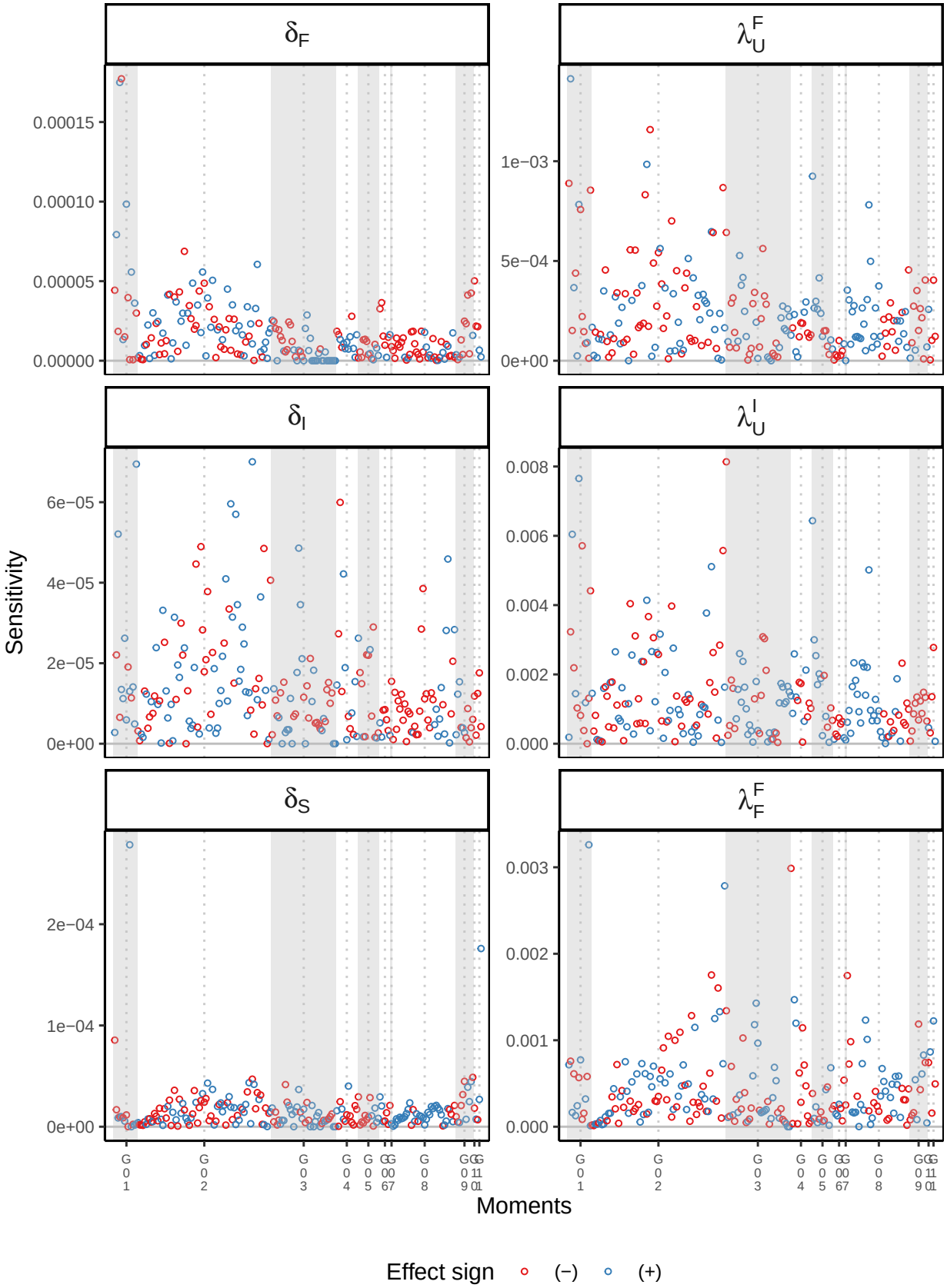


Figure A.13: Sensitivity Matrix - III

