The impact of pension systems in labor markets with informality[*]

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Abstract

This paper examines the impact of pension systems in economies with large informal labor markets using Peru as a case study. In these economies, mandatory participation in contributory pension systems can only be enforced on formal-sector workers. As a result, the design of the pension system can have an important impact on workers' decisions to work in the formal sector. I develop a heterogeneous agent life-cycle, overlapping generations (OLG) model where informality arises endogenously as workers choose their optimal working sector each period. In the model, formal workers choose between a pay-as-you-go and an individual-account pension system, while the government finances a non-contributory means-tested pension for the poor and uncovered elderly. Workers in the economy face earnings and job separation risk. The mandatory contributions formal workers make to the pension system impose a liquidity constraint on lower income workers making them more likely to choose informal jobs. I show that both types of contributory pension systems present in the model affect labor decisions and that removing them increases formality and is welfare improving. Without any contributory pension system, the number of elderly individuals receiving the non-contributory social pension expands, but the government has a larger tax base of formal workers to offset financing this increase. Finally, in comparison to having both types of pension system or only an individual-account system, an economy with a PAYG-only system has the highest ex-ante welfare. Such economy has more high-income workers in the PAYG system which increases contributions. In addition, pension outlays are lower because benefits paid are limited to individuals with a minimum number of contributions and capped. In general equilibrium, the relatively lower cost of the PAYG system allows the government to lower income taxes, which further increases formality.

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1 Introduction

This study evaluates how the design of the pension system impact workers' decisions about whether to pursue jobs in the formal or informal labor market. Informal jobs are, to a great extent, unregulated by the government. By choosing to work informally, workers avoid paying taxes and making mandatory contributions to the pension system, as well as, other regulatory requirements. The International Labour Office (2018) estimates that around 60% of the world's total labor force is employed informally[1], with significant differences between developed (18%), and developing and emerging economies (70%). A major concern for countries with high informal labor rates is the lack of social protection for these workers. Since pension systems are linked to workers' sector status, emerging economies are particularly vulnerable to having a large portion of the elderly population retiring without a pension (Frölich et al., 2014). However, from a worker's perspective, higher wages and the opportunity to receive a pension in old-age may not provide enough incentive for them to choose a formal job over an informal one when given the opportunity. Instead, a mandate to contribute to the pension system could be a significant disincentive to enter the formal sector. Even with lower-paying jobs, workers might find the informal sector attractive because it allows them to avoid contributions to the pension system and, consequently, have higher liquid income available to consume.

In this paper I assess how the distribution of labor across formal and informal sectors is impacted by the structure of a country's pension scheme and the welfare implications of alternative pension system arrangements in economies with large informal labor markets. How does the design of the pension system impact workers' decisions to work in the formal versus the informal sector? In particular, how important is the pension system design for the overall size of the informal sector? What are the welfare implications of alternative pension systems designs? Expanding on these questions, I evaluate the consequences of various pension system designs for workers' sector choices, the composition of the labor force, and welfare.

To answer these questions, I use Peru as a case study because it is representative of other developing economies in significant ways. First, Peru's economy has high levels of labor informality, more than 60% of the labor force in the country is informal. Second, formal workers in Peru must choose between the two most widespread types of contributory pension systems: individual-account (defined-contributions) and pay-as-you-go (defined-benefits). Finally, like many

[1] If I exclude the agricultural sector, the estimated informal employment still represents 50% of the global labor force (ILO, 2018).

countries facing similar challenges, Peru's pension design attempts to address the reduced coverage of the contributory system by including a non-contributory pension targeted to elderly people living in poverty. The non-contributory pension is means-tested and financed from the government's general budget. However, unlike the contributory pension, it is available to anyone who meets the means-test regardless of their past labor market status.

To quantify the impact of the pension system on a worker's decision between a formal or informal job, I build a heterogeneous agent life-cycle overlapping generations (OLG) model in which informal labor is endogenously determined by workers each period. In my model, an individual chooses between working as a formal worker, an informal worker, or informal self-employed. Each sector has its own earning process and probabilities of job offer arrivals that increase with education. Informality is divided into two categories—informal workers and informal self-employed—to account for the different motivations in job choice and job rationing dynamics observed in the informal labor market. This feature of the model allows me to capture the impact of changing the design of the pension system on informal workers with comparable formal jobs and on self-employed workers who do not find formal jobs attractive initially. In the benchmark model, only formal workers pay incomes taxes and make contributions to the pension system. In the mandatory contributory pension system, formal workers choose between enrolling in either an individual-account system or a pay-as-you-go (PAYG) system. Additionally, the government provides a means-tested non-contributory pension for all qualifying poor elderly individuals, which acts as a consumption floor. Thus, the model can be used to evaluate the labor market implications of contributory pension systems in economies where both types of contributory system are available as well as in economies where PAYG is the only system or where an individual-account system is the only option. The model also allows me to examine the effect of a complementary non-contributory pension.

With this setup, I introduce a two-asset economy similar to that of Kaplan et al. (2014). Workers in all sectors can save in liquid assets and workers in the formal sector contribute to an illiquid asset, their future pensions. Contributions are mandatory for workers in formal jobs, which imposes a liquidity constraint during the working period. Mandatory contributions for retirement seek to insure workers against longevity risk at the expense of reducing current consumption and liquid precautionary savings. However, for some workers, the constraint these contributions impose on their consumption and liquid savings is binding and they will be better-off in an informal job.

I discipline the model by incorporating detailed features of the Peruvian pen-

sion system design and targeting key labor market moments for the Peruvian economy estimated from two waves of 5-year panels, 2011–2015 and 2014–2018, from the Peruvian Household National Survey-ENAHO (INEI, 2018). First, I identify informal and formal labor in the data using observations on workers' contribution to the pension system. I estimate annual transition probabilities for workers between formal jobs, informal jobs and self-employment, and elaborate workers' weighted-average transition matrix for each education level. I use a panel data regression to estimate the earning process for formal, informal and self-employed individuals. Correlated earnings shocks by sectors are obtained from previous literature estimates for Chile. The model also includes main features from the Peruvian pension system design, such as contribution requirements or payroll tax. For the individual-account system it incorporates average fees and returns; and for the PAYG system, minimum and maximum pension values, replacement rates, and minimum number of contributions to received a benefits. The parameters use to model the pension system are obtain from the legislation and data for the period of study (2011–2018).

I calibrate the model to match the workers' transition matrix between these sectors for each education level, as well as the proportion of workers in each sector by education. These two sets of moments, transition matrix and distribution of the labor force, are determined simultaneously in the model. In addition, I match moments corresponding to retirement behavior, such as the percentage of elderly individuals working and the proportion receiving a non-contributory pension. While, the mortality risk faced by individuals with age 65 and above is calculated from the Peruvian mortality tables. Finally, real interest rates for liquid and illiquid assets are calculated from historic averages for Peru and the discount factor is calibrated to match the capital-output ratio of the country. Workers are organized in three education levels with weights to match the distribution in the data. Meanwhile, workers' initial wealth distribution is obtained from the US wealth distribution estimates for individuals under 31 years. The calibration results show that the benchmark model does well matching the distribution of workers according to the pension system and income ratios between sectors.

The findings of this paper are organized in two parts. The first part, explores the implications of removing the contributory pension system entirely. The second part compares the implications of having only a PAYG contributory system versus only an individual-account system.

I find that when I remove the contributory pension system, the percentage of workers choosing formal jobs increases. Without any contributory system, the

percentage of formal workers in the economy increases in $3.5pp$, going from 33.2% to 36.7% of the workers, in partial equilibrium. In general equilibrium, formality increases slightly less ($3.3pp$) and the fraction of workers in the formal sector is 36.5% The impact differs by education level, as workers with higher education levels have a higher probability of receiving a formal job offer. The proportion of formal workers with more than high school education increase in $5.5pp$, going from 44.0% to 49.5% of workers from this educational group. While for workers with less than high school education,the least educated group, the increase in formality rate is $1pp$, going from 24.3% to 25.3% of the workers.

Considering both defined-benefit and defined-contribution systems, regardless of the design, contributory pensions generate disincentives to take formal jobs in an economy with a significant informal labor market. Contributing a percentage of your income to a pension system is not optimal for all workers, and some prefer informal jobs over higher-paying formal jobs in order to avoid contributions and keep more liquid income. Without a contributory pension system, a higher number of workers rely on non-contributory social pensions, going from 20% of all elderly individuals to 49% when the contributory system is removed, putting pressure on the government budget. However, in general equilibrium the increased number of formal workers widens the taxable base, boosting government income. These two off-setting effects lead to minimal tax adjustments to keep the budget balanced, average income tax goes from 15.0% to 15.85%. Resulting in higher formality and welfare gains in general equilibrium. Removing the contributory system leads to an increase of 3.8% in lifetime-consumption in average. For workers with more than high school education, consumption increases 5.2% when mandatory contributions are removed because, in average, they spend more time in formal jobs. Meanwhile, workers with less than high school education see a smaller increase, 2.6% of their lifetime-consumption.

I also show that the non-contributory pension system has limited distortionary effect on the labor composition. When the contributory system is removed and the non-contributory pension is kept the same, 20% of the elderly population, the effect on the formality rate is similar to the previous partial equilibrium results. Formality increase $3.6pp$ or the proportion of formal workers goes from 33.2% to 36.8%. I demonstrate that, in an economy with informal labor, a pension system that solely relays in non-contributory means-tested social pensions is welfare improving.

Second, the disincentive effects to work in the formal sector are smallest when the contributory system consists of only a PAYG program. The proportion of formal workers increase in $3.1pp$, with formality rates of 36.3%, in comparison

to the benchmark economy with both systems that has formality rates at 33.2%. Compared to the case when the economy only has an individual-accounts program, where formal workers represent 32.4% of the labor force, the increase is 3.9 *pp*. In partial equilibrium, a PAYG-only system has two opposite effects on formality. On the one hand, because it has a minimum pension benefit guarantee, it makes formality relatively less costly for low-income workers. In addition, benefits are only available if contributions are made for a minimum number of years which increase the incentive to keep working in the formal sector. On the other hand, pension benefits are capped at a maximum, discouraging high-income workers from working in the formal sector. The net effect on the government consolidated budget of having only a PAYG system, as opposed to only individual-account (defined-contribution) or both systems, is positive. Payroll taxes are collected from all formal workers, while pensions paid are capped at a maximum and restricted to individuals that reached the minimum years of contribution. In general equilibrium, the government reduces income tax which further increases the attractiveness of formal jobs, resulting in higher formality rates and welfare gains for all workers. In general equilibrium, a PAYG-only economy increases 2.2% lifetime consumption in comparison to the benchmark economy with two parallel system, while an economy with only an individual-account system reduces lifetime consumption in 0.8% in comparison to the benchmark.

The main contribution of this paper comes from understanding the liquidity mechanism and quantifying the impact that mandatory pension contributions generate in the workers' formality decisions and welfare. Previous studies have focused on other variables such as income taxes (De Paula and Scheinkman, 2010) and unemployment insurance (Cirelli et al., 2021) (Bosch and Esteban-Pretel, 2015), that are additional factors affecting why people might choose to work in one sector over the other.

My research belongs to the streams of literature regarding informal labor market decisions and social security systems. First, this study adds to the recent literature that uses models informality as a function of workers' decisions over consumption, savings and contributions to a pension system. A recent study by McKiernan (2021) shows the effects of going from a PAYG to an individual accounts system in labor markets with informality, finding long-run welfare gains from the privatization of the system in Chile. However, her results also reveal that the PAYG payroll tax is less distortionary in a labor market with informality, thereby reducing the welfare gains from the reform. In contrast to McKiernan, my results suggest that both systems, public PAYG and private individual-account system, create distortions in the labor market by only imposing contributions toward retirement on formal workers. To capture the impact of an individual-

account system on the labor market, I use a two-asset approach that accounts for contributions to the private pension system as savings toward an illiquid asset. In a study more closely aligned to mine, Joubert (2015) models households' decisions in the Chilean individual-account pension system. Joubert shows that increasing the contribution rate encourages informality and increases the size of the informal sector. My paper expands on this framework with a general equilibrium analysis of the effects of contributory systems in an informal economy and distinguish effects between economies with only an individual-account system, only-PAYG, or a combination of the two. Tkhir (2021) studies the Brazilian social security system and evaluates the effect of different reforms to reduce the deficit. Similar to my results, she finds that changes in the social security have an effect on formality rates, that affect the size of the government's taxable base; therefore, taxes are readjusted amplifying the impact of potential pension reforms over formality.

Other frameworks seeking to explain the informal sector focus on firms' choices. Meghir et al. (2015), Ulyssea (2010) and Bosch and Esteban-Pretel (2012), modelling Brazil's informal sector, find that a firm's formal entry cost and government enforcement are leading informality factors. Almeida and Carneiro (2012) find that for lower-paid jobs, enforcement of labor regulations evidenced by more inspections might make formal benefits, like minimum wage, attractive. Amaral and Quintin (2006) explore the relevance of access to outside financing, and Sarte (2000) models the effect of bureaucracies' costs generated by rent-seeking officials on firms' decisions. However, Galiani and Weinschelbaum (2012) argue that the informal sector should be modelled as stemming from both households *and* firms making decisions about labor. I do not model firms' decisions but instead incorporate labor demand with exogenous job probabilities to capture the potential effects of these factors on job rationing.

This study also contributes to the understanding of social security systems. The privatization of the Social Security in the US has been evaluated, with studies finding evidence of long-run welfare gains (Fuster et al., 2007) (Feldstein, 1995). Other studies suggest that those results are contingent on factors like the openness of the economy, the annuity market, matching programs, and idiosyncratic earning risks, among others (Nishiyama and Smetters, 2007). Evaluations of Latin American economies where pension reforms have already taken place have mainly focus on the Chilean privatization. Some tentative promoters of the fully funded system looked into potential gains in overall savings and economic growth (Corsetti and Schmidt-Hebbel, 1997), and increase in formality (Holzmann, 1997), that the current data contests. This paper adds to the literature with a welfare analysis and comparisons between an individual-account system,

a PAYG system or no contributory system at all, in the context of high informality. I show that an economy without a pension system based on contributions is welfare improving and boosts formality.

Following the mainstream literature on social security systems, this paper shows that contributions to the PAYG system are perceived by workers as a "tax" affecting their liquidity constrain. This results in a distortion in the workers' allocation of consumption over the life cycle (İmrohoroğlu et al., 1995). Furthermore, I show that this distortionary effect is also present in individual-account systems and the extend of the distortion is not only restrained to consumption allocation but also formal/informal sector choice along the life-cycle for workers in economies with informal labor markets. Finally, similar to findings in Braun et al. (2017) for the US, I find welfare benefits from removing contributions to social security and sustaining a means-tested social insurance programs for the old. This paper shows that, additionally, in economies with large informal labor, formality rates increase enhancing the welfare gains of removing contributions to the pension system.

The paper is organized as follows. Section 2 presents some facts for the Peruvian labor market. Section 3 covers the different pension system designs and discusses their impact on workers' decisions. Section 4 describes the model. Section 5 shows estimation and calibration details. Section 6 presents the result and Section 7 concludes.

2 Case study of Peru

Peru provides an ideal case study of a country with high informality levels, estimated to account for 66% of the labor force, and a pension system design with contributory and non-contributory features. Peru is located in Latin America and has had an average real GDP growth rate of 4.5% from 2010 to 2019 and a population growth of 1.2% on average over the same period (BCRP, 2021).

2.1 The data

My case study uses two types of data from the Peruvian National Household Survey (ENAHO), collected by the Peruvian National Statistics Institution (INEI, 2018), to examine trends and empirical facts about the Peruvian labor market and pension system. The first data set comprises quarterly survey results from

2011 to 2017 weighted to create nationally representative estimates.[2] In addition, to estimate the evolution of critical variables in the model, I use two waves of five-year panel survey results, where the first wave covers the years 2011 to 2015 and the second wave follows individuals from 2014 to 2018.

Estimations and analysis of the workforce focus on the subsample of workers in the 20–65 age range because Peru's legal retirement age is 65. The employed workforce represents approximately 70% of the total population in my datasets, and 90% of those employed are in the 20–65 age range.

To identify formal and informal workers in the data, I use a binary variable that takes the value of 1 if the employed worker contributed to a pension system (individual-account or PAYG) in the previous or current month when the survey was taken. The variable takes the value of zero if no contribution was made, my definition of an informal worker. Workers differ in some key characteristics depending on their formality status. Formal workers, on average, are more highly educated, earn higher income, and work more hours per week. These associations are not surprising: Having more education increases the likelihood of getting a higher-paying job, leading to higher income. The informal labor force includes larger proportions of self-employed and female workers.

Informal workers can be categorized according to the type of job between non-agricultural labor and agricultural labor. This distinction is usually made due to the lack of formal jobs in agriculture. In Peru, 97% of agricultural workers are classified as informal, accounting for 25.7% of all informal workers. Agricultural work is typically in rural areas where there are fewer formal jobs offered and lower access to financial institutions. To understand workers' behavior and decisions in markets with informality, my analyses focus on non-agricultural labor. The main occupations in the non-agricultural informal sector are commerce, transportation, and sales.

2.2 Labor Market Facts

This section provides an overview of the Peruvian labor market for non-agricultural male workers. Prior studies have found that workers voluntarily enter the informal labor force, which is not generally considered to be inferior to the formal workforce (Maloney, 2004; Bosch and Maloney, 2010). The informal sector is

[2]The total number of individual observations is 576,066 across 28 quarterly periods; savings behavior data are only available from 2015 (12 quarters).

primarily made up of two types of workers: some work for firms and others are self-employed. The self-employed group is usually incorporated to the informal labor analysis as it is a highly unregulated segment of the workforce that avoids making pension contributions. More highly educated workers are concentrated in formal jobs, as shown in Table 1. Ilater show that formal jobs are able to attract more productive workers by providing a wage premium compared to the tax-free and contribution-free informal wage.

Table 1: Employed labor force distribution by education

Status	All	Less than high school	High school completed	More than high school
Formal worker	0.334	0.244	0.305	0.446
	(0.004)	(0.006)	(0.007)	(0.007)
Informal worker	0.350	0.384	0.359	0.308
	(0.004)	(0.007)	(0.007)	(0.007)
Informal self-employed	0.316	0.372	0.336	0.246
	(0.004)	(0.007)	(0.007)	(0.006)

Note: This table shows the weighted average participation by sector across education. Data come from the ENAHO panel survey INEI (2018). The sample comprises male workers 20–64 years old with non-agricultural jobs. Waves correspond to the years 2011–2015 and 2014–2018. Robust standard errors are shown in parentheses.

The prior literature offers evidence of two distinct types of informal labor: informal workers for a firm and informal self-employed. Perry et al. (2007) find that informal self-employed earn more, value flexibility more, and express greater satisfaction than they would get working for a firm. Maloney (2004) shows that the majority of entrepreneurs in Brazil and Mexico do not want a formal job. Earle and Sakova (2000) evaluate a set of transitional economies and find that self-employed workers have different characteristics than employees and that some may self-select into self-employment due to their comparative advantage as entrepreneurs. However, others may end up self-employed due to lack of opportunities. Informal employees at firms have different motivations for entering the informal labor market than do the self-employed. Some informal workers are looking for opportunities to transition into a similar formal job (García and Badillo, 2018). Young workers may take informal jobs to gain experience and test qualifications (Perry et al., 2007). Consequently, informal work can be understood as an screening mechanism to prove their skills (Cano-Urbina, 2015).