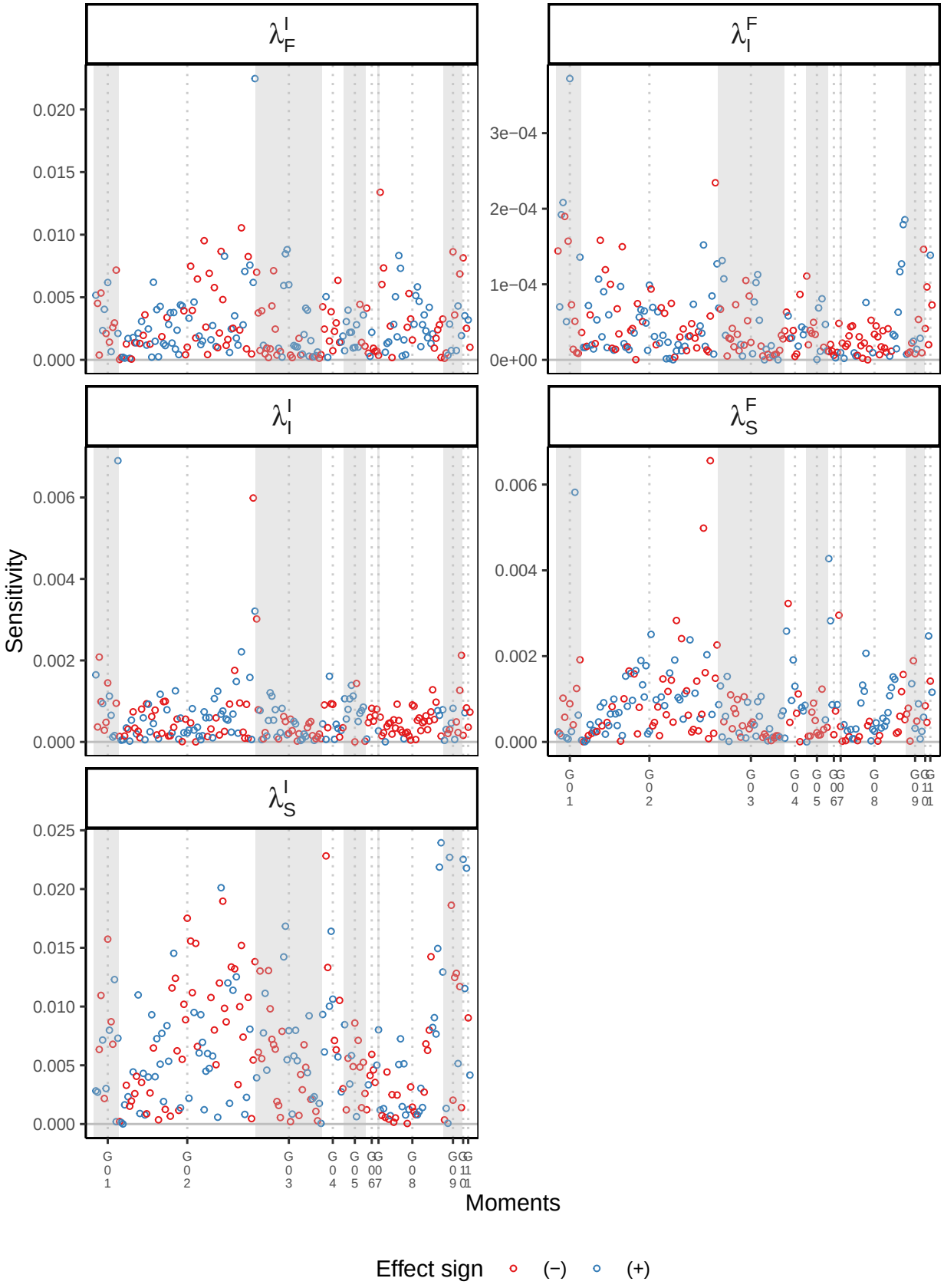


Figure A.14: Sensitivity Matrix - IV