Using quarterly survey data (ENAHO) from 2011 to 2017, Ifind results consistent with findings in the literature (Pagés and Stampini, 2009): Informal jobs pay, on average, lower wages than formal jobs. Table 2 shows that this pattern holds across education levels and for the two types of informal employment. In addition, both types of informal labor have similar average earnings.

Table 2: Average real monthly income by type of worker

Education level	Formal worker	Informal worker	Informal self-employed
Less than high school			
Average real income	7.06	6.58	6.57
	(0.01)	*(0.01)*	*(0.01)*
High school completed			
Average real income	7.14	6.70	6.80
	(0.01)	*(0.01)*	*(0.01)*
More than high school			
Average real income	7.51	6.86	6.87
	(0.01)	*(0.01)*	*(0.01)*

Note: Bootstrapped standard errors are shown in parentheses. This table shows average real monthly log income before taxes and deductions for non-agricultural males between 20 to 64 years old. Data are from ENAHO weighted quarterly survey from 2011 to 2017 (INEI, 2018).

Even given this wage premium in formal jobs, informal jobs are still competitive for some groups of workers. Figure A.1 in the appendix shows the income distribution for formal and informal workers, excluding the self-employed. Both sets of workers are employees, and I see significant overlap in their income distribution. This overlap provides preliminary evidence of the presence of parallel labor markets with incentives and gains beyond just earnings. This finding is in line with prior research, which has found evidence of small or no wage premium for the formal sector in other Latin American countries (Pratap and Quintin, 2006).

Figure A.1 also shows that the distribution of informal wages has wider ends, indicating that the informal workforce have a higher variance in earning and contains a larger percentage of workers with very low earnings. This finding is not surprising as there is no minimum wage requirement for these jobs. In contrast, in the more regulated formal sector, employers must abide by federal minimum wage laws. Nevertheless, Boeri et al. (2011) show that in Brazil, changes in the

formal minimum wage translate to changes in wages in the informal sector as well. This link between sectors' earnings, called the "lighthouse" effect, keeps the wage differential between sectors contained and can make an informal job competitive with formal employment. The overlapping income distribution supports the understanding of the informal sector as a sector attractive for a group of workers (Maloney, 2004). For example, Oviedo et al. (2009) finds that in countries where the benefits that require a contribution from a formal wage are low perceived, a formal job does not have a clear advantage . Furthermore, the gains from the informal sector are not always monetary in nature. Packard (2007) cites factors such as moral hazard, a preference for present consumption, or favoring other types of savings as some reasons workers may want to avoid contributions and take informal jobs.

The different nature of the sectors and how they relate to one another can also be seen in how workers transition between these three types of work. Table 3 summarizes the annual transition probabilities between sectors. Across education levels, informal workers and the informal self-employed have distinctive probabilities of transitioning to formal jobs. The lower probabilities of moving from self-employment to a formal job are consistent with the estimates for Argentina, Brazil, and Mexico by Bosch and Maloney (2010) and reinforce the decision to separate informal labor into two types that exhibit different behaviors. Some informal workers are gaining experience and skills that will allow them to transition to a formal job when the opportunity arises. For self-employed individuals, the investment required (either on capital or abilities) makes transitioning out of the sector less attractive. Additionally, without a risk of getting fire, individuals who are self-employed have a higher level of stability in their activities.

Table 3: Peruvian transition matrix between sectors by education

Less than high school education

Currently \ Previously	Formal	Informal	Self-employed
Formal worker	0.79	0.16	0.03
Informal worker	0.15	0.63	0.16
Informal self-employed	0.05	0.21	0.80

High school education

Currently \ Previously	Formal	Informal	Self-employed
Formal worker	0.82	0.20	0.04
Informal worker	0.14	0.62	0.15
Informal self-employed	0.04	0.18	0.82

More than high school education

Currently \ Previously	Formal	Informal	Self-employed
Formal worker	0.86	0.27	0.06
Informal worker	0.10	0.53	0.17
Informal self-employed	0.04	0.19	0.77

Note: Workers' average annual probability of transitioning between sectors by education level, estimated from ENAHO panel survey 2011–2015 and 2014–2018 INEI (2018) for a weighted sample of male workers ages 20–64 in non-agricultural jobs.

2.3 Retirement Facts

When faced with a limited social protection system and a risk of meager pension, some individuals choose to work beyond retirement age. In Peru, workers are eligible for retirement at 65 years old, but it is common for retirees to continue working as informal workers. In Table 4, I follow the status of workers in five-year cohorts after reaching retirement age. As workers continue to age, those who were part of the formal labor force show the most significant change in behavior after turning 65. Whereas workers who were employed in the informal sector gradually transition into retirement, formal workers rapidly transition to informal positions or leave the labor force entirely. For this latter group of workers, if their savings and now-accessible pension generates an adequate income, they may choose to

retire. For formal workers with smaller or insufficient pension benefits, an informal job offers additional liquid income to complement their pension benefits.

Table 4: Occupation of workers age 65+, by age group

Age cohort	Nonworking	Formal	Informal	Self-employed
Overall	0.584	0.053	0.135	0.228
	(0.009)	(0.004)	(0.007)	(0.008)
65–69	0.358	0.124	0.196	0.322
	(0.016)	(0.011)	(0.013)	(0.016)
70–74	0.544	0.032	0.153	0.271
	(0.019)	(0.007)	(0.014)	(0.016)
75–79	0.680	0.013	0.131	0.176
	(0.021)	(0.004)	(0.016)	(0.017)
80 or more	0.867	0.007	0.032	0.094
	(0.012)	(0.003)	(0.006)	(0.011)

Notes: This table shows weighted averages from ENAHO panel survey INEI (2018) for a sample of male retirees from the non-agricultural sector. Waves correspond to years 2011–2015 and 2014–2018. Robust standard errors are shown in parentheses.

Table 5 shows that the probability of transitioning between sectors diminishes with age. Furthermore, the majority of the changes reflect older workers leaving the labor force. Individuals over 64 years old who are not working are unlikely to return to work. For the 65–69 age cohort, the probability of going back to work during the next period is 13.6%, dropping to 7.9% for the 70–74 age cohort. As expected, these probabilities decrease rapidly with age.

Table 5: Probability of changing work status after retirement age

Age cohort	For nonworking individuals Prob. of working	For all individuals Prob. of changing status
65–69	13.6%	35.1%
70–74	7.9%	30.4%
75–79	6.6%	26.6%
80 or more	2.3%	18.2%

Note: This table shows the probability of changing status in the next period conditioned on previous working status for elderly workers organized in 5-year cohorts. The weighed averages from ENAHO panel survey data INEI (2018), 2011–2015 and 2014–2018.

3 Pension System Design

The literature generally defines workers as informal if they are not covered or are insufficiently covered by formal arrangements, i.e., contracts, benefits, or social protection policies (OECD and ILO, 2019). In this study, I identify workers' formality status based on their contributions to a pension system. The design of the pension system determines the extend of this definition; however, it also affects the worker's current formality choice, introducing forward-looking variables into the decision and budget constraint. To shed light on the mechanisms impacting the formality decision, I first describe the pension system schemes I use in the case study to later expose the channels. The Peruvian system works with two parallel schemes, serving as a baseline to study the impact of the two most popular pension designs in Latin America on informal labor.

3.1 Peruvian Pension System

In the Peruvian pension system, formal workers make mandatory contributions. All salaried workers have to contribute a percentage of their monthly salary for retirement. Because enforcement of a mandatory savings policy is only possible in formal salaried jobs, coverage is restricted to formal workers. These workers can choose from two available pension schemes. The first is a defined-benefit or pay-as-you-go (PAYG) pension plan that is managed by a public entity following the previous social security system. The second is an individual-account or defined-contribution plan that is managed by private managers. Workers make a one-time decision to enroll in either the PAYG or individual-account pension system when they begin their first formal job, [3] but the default option is the individual-account system.

Both types of system are popular and found in many countries around the world; however, few settings have both mandatory schemes working in parallel or competing for participants, a scheme that is particular to some countries in the Latin American region. This distinctive characteristic of the Peruvian pension system allows us to examine how each pension scheme behaves in an economy with a sizable informal labor force.

In the PAYG pension system, younger generations finance the pensions of the older generations. In 2020, 38% of the affiliates to the pension system were enrolled in the PAYG system, and only 45% made contributions that year. Workers are required to make mandatory monthly contributions of 13% of their salary,

[3] A worker who initially chooses the PAYG system can later decide to transfer to the defined-contributions system, but the reverse is not possible.

and they pay no management fee. To have access to a pension, the worker must reach the retirement age of 65 and have contributed for at least 20 years. The pension is defined as a 40% replacement rate based on the average of the worker's salary over the last five years of employment. This system provides a minimum pension benefit as well as a maximum.

The second option is to contribute to the individual-account system, where the pension is a function of the worker's monthly contributions to an individual account. Here, 10% of the worker's salary is deposited into his or her individual retirement account. In addition to this contribution, the worker has to pay a management commission to the fund administrator as well as an extra fee of 1.5% to the insurance company. The worker chooses a private fund manager to invest their accumulated savings in financial markets. The fund manager can be changed at any time and without cost; however, currently there are only four pension fund administrators or AFPs (acronym in Spanish). At age 65, the workers gain access to their pension savings and must choose one of three alternatives: to receive a monthly pension as a scheduled withdrawal from their individual account, to buy an annuity, or to withdraw the 95.5% of their pension fund.[4] One characteristic that impacts the attractiveness of this system, especially for lower-income workers, is the lack of a minimum guaranteed pension. In the defined-contribution system, the pension level is a function of the worker's lifetime salary and financial market returns. The annualized real return rate was 4.5% on average from January 2015 to December 2020.[5]

Contributing to the system is optional for self-employed and informal workers, the largest sector of the workforce. Consequently, only a small portion of the age 65+ population is covered by either of the two contributory plans. Table 6 summarizes the current coverage rate of the system and shows that more than half of the population age 65+ is not receiving a pension or monetary transfer from any system.

[4]Since May 2016, new retirees can withdraw up to 95.5% of their fund. In December 2019, 115 new retirees accessed a monthly pension. That same month, 6,418 individuals withdrew up to 95.5% of their individual accounts (Super Intendencia de Banca, 2018).

[5]The average real rate from the individual-account system over the period January 2015–December 2020 for Fund type 2, the most popular type of retirement fund with 91% of the affiliates.

Table 6: Peruvian labor force and retiree coverage rates by pension scheme

Pension scheme	Contributory		Non-contributory	
	individual-account	PAYG	Pension 65	None
Labor force	19%	10%		71%
Adults over 65	6%	20%	20%	54%

Note: Percentage using 2019 estimates. Excludes Army Force pensions and retirees with withdrawals of 95.5% of their pension fund.
Source: SBS (2020), Midis (2020), INEI (2020)

The need to extend pension coverage to a larger portion of the elderly population has driven reforms in several countries. In Latin America, the most popular means of extending coverage has been to implement non-contributory pensions, with at least 15 countries in the region introducing such programs (Bando et al., 2020). In 2012, Peru added *Pensión 65*, a non-contributory pension scheme that works as a mean-tested social program. It focused on people of retirement age who were living in extreme poverty, providing them with a monetary pension transfer and free access to the Integral Health Insurance Program (MIDIS, 2021). The program extended pension coverage to another 20% of the population older than 65 years; however, the benefit is only 27% of the minimum wage (about US$ 70), paid out once every 2 months.

3.2 Pension System Channels

Each pension system design introduces different incentives that affect a worker's decision of whether to pursue an informal or formal job as well as the overall size of the informal labor market. This study explores the different mechanisms and impacts of these interactions in the three most extended types of pension schemes: individual-account, PAYG, and a non-contributory social pension.

3.2.1 Individual-account system (defined-contributions)

Every period, workers have to contribute a minimum percentage of their labor income toward their retirement. The accumulated retirement savings are high-return assets; however, they are only available to the worker once she reaches the retirement age. Thus, following Kaplan et al. (2018), workers under an individual-account system hold retirement savings as illiquid assets.[6] The mandatory con-

[6]This definition of illiquid assets assumes that the transaction cost for withdrawing from retirement accounts during working periods is high enough to preclude any household access

tribution of income toward an illiquid asset is not optimal for *all* households. For low-income households, a minimum contribution toward retirement savings reduces disposable income, negatively affecting the worker's utility. Households that are income-constrained would prefer a job in the informal sector with the risk of lower salaries but potentially higher disposable income each period.

Furthermore, a formal job with mandatory contributions toward an illiquid asset also imposes a binding liquidity constraint for workers that initially took a formal job. For example, workers that accumulated significant levels of illiquid assets but are subject to negative income shocks would rather take an informal job in the next period to avoid making further contributions and hold more precautionary liquid savings instead.

Individual retirement accounts keep accumulating returns, even if the worker does not actively contribute. This feature benefits workers that transitioned to informal jobs and makes the informal sector more attractive for workers enrolled in this type of pension system.

Lastly, accumulating enough retirement savings to achieve an attractive pension is difficult for low-productivity workers. First, the contributions are proportionate to their income level; thus, a low-income worker would correspondingly receive a small pension. Second, a low-productivity worker has a lower probability of keeping and finding a formal job, making contributions to their individual account sporadic. Smaller and less frequent contributions translate into meager pensions for some workers in an individual account system. In the presence of labor informality and without a minimum pension guarantee, an individual accounts system might fail to insure all enrolled workers. On the other hand, highly productive, high-income workers would prefer to take advantage of the larger salaries offered in the formal labor market and the higher returns on their retirement savings. For these workers with a nonbinding liquidity constraint in a formal job, a pension system with individual accounts is an attractive feature of the formal sector.

3.2.2 PAYG (defined-benefits)

Workers enrolled in a PAYG pension system are also subject to a liquidity constraint and face the same trade-offs as those in an individual-account system. Nevertheless, the pension is not proportionate to their contributions. The pri-

to these funds before retirement.

mary requirement for collecting a pension in this system is contributing for a minimum number of years. This requirement deters workers from taking informal jobs before reaching that minimum, independent of income level. This system has a minimum pension, which benefits low-income workers; however, the chance of getting no pension at all is still higher for low-productivity workers. With a lower probability of getting a formal job offer or keeping a formal job, these workers have a higher risk of not meeting the minimum contributions requirement by the end of their working life and therefore not receiving a pension.

High-productivity workers face a different trade-off to holding formal employment under a PAYG system. In this case, the existence of a maximum pension level will discourage high-income workers from contributing because they could save more assets to be used during retirement if they work in an informal job.

3.2.3 Non-contributory pension (social pension)

To qualify for the non-contributory pension, people must not be receiving other types of contributory pensions and must be living under a wealth threshold. Workers enrolled in an individual account system will not qualify, but workers enrolled in the PAYG system who did not meet the minimum contributions requirements before retiring do qualify. In other words, the social pension not only provides a minimum pension to elderly people at risk of poverty but also provides a safety net for low-productivity workers who work for short periods in formal jobs. Having a non-contributory pension makes the PAYG system a more attractive option for low-income workers and workers with a low probability of keeping a formal job.

Additionally, a non-contributory pension also provides the protection of a pension for all informal workers that qualify for this means-tested pension. This program creates incentives to keep an informal job and reduces participation in the formal system (Attanasio et al., 2011). The impact of this effect is expected to be small given that many of the workers that could qualify for the non-contributory pension would not optimally take a formal job in the first place. That is because low-income workers are income and liquidity constrained and have a higher risk of separation from a formal job, reasons that make a formal job offer less attractive.

Finally, non-contributory pensions are financed from the general budget. Then, any modification to the non-contributory pension program will have unintended effect over taxes, that will only affect workers on formal jobs. For example, an expansion of this program (either in level of the transfer or number of people

receiving the social pension) would lead to an increase in government expenses resulting in a higher income tax rate. This would tighten the liquidity constraint and make formal jobs less attractive.

4 The Model

This section presents a model incorporating the mechanisms affecting decisions over formality. The framework is an extended Roy Model that allows for endogenous formality/informality choices each period. The economy follows the two-asset approach from Kaplan et al. (2014) in an overlapping generations model with an incomplete market and a contributory pension system.

4.1 Model Description

Demographics.— The economy is occupied by a continuum of households that are heterogeneous in education level e, entrepreneurial ability θ, and age, indexed by $t = 1, 2, ..., T$. There is no population growth, and the initial number of households n is normalized to sum to one. Households have two stages in their life: young and old. Young households are composed of working individuals with ages from $t = 1, 2, ..., R-1$. Old households comprise individuals eligible to retire with age range $t = R, ..., T$ and subject to a mortality risk Γ_t.

Timing.— The time in the model is annually.

Preferences.— Households exhibit CRRA preferences over consumption c_t, with risk aversion parameter $\gamma > 0$, and $\beta \in (0, 1)$ as the discount factor.

Assets.— Household can hold liquid assets a_t and illiquid assets in the form of pension fund $\tilde{Y}_t$ if they are enrolled in the individual accounts scheme. The return for liquid assets is given by the interest rate r and can differ by sector. Meanwhile, the pension funds accumulate with a return given by the parameter ϱ. Illiquid assets yield a higher return but are only available at the end of one's working life in the form of a pension. Returns are exogenous in the model, and borrowing is not allow.

Pension system.— The economy has contributory pension systems. Only formal workers have to contribute a percentage of their salary into the system. Benefits from the pension systems are accessible at retirement age R. Workers make a one-time decision to enroll in one of the two competing parallel pension

schemes: pay-as-you-go or individual-account.

In the *individual-account* or defined-contribution system $p = 1$, workers must contribute a percentage $\bar{x}_1$ of their income into their individual retirement account $\tilde{Y}_t$. The individual retirement fund is managed by private managers that receive a management fee paid by the formal worker. The fee is calculated as a percentage of the formal worker's income η. The individual account $\tilde{Y}_t$ accumulates returns at an effective rate ρ each period, independent of the individual's labor status. Workers in this individual-account system receive a pension in the form of an annuity calculated over the level of their individual retirement savings account $\tilde{Y}_R$ at the age of retirement and mortality probabilities Γ_t.

In the *PAYG* or defined-benefits system $p = 2$, workers must contribute a percentage $\bar{x}_2$ of their income to the system. Because the PAYG system is a public system, the management fee is zero; however, access to pension benefits is conditional on a minimum number of years contributing to the system set for all workers as z_{min}.The pension is calculated with a replacement rate μ over the average income of the last five working periods in the formal sector but is subject to minimum and maximum values. However, if the required years of contribution are not reached, the workers receive zero benefits.

The economy also presents a *non-contributory pension* or social pension that provides a monetary transfer $\bar{c}$ to guarantee a minimum level of consumption to the elderly. The social pension runs as a means-tested government program targeting older adults with zero pension and assets a below a wealth threshold M.