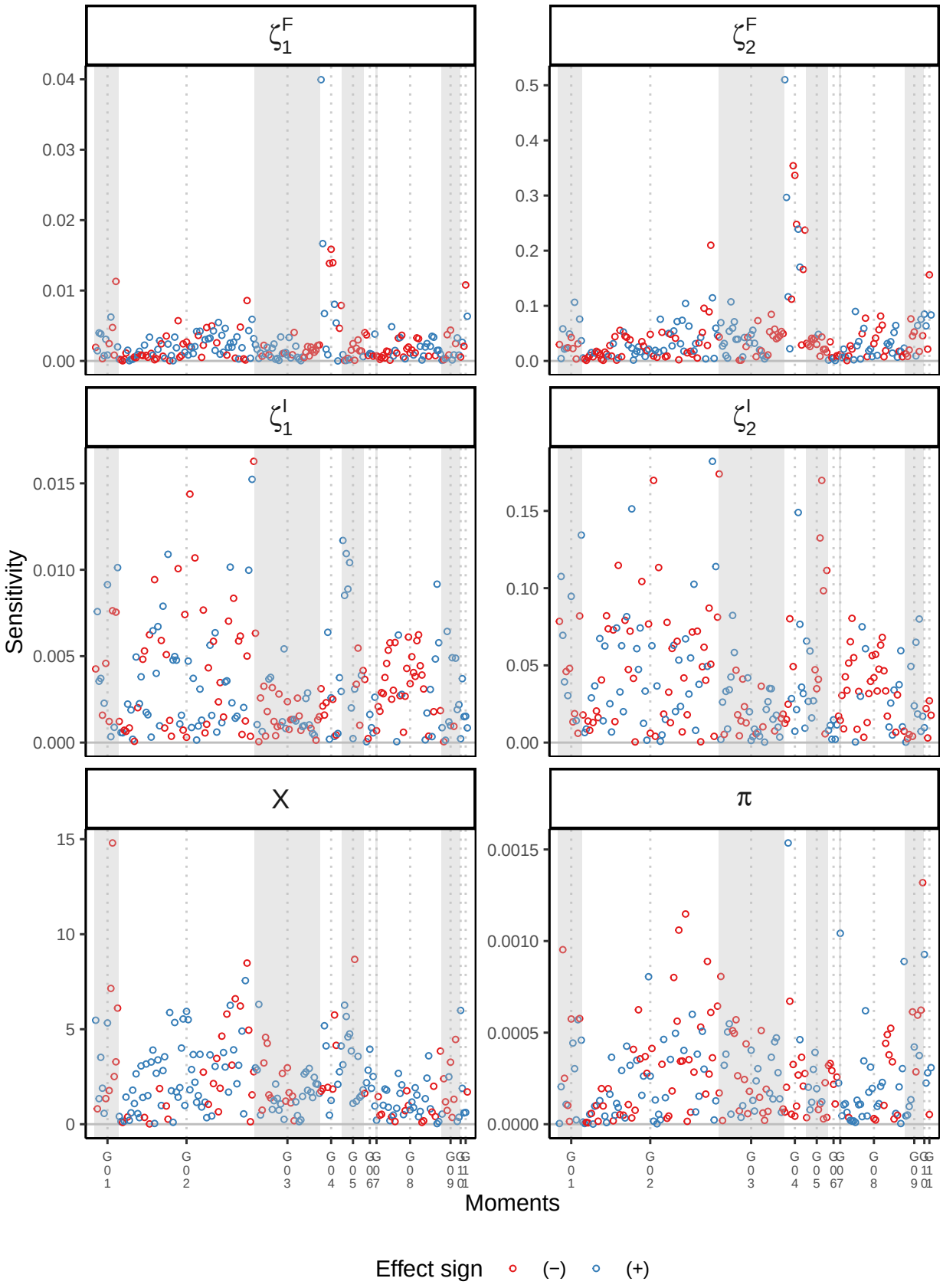


Figure A.15: Sensitivity Matrix - V