Labor market.— The labor market has three types of workers: formal workers, informal workers, and informal self-employed workers; each works in their corresponding sector, indexed by $j = \{f, i, s\}$, respectively. All workers enter the labor market as informal workers in period $t = 1$.The labor demand has degrees of job rationing by education to characterize the different risks each group faces in labor markets with informality. The worker's probability of finding or keeping a formal job $\gamma^f(j, e)$ or an informal job $\gamma^i(j, e)$ is less than one, exogenous, and specific to their current sector j_t and education level e. A separation from a job leads to unemployment and sends the worker to their next informal job.

Given the annual timing of the model, unemployment is added to the model as an exogenous cost $\nu_{e,j}$ that varies with education level e and sector j and reduces the worker's utility during the period of the separation.

Earnings process.— Every working period, individuals employed by a firm

earn wages $y^j = w\ \Omega^j(t, e, l, \varepsilon^j)$ according to their sector status j. The first term reflects the wage per efficiency unit of labor services, w, independent of the worker's sector j. The second term corresponds to the efficiency unit of labor worked, contemplated in function $\Omega^j(.)$, that varies according to the worker sector j and depends on the worker's age t, education e, sector experience (previous status) l, and a sector-dependent stochastic component ε^j. Individuals in formal jobs $j = f$ reach higher efficiency units of labor than those preforming informal jobs $j = i$.

Self-employed households have earnings based on $y^s = \theta k^\alpha\ \Omega^s(t, e, l, \varepsilon^i)$. This measure includes a production function that originates from their capacity to use assets, k, according to their ability θ[7] and the production parameter $\alpha \in (0, 1)$ and a deterministic earning process. Entrepreneurial ability is exogenously given and known by all at the beginning of their life. Higher ability corresponds to higher average and marginal returns from capital.

Uncertainty.— Individuals face two types of risk during their life. While working, they are subject to earnings uncertainty, and upon retirement age, they face survival uncertainty.

Earnings risk exists in all income processes as a sector-dependent stochastic shock ε^j that obeys a first-order autoregressive process and is correlated by sector. Shocks in the formal sector $j = f$ affect formal workers' income, and shocks in the informal sector $j = i$ affect income processes for informal workers and informal self-employed individuals. The earnings shock ε^j follows an age-invariant Markov process known to the individual with transition probability $\pi(\varepsilon^{j\prime}|\varepsilon^f, \varepsilon^i)$, which depends on previous formal and informal productivity shocks ε^j and ε^i. Newborn individuals draw income shocks for each sector simultaneously from an initial multivariate normal distribution.

Survival risk only depends on a person's age and is specified by the mortality probabilities. The likelihood that an individual of age t survives to age $t + 1$ is Γ_t if $t \geq R$ and 1 if $t < R$.

4.2 The Young's Problem

Individuals are heterogeneous in entrepreneurial ability θ and education e. Both variables are fixed and known to the individual. The individual enters each pe-

[7] Cagetti and De Nardi (2006) define entrepreneurial ability θ as the individual's capacity to invest capital more or less productively.

riod with liquid assets a and accumulated retirement savings as illiquid assets $\tilde{Y}$ or years of contributions z in the PAYG system, depending on their choice of pension system p.

They start the period with a job in sector $j = \{f, i, s\}$, with job experience l, known probabilities of a job offer from each sector $\gamma^j(j, e)$ and observes current labor productivity shocks by sector ε^f and ε^i. Each individual chooses consumption c, liquid savings a', and self-employed capital k that maximizes their utility in each sector $V^j(\mathbf{s})$ based on their current state $\mathbf{s}$. The state space $\mathbf{s}$ is defined as a vector containing age-dependent variables and education e, entrepreneurial ability θ, and pension scheme p. It follows that $\mathbf{s} = (\theta, e, p, t, j, a, \tilde{Y}, z, l, \varepsilon^f, \varepsilon^i)$.

All working-age individuals choose their optimal labor sector (formal, informal, or informal self-employed) by selecting the sector that provides the highest utility. Thus, the worker's maximization problem for ages $t < R$ exhibits the next structure each period:

$$V(\mathbf{s}) = \max \{V^f(\mathbf{s}),\ V^i(\mathbf{s}),\ V^s(\mathbf{s})\}, \tag{1}$$

where $V^j(\mathbf{s})$ is the value function corresponding to the j sector.

The timing of the model for young households at each age is divided into two steps: First, workers solve each household problem by selecting the optimal liquid asset level a' and k (if self-employed) that maximizes $V^j(\mathbf{s})$; second, they solve equation (1), choosing the sector that yields greater utility at every age t.

4.2.1 Formal household problem

As noted in Levy and Schady (2013), formal workers are the ones covered by the social protection system. In the model, the social protection layout is featured in the pension system. All workers start their working life without a default pension system, $p = 0$. When they begin their first formal job, workers make a one-time decision to enroll in one of the two pension systems: the defined-contribution system (privately managed individual-account) $p = 1$, or the defined-benefit system (publicly managed PAYG) $p = 2$. The timing of this decision might be different for different workers as it depends on when they start a formal job. After this decision is made, the following value functions in the formal sector are contingent on which pension system p the worker enrolled in.

Thus, the value function for a formal worker is set based on her pension system choice p as

$$V^f(\mathbf{s}) = \mathbb{1}_{p=0}\max\big\{\mathbb{E}[\tilde{V}^f(\mathbf{s}; p = 1),\ \mathbb{E}[\tilde{V}^f(\mathbf{s}; p = 2)]\big\} + \mathbb{1}_{p\neq 0}\mathbb{E}[\tilde{V}^f(\mathbf{s}; p)].$$

Additionally, each period, workers in the formal sector receive a wage y^f and are subject to a payroll tax τ. They contribute x_p portion of their income to the pension system of their choice p. If the worker is enrolled in the defined-contribution system $p = 1$, she also has to pay a proportion η of her income as a management fee to a private fund manager. The indicator function $\mathbb{1}_{p=1}\{\eta y^f\}$ accounts for the pension fund management fee. The worker's pension fund in the next period follows the law of motion for $\tilde{Y}'$ as a function of the net return on illiquid assets ϱ and the worker's contributions that period $x_1 y^f$. Workers in the defined-benefits system $p = 2$ keep track of their active years contributing z into the PAYG public system.

With probability $\gamma^f(f, e)$, a worker in the formal sector with a given education level receives a formal job offer with the possibility of keeping the formal job or transitioning to an informal job. For tractability purposes, I simplify this decision with the assumption that given the offer from a formal job, formal workers will continue in their formal job. With probability $(1 - \gamma^f(f, e))$, the worker is separated from her formal job. Once separated, the worker starts an informal job after a period of unemployment, accounted for by a decrease in their utility of $\nu_{f,e}$.

Therefore, workers of age $t < R$ with $p = \{1, 2\}$ face the following optimization problem in the formal sector:

$$\begin{aligned}
\tilde{V}^f(\mathbf{s}) = \max_{a'} \Big\{ & u(c) + \beta \Big(\gamma^f(f,e) \left(\mathbb{E}[\tilde{V}^f(\mathbf{s}')|\varepsilon^f] \right) \\
& + (1 - \gamma^f(f,e)) \left(\mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i] - \nu_{f,e} \right) \Big) \Big\}, \qquad (2) \\
& s.t. \\
c + a' &= (1 - \tau - x_p)\, y^f - \mathbb{1}_{p=1}\{\eta y^f\} + (1 + r)\, a \\
\tilde{Y}' &= (1 + \varrho)\, \tilde{Y} + x_1 y^f \quad \text{if } p = 1 \\
z' &= z + 1 \quad \text{if } p = 2 \\
a' &\geq 0.
\end{aligned}$$

The formal sector is particularly attractive to workers with high education levels, given that this sector provides higher wages that are increasing in education. Moreover, the probability of keeping their job is also increasing with education, making the risk of being unemployed smaller for this group. Additionally, the high-income group would be less constrained and could take advantage of the individual-account pension system with higher returns over this illiquid asset.

4.2.2 Informal household problem

The informal sector pays a wage of y^i without forcing workers to pay taxes τ or make contributions to the pension system x. Even though this sector offers lower wages than the formal sector, the wages are more liquid. Moreover, workers that transition from the formal into the informal sector keep their initial enrolment decision regarding their pension system p. Thus, if the worker enrolled in the individual accounts system $p = 1$, she will continue to accumulate a return ϱ on her pension fund $\tilde{Y}$. Workers in the PAYG system $p = 2$ are not adding years of contributions z.

Informal workers receive an offer to work in the formal sector in the next period with probability $\gamma^f(i, e)$ depending on their education e. The workers choose between taking the formal job, continuing in their informal job, or transitioning into self-employment. With probability $(1 - \gamma^f(i, e))$, there is no offer from the formal sector and workers might receive an offer to continue their informal job with probability $\gamma^i(i, e)$. In this scenario, workers are able to choose between keeping their informal job or transitioning to self-employment. Workers will transition to self-employment if a job offer from the informal sector does not arrive; this happens with probability $(1 - \gamma^i(i, e))$ after experiencing a period of unemployment, reflected by a decrease in their utility $\nu_{i,e}$.

Workers in this sector maximize their utility by deciding their optimal liquid asset level in the next period, a'. It follows that the value function for a worker in the informal sector is expressed as

$$
\begin{aligned}
V^i(\mathbf{s}) = \max_{a'} \Big\{ u(c) + \beta \Big(& \gamma^f(i,e) \max \left\{ \mathbb{E}[V^f(\mathbf{s}')|\varepsilon^f], \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} \\
& + (1 - \gamma^f(i,e)) \Big[\gamma^i(i,e) \max \left\{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} \\
& + (1 - \gamma^i(i,e)) (\mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] - \nu_{i,e}) \Big] \Big) \Big\}, \qquad (3)
\end{aligned}
$$

$$
\begin{aligned}
& s.t. \\
c + a' &= y^i + (1 + r^*) a \\
\tilde{Y}' &= (1 + \varrho)\, \tilde{Y} \quad \text{if } p = 1 \\
z' &= z \quad \text{if } p = 2 \\
a' &\geq 0.
\end{aligned}
$$

The interest rate for liquid savings in the informal market is represented as r^* and might be smaller than the interest rate gain by a worker in the formal

sector, $r^* \leq r$. The access to different interest rates based on the worker's sector status introduces a new channel affecting the worker's labor market decisions. To focus on the mechanism impacting workers' decisions linked to the pension system design, for this study, I close the interest rate gap channel by assuming that the interest rate for liquid assets is the same across sectors.

4.2.3 Self-employed household problem

Self-employed workers are not subject to contributions to the pension system x, and they do not have to pay payroll taxes τ. Income is also more liquid in this sector, but the income gap between self-employment and the formal sector will now also depend on the worker's entrepreneurial ability θ. Self-employed individuals who are enrolled in the individual accounts system $p = 1$ continue to accumulate returns ϱ on their pension funds $\tilde{Y}$. However, if they are enrolled in the PAYG system $p = 2$, they are not accumulating additional years of contributions z.

Self-employed workers, with probability $\gamma^i(s, e)$, can choose between taking an informal job offer or staying in their self-employed business. With probability $(1 - \gamma^i(s, e))$, entrepreneurs will continue with their self-employed venture.

Following Evans and Jovanovic (1989), each period, self-employed individuals choose the optimal amount of liquid assets a to transform into capital k and receive an income from their entrepreneurial activities, y^s. Individuals can invest an amount proportional to their liquid wealth a each period with no transformation cost. The capital depreciates each period at a rate δ. Additionally, the entrepreneur makes a decision on how much liquid savings to hold in the next period, a'. Then, the utility-maximizing problem for the self-employed worker is expressed as follows:

$$V^s(\mathbf{s}) = \max_{a',k} \Big\{ u(c) + \beta \Big(\gamma^i(s,e) \max \left\{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i],\, \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} + (1 - \gamma^i(s,e))\, \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \Big) \Big\}, \tag{4}$$

$$
\begin{aligned}
& s.t. \\
c + a' &= y^s + (1 + r^*)(a - k) + (1 - \delta)k \\
\tilde{Y}' &= (1 + \varrho)\, \tilde{Y} \\
z' &= z \\
0 \leq & \delta \leq 1 \\
0 \leq & k \leq a \\
a' &\geq 0.
\end{aligned}
$$

Individuals have no access to borrowing. Bianchi and Bobba (2013) find evidence of a strong financial constraint to entrepreneurs using Mexico as a case study. Therefore, their capital decision is limited to the amount of liquid assets a they hold at each age t. A worker with inherent high entrepreneurial ability will need to accumulate liquid assets a in order to use her comparative advantage (entrepreneurial productivity). This creates an incentive to work as an informal worker, with the possibility of a higher liquid income by avoiding taxes and contributions, leading to greater accumulated liquid savings a.

4.3 The Old's Problem

At age $t \geq R$, the individual decides whether to exit the labor force and become a retiree with a value function of W^r or to continue working after retirement in the informal sector, expressed in the value function W^i. Hence, the individual's choice can be summarized as

$$W(\mathbf{s}) = \max \{W^r(\mathbf{s}), W^i(\mathbf{s})\}. \tag{5}$$

If an individual decides to retire completely from the labor force, she will continue with that status without the possibility of returning to the labor market in subsequent periods. In this case, $W(\mathbf{s}) = W^r(\mathbf{s})$ for all following years. In this way, retirement in the model is an absorbing state.

Once retirement age R is reached, the retiree faces a mortality risk with the probability of surviving an extra year given by Γ_t. All individuals of retirement age R or older have access to pension benefits depending on the pension system to which they contributed: a benefit b if enrolled in the PAYG system $p = 2$ or, if enrolled in the individual-account system $p = 1$, the pension is calculated with an annuity from the individual's retirement account balance $\tilde{Y}_R$.

4.3.1 Pension and transfers set-up

A person over the retirement age R might be eligible for a pension or a monetary transfer depending on the pension system design.

i. Contributory pensions: $\tilde{P}$

Individuals receive a pension corresponding to the pension system in which they enrolled and to which they contributed during their working years.

Individual-account (defined-contribution system).– Retirees who participated in the individual-account pension system $p = 1$ receive a pension in the form of an annuity. The pension is calculated as the function $\zeta(.)$, which uses the market return rate r and mortality risk Γ_t to generate an annuity weighting the individual's retirement account balance $\tilde{Y}_R$ at the legal age of retirement R. For simplicity, the function $\zeta(.)$ adopts an ordinary annuity formula or the "money's worth" calculation (Brown et al., 2000). The annuity $\tilde{P}$ provides a constant pension until the individual's last possible period T such that the expected present discounted value of the annuity equals the fund at the time of retirement

$$\tilde{Y}_R = \sum_{t=R}^{T} \frac{\tilde{P}\,\Gamma_t}{(1+r)^{t-R+1}}.$$

PAYG (defined-benefit system).– Retirees who participate in the PAYG pension system $p = 2$ need at least 20 years of contributions, $z_{min} = 20$, to access their pension. The system has a minimum, ϑ_{min}, and a maximum, ϑ_{max}, pension level independent of how much the retiree contributed during her working life. The pension benefit b is calculated based on the average wage during the last five years before retirement $\tilde{w}_R$ and an exogenous replacement rate μ, given by the following formula:

$$b = \begin{cases} 0 & \text{if } z < 20 \\ \mu\tilde{w}_R & \text{if } z = 20 \\ (1.02)^{z-20}[\mu\tilde{w}_R] & \text{if } z \geq 20, \end{cases}$$

where, if a worker did not reach the minimum years z_{min} of contribution, her pension is zero. However, if the worker contributed for more than the required number of years, she earns a 2% increase in her pension benefit for each additional year. Thus, the pension received from the public PAYG system can be expressed as

$$\tilde{P} = \min\big(\vartheta_{max}, \max(b, \vartheta_{min})\big).$$

With a minimum pension guarantee ϑ_{min} in the PAYG system, workers with very small average contributions to the system (that would be reflected in a small pension fund $\tilde{Y}$ in an individual accounts system) would be better off aiming for

the minimum pension ϑ_{min}. On the other hand, workers with high average contributions to the system would be discouraged from contributing to the PAYG system, which imposes a maximum pension ϑ_{max}.

ii. Non-contributory pension: $\bar{c}$

Retirees might qualify to receive a non-contributory social pension $\bar{c}$. This pension is a means-tested transfer to retirees that do not receive a pension from the formal pension system $\tilde{P} = 0$ and have accumulated wealth (liquid assets $a(1+r)$ plus current income) below a threshold level M exogenously fixed. These conditions are determined by the interaction of two indicator terms:

$$[\mathbb{1}_{(\Xi<M)}\mathbb{1}_{(\tilde{P}=0)}],$$

where M is the maximum level of wealth Ξ an individual can hold in order to receive a pension transfer and $\tilde{P}$ is the pension benefit corresponding to a pension system p.

4.3.2 Retiree's problem

An individual retired from the labor force chooses the next period liquid asset level a' to maximize her utility, considering her future periods outside the labor force and mortality probability. The decision is given by the following value function:

$$\begin{aligned} W^r(\mathbf{s}) &= \max_{a'} \{u(c) + \beta\, \Gamma_t\, W^r(\mathbf{s}')\} \\ &s.t. \\ c + a' &= \tilde{P} + \bar{c}\,[\mathbb{1}_{(\Xi<M)}\mathbb{1}_{(\tilde{P}=0)}] + (1+r)a \\ a' &\geq 0, \end{aligned} \tag{6}$$

where the formal sector pension is given by $\tilde{P}$ and the non-contributory pension, $\bar{c}$, is conditioned on wealth requirements by two indicator functions. Retirees do not have access to borrowing and do not experience income uncertainty; however, each period, they are subject to an age-dependent mortality risk Γ_t.

4.3.3 Informal problem

A retiree who works in the informal market receives an income y^i but suffers disutility of working, expressed as fixed cost ϕ_t, which is increasing in age. The worker maximizes utility by choosing her optimal liquid savings level a, with a

value function as follows:

$$W^i(\mathbf{s}) = \max_{a'} \left\{ u(c) - \phi_t + \beta\, \Gamma_t \max \left\{ W^r(\mathbf{s}'), \mathbb{E}[W^i(\mathbf{s}')|\varepsilon^i] \right\} \right\} \tag{7}$$

$$s.t.$$

$$c + a' = y^i + \tilde{P} + \bar{c}\,[\mathbb{1}_{(\Xi<M)}\mathbb{1}_{(\tilde{P}=0)}] + (1+r)a$$

$$a' \geq 0,$$

where the retiree perceives a working income from the informal sector y^i. Additionally, she has access to a formal pension $\tilde{P}$ and might qualify for the non-contributory pension $\bar{c}$. The informal worker is still subject to an income risk from the informal sector ^{i} and a mortality risk with no access to borrowing. I assume that the informal worker always has an informal job available after retirement ($\gamma^i(i,e) = 1$), until they completely exit the labor force, after which this probability drops to zero.

4.4 The Government's Problem

The government collects income tax τ from workers in the formal labor market and contributions to the PAYG system $x_{p=2}$ from formal workers enrolled in this system. The government revenues finance payments of the PAYG benefits b, the non-contributory pension transfers $\bar{c}$, and government expenditures G. The government budget is balanced each period, such that

$$G + \bar{c}\, n^{\bar{c}} + \sum_{t=R}^{T} \sum_{i}^{n_t} \mathbb{1}_{p=2}\, b_{i,t} = \sum_{t=1}^{R-1} \sum_{i}^{n_t} \mathbb{1}_{j=f}\, \tau\, y^f_{i,t} + \sum_{t=1}^{R-1} \sum_{i}^{n_t} \mathbb{1}_{j=f} \mathbb{1}_{p=2}\, (x_p\, y^f_{i,t}), \tag{8}$$

where $n^{\bar{c}}$ is the number of total beneficiaries that qualify for the non-contributory social pension. n_t is the number of households age t with population measure Ψ_t. With no population rate, n_t is normalized to 1 and decreases according to the mortality rate Γ_t after reaching retirement rate R. The indicator function $\mathbb{1}_{p=2}$ is 1 when the worker i is enrolled in the PAYG pension system, and $\mathbb{1}_{j=f}$ is 1 when current individual i is a worker in the formal sector $j = f$.

Given that payroll taxes, the PAYG contribution rate, and benefit levels are set by legislation and based on national data, I do not define a separate budget constraint for the PAYG system.

4.5 Production Technology

There is perfect competition of firms in the nonentrepreneurial sector that produces a single good using a constant returns-to-scale technology combining capital

K and labor L:

$$F(K, L) = AK^{\alpha}L^{1-\alpha},$$

where L is the sum of informal and formal labor $L = L^f + L^i$ firms hire, and A is the total factor productivity and is fixed. All capital depreciates at a constant rate $\delta \in (0, 1)$. I consider a small open economy with access to international capital markets, providing the model with an exogenous interest rate. Therefore, in equilibrium, capital per worker is given by

$$r = \alpha \ A \ (K/L)^{\alpha-1} - \delta, \tag{9}$$

which determines the liquid assets return rate r and the wage per efficiency unit of labor services,

$$w = (1 - \alpha) \ A \ (K/L)^{\alpha}. \tag{10}$$

4.6 Definition of Equilibrium

The model's small open economy has a competitive steady-state equilibrium. Appendix Section C.1 provides a full definition of equilibrium.

5 Estimation

To replicate key features of the Peruvian economy, I use sectoral income processes estimated from Peruvian data. The model is parameterized to match a set of moments in this economy.

5.1 Income Process

The income process for each sector is estimated using two weighted waves of panel data from the Peruvian National Household Survey (ENAHO) for the years 2011–2015 and 2014–2018 (INEI, 2018), with representation at the national level. The data were collected annually, and I restrict the sample to men between the ages of 20 to 64 who hold non-agricultural jobs.

5.1.1 Formal and informal workers' income

I normalize the wage for an efficiency unit of labor service w to 1 and set it equal across sectors. I calculate the efficiency unit of labor worked, function Ω^j, estimating each sector's labor earning process using a linear panel regression that controls for the workers' deterministic age profile χ as well as an individual-specific effect Λ_t based on previous job experience l and education e, as follows:

$$\log y_t^j = \chi_t + \Lambda_t + \varepsilon_t^j.$$

Age profile χ incorporates interactions between age and education, which in the informal sector signals experience. Informal jobs have a higher return on age when they require more on-the-job experience than training. The individual-specific effects Λ_t encompass two main variables, education level and sector experience.

Using a panel regression, I am able to estimate the earning process controlling for worker's in-sector experience. The variable *Change sector* calculates the relative importance of the previous sector in the current-sector wage. For example, in Table 7, which presents determinants of earnings by sector, I find a positive effect in the wages of informal workers if the individual's previous job experience was in the formal sector. This formal sector experience signals a level of knowledge that is carried and valued in the informal job. I run external tests and determine that the effect of coming from the formal sector has an effect on the informal workers' wages that lasts until their third year in the informal sector. I also observe the opposite effect for workers transitioning from informal to formal jobs. They earn lower wages in comparison to workers with the same age profile and qualifications, indicating that experience accumulated in the formal sector is more valuable in both sectors.

In addition to the existence of a wage premium in the formal sector, the results in Table 7 show that returns to education are higher for formal workers, too.

Table 7: Determinants of earnings by sector

	Formal worker	Informal worker	Informal Self-employed
Education level	0.062*	-0.151***	0.090***
	(0.037)	(0.043)	(0.013)
Age	0.053***	0.066***	0.132***
	(0.005)	(0.006)	(0.007)
High school # Age	-0.001	0.007***	
	(0.001)	(0.001)	
More than High school # Age	0.002	0.013***	
	(0.002)	(0.002)	
Age^2	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)
Change sector current year	-0.085***	0.250***	
	(0.024)	(0.044)	
Change sector 1 years ago	-0.079**	0.216***	
	(0.031)	(0.059)	
Change sector 2 years ago	-0.155**	0.289**	
	(0.069)	(0.124)	
Controlled by year	✓	✓	✓
Constant	5.972***	5.403***	3.701***
	(0.134)	(0.139)	(0.147)
Observations	5,009	4,752	7,756
R-squared	0.072	0.103	0.067

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The earning processes will use the coefficients here estimated for a log-linear transformation of the workers' wages. Some adaptations are made during the calibration. First, I use the average weight of the variable change of sector for the 3 periods. Second, the constant for all sectors is adjusted (reductions between 0.15 and 0.20 decimals) in the calibration to better match the models' mean earnings by sector to the data for the benchmark economy with income uncertainty.

5.1.2 Informal Self-employed income

The self-employed production function considers entrepreneurial ability and physical capital to complement each other, with marginal returns to capital increasing in ability. The model borrows from Evans and Jovanovic (1989) such that the return from investing in capital is given by the self-employed production function θk^{α}. I follow McKenzie and Woodruff (2006) in developing a profit equation for entrepreneurs that includes ability θ. Total income comes from the entrepreneur's return on capital and her age-education profile, such that

$$\log y_t^s = \theta k_t^{\alpha} + \chi_t + e + \varepsilon_t^i.$$

I estimate the effects of the age variables χ and education e using a linear regression. The results are shown in Table 7. I determine the return on capital and return on ability —the production function θk^{α}— using a percentage of the constant of this estimation as a proxy.

First, I assume that the capital share in the self-employed production function α is 0.2 and depreciation δ is set to 10%. Second, I set two potential levels of entrepreneurial ability: high θ_H and low θ_L. I assume that individuals with θ_H are able to earn 20% over the average self-employed production earnings and that individuals with θ_L will have earnings 20% below the average. I then estimate that the earnings produced by the self-employed production function account for 20% of the constant estimated in column 3 of Table 7. Finally, I solve for the ability values $\theta = \{\theta_H, \theta_L\}$ that, given the optimal level of capital in first year of working life, will provide this difference in production earnings θk^{α} for the high school education level ($e = 2$).[8]

Table 8: Parameters in self-employed production function

	$\tilde{\beta}_0$	θ_H	θ_L	α	δ
Value	2.96	0.60	0.42	0.2	0.1

5.1.3 Earning risk

Income from any job is subject to earning risk that will vary according to the worker's formality status. Earning risk follows a first-order autoregressive process such that, for each sector j, the shock can be expressed as

$$\varepsilon_t^j = \rho_j \varepsilon_{t-1}^j + \epsilon_t^j,$$

[8]Differences by education level are small so I use the medium level of education as a reference.

where ϵ^j is an *iid* shock with distribution $\sim \mathcal{N}(0, \sigma^2_{\epsilon^j})$ for each sector j. Earning shocks are correlated between sectors with $\mathbb{E}\left[\varepsilon^f_t \varepsilon^i_t\right] = \rho_{fi}\, \sigma_f \sigma_i$.

Then, I let workers withdraw simultaneously the shocks in earnings in the formal work and for the informal sector from a multivariate normal distribution $\sim \mathcal{N}(0, \Sigma)$. The informal sector shock affects earning from both types of informal jobs: workers and self-employed. Lopez Garcia (2015) estimates these numbers using an income process for formal and informal workers in Chile, which I borrow for my model. The results are summarized in Table 9.

Table 9: Earning shock parameters

	Formal		Informal	
Autocorrelation (ρ)	0.91	(0.004)	0.87	(0.009)
Std. deviation (σ_j)	0.25	(0.003)	0.27	(0.007)
Correlation		0.32	(0.03)	

Source: Lopez Garcia (2015)

I use the discrete approximation of the Rouwenhorst method proposed by Kopecky and Suen (2010), which has proven to perform well with highly persistent processes. First, using the information in Table 9, I decompose the underlying process into a set of AR(1) processes, one that is independent (the formal sector) and the other that is perfectly correlated with the previous one in their error term (the informal sector). I then construct a two-state Markov chain with transition probability π_{ε^j} for each sector j.

5.2 Calibration

The model is calibrated to match a set of moments for the Peruvian labor market and aggregate moments for the Peruvian economy and social security features. The data used to characterize the moments of the Peruvian labor economy are restricted to the sample of male non-agricultural workers using averages from 2011 to 2018. I make an initial guess on relevant parameters and compare them to the data-estimated targets. The process for calibration is done by updating the parameter values until the differences between model moments and targeted values are significantly small. Other groups of parameters are set using direct estimates from historical averages for the same time period or obtained from previous literature. This section covers both type of parameters: nontargeted and targeted.

5.2.1 Non-targeted parameters

Individuals are born with one of the three education levels e: less than high school $e = 1$; high school completed $e = 2$; or more than high school $e = 3$, which includes any instruction after high school, such as technical, college, or university complete or incomplete. Education is distributed following the average distribution of the education level of male workers between 20 and 64 years old in non-agricultural jobs.

In the model demographics, the individuals are born at age 20, when they start their working life, and they can live to a maximum age of 100. They can retire when they reach 65 years old, following the legal retirement age in the Peruvian pension system (SBS, 2021). After 64 years old, the individuals are subject to a mortality risk Γ. The probability of survival at each age are obtained from the Peruvian mortality tables for males (Instituto Nacional de Estadistica e Informatica, 2019). The abbreviated mortality tables for 2015–2020 are available in five-year cohorts, and mortality is 1 when the individual reaches 100 years old. Using a linear interpolation, I estimate the annual survival probabilities for individuals age 65 through age 100 and use them in the model. Mortality probabilities are available in Section C.1 of the Appendix.

The individuals hold CRRA preferences with a coefficient of risk aversion, γ, equal to 2 following previous literature.

The real interest rate for the model's economy is estimated from the annual real interest rate in the local currency nuevos soles (S/. PEN) for year 2017, 1.8% (BCRP, 2021). For simplicity, in the model, the same interest rate is available for formal and informal workers.[9] The interest rate for the illiquid assets corresponds to the average annualized real return for the period 2015 to 2020 for the moderate-risk pension fund, fund type 2, calculated at 4.5% (Super Intendencia de Banca, 2018).

The pension system design in the model incorporates the most important features of the Peruvian pension system. In the PAYG system, contributions x_{public} to the system are 13% of an individual's salary, and pensions are calculated with a replacement rate μ of 40% after 20 years of contributions with a 2% pension increase for every extra year. The average wage $\tilde{w}_R$ used for the replacement rate

[9]The importance of the gap in interest rates by sector has a higher relevance in a model with borrowing. Amaral and Quintin (2006) study the informal market in Brazil and find that the difference in access and the cost of borrowing in the informal sector is one of the potential arguments for the size of the informal economy.

is estimated for each income profile using the average salary for a formal worker from age 60 to 64.[10] The minimum pension benefit in the PAYG system is 500 (PEN) and the maximum is 893 (PEN) according to the law DL N°19990 (ONP, 2020).For the individual accounts system, contributions $x_{private}$ are set as 10% of the salary, and workers pay a management fee η of 3% of their salary. The AFP's management fee has fluctuated over the period of study but has hovered around this value. A benefit of including a 3% management fee in the model is that both systems display a level of contribution that represents 13% of workers' disposable income each period. In this sense, both system impact current workers' liquidity in the same magnitude. Thus, the current set-up of this parameter helps us compare both system designs beyond their effect on current income liquidity. The pension estimated from the individual accounts system at each fund level $\zeta(\tilde{Y}_R^f)$ is calculated as an ordinary annuity using the interest rate of liquid assets r and the mortality tables for Peru.

The non-contributory pension parameter $\tilde{c}$ follows the benefit payment value from the Peruvian social pension program *Pensión 65*, set at 125 PEN (MIDIS, 2021).

The initial liquid asset distribution for the youngest cohort uses estimates of wealth distribution for individuals under 31 years old for the US economy from Kuhn and Ríos-Rull (2016). The income tax parameter in the model τ is a simple average of the first four income tax levels in the Peruvian economy, 15% (SUNAT, 2021). The highest open bracket is left outside of the calculation.

5.2.2 Targeted parameters

The subjective discount factor β is calibrated to match the capital-output ratio in Peru, calculated as the output-side real GDP (in millions of 2017 US dollars) over capital stock (in millions of 2017 US dollars) using estimates from the Penn World table (Feenstra et al., 2015). As this ratio is increasing over time, I use the estimate for 2019 as my target. In the model, capital is defined as the stock of liquid assets plus the illiquid assets in the economy, and income from all sectors is added up to determine the output in the model.
The percentage of retirees still in the labor force after retirement is obtained from the overall calculations in Table 4 of those age 65+ who are working. This parameter is matched in the model by adjusting the disutility of working after reaching age 64 ϕ. This value is linearly decreasing with age to replicate the decline in participation observed in Table 4. The means-target eligibility criteria

[10] By law, the average salary for the last five years of contributions must be used.

for the non-contributory pension establish a maximum level of consumption M that is set to match the percentage of elderly collecting a benefit from the social pension *Pensión 65*. This will help us compare the impact of social pension program to similar *consumption floor* programs in other countries. Results for this set of calibrated parameters for the baseline economy are compile in Table 23 in Section B.2 of the Appendix.

The parameters governing the job separation cost $\nu(j, e)$ by sector and education level are set such that the average distribution of the labor force across sectors and education levels matches the estimated distribution from the Peruvian labor market in Table 1. Table 10 summarizes the values for the parameters ruling the labor market structure in the model.

Table 10: Calibrated labor market parameters across education levels

Labor market parameters	Education levels, e		
	1	2	3
Separation cost:			
From formal job, ν^f	0.0022	0.0018	0.0019
From informal job, ν^i	0.0005	0.00130	0.0022
Job offer arrival:			
(From data) formal offer for formal worker, γ_f^f	0.79	0.82	0.86
Formal offer for informal worker, γ_f^i	0.48	0.60	0.73
Informal offer for informal worker, γ_i^i	0.59	0.60	0.61
Informal offer for self-employed, γ_i^s	0.30	0.31	0.40

Note: Separation cost parameters are calibrated by targeting the labor force distribution. Job offer arrivals by sector use the transition matrix as the target. Education levels: $e = 1$ Less than high school, $e = 2$ High school completed, $e = 3$ More than high school.

Because the demand side of the labor market is not modeled, the arrival of a job offer $\gamma(j, e)$ by sector j and education e in Table 10 is calibrated by targeting the transition matrix between sectors by education for the Peruvian labor market. For tractability and due to the reduced probability of the event (less than 5%), the model exempts decisions from formal workers to become self-employed and self-employed to transition into formal jobs. For calibration purposes, I adjust the transition matrix estimated from the data to examine the transition opportunities presented in the model. The targeted transition matrix incorporates these cases by assigning a zero probability to these specific transitions and adding the

residual probability from the data into the informal sector. Computing the probabilities in this way ensures that the matrix of probabilities adds up to one and that the transitions correspond to the choices available in the model. This simplification also allows us to equate the probability of keeping a formal job $\gamma^f(f, e)$ to the targeted transition probability from the data. This is due to the model assumption that formal workers will only transition out of the formal sector if they do not receive a job offer to continue (an exogenous separation). Table 11 presents the results of the targeted labor transition matrix for the benchmark economy along with the model results.

Table 11: Target transition matrix by education

Less than high school education, $e = 1$

Previously / Currently	Formal		Informal		Self-employed	
	Data	Model	Data	Model	Data	Model
Formal Worker	0.79	0.79	0.16	0.14	-	-
Informal Worker	0.21	0.21	0.63	0.63	0.20	0.24
Informal Self-employed	-	-	0.21	0.23	0.80	0.76

High school education, $e = 2$

Previously / Currently	Formal		Informal		Self-employed	
	Data	Model	Data	Model	Data	Model
Formal worker	0.82	0.82	0.20	0.16	-	-
Informal worker	0.18	0.18	0.62	0.66	0.18	0.21
Informal self-employed	-	-	0.18	0.18	0.82	0.79

More than high school education, $e = 3$

Previously / Currently	Formal		Informal		Self-employed	
	Data	Model	Data	Model	Data	Model
Formal worker	0.86	0.86	0.27	0.21	-	-
Informal worker	0.14	0.14	0.53	0.65	0.23	0.22
Informal self-employed	-	-	0.19	0.14	0.77	0.78

5.3 Goodness of fit

The model reproduces key moments well, as shown in Table 12, particularly the initial labor force distribution by education and the transition matrix presented in Table 11. These two elements characterize the labor force in the model and

provide 15 (five for each education type) parameters that have to be disciplined in the model simultaneously. The model is able to capture the key features of the labor market.

Table 12: Moments targeted in the calibration

Moment	Parameter	Data	Model
Capital-output ratio	β	3.7	3.7
Fraction of elderly:			
working	ϕ	41.6	46.7
with non-contributory social pension	M	20.0	19.8
Labor force distribution by education:			
Less than high school, $e = 1$	$\nu(f,1); \nu(i,1)$		
Formal worker		24.4	24.3
Informal worker		38.4	38.1
Informal self-employed		37.2	37.7
High school completed, $e = 2$	$\nu(f,2); \nu(i,2)$		
Formal worker		30.5	30.7
Informal worker		35.9	35.8
Informal self-employed		33.6	33.5
More than high school, $e = 3$	$\nu(f,3); \nu(i,3)$		
Formal worker		44.6	44.0
Informal worker		30.8	31.5
Informal self-employed		24.6	24.5

Other sets of untargeted moments prove the predictive power of the model. In the model workers have the option to choose their optimal pension system to contribute to. Values for average fraction of workers in PAYG and individual accounts from current numbers in the Peruvian economy showed are similar as the ones resulted by the workers endogenous decisions in the model.
The simultaneous calibration of parameters governing transition matrix and composition of labor force by education provides one degree if freedom. I can see that the overall fraction of labor force by sector resulted from this calibration matches very closely the data. Finally, average income rates from informal and self-employed sector versus formal sector are close in range to the average ratios obtained from the panel survey data from Peruvian households.

Table 13: Untargeted Moments

Moment	Data	Model
Fraction of workers contributing to PAYG	18.2	19.2
Fraction of workers contributing to individual accounts	9.3	14.0
Fraction of total labor force		
Formal	33.4	33.2
Informal worker	35.0	35.0
Informal self-employed	31.6	31.7
Average income of formal workers/ informal workers	1.08	1.03
Average income of formal workers/ self-employed	1.09	1.08

6 Results

I use the calibrated model as a benchmark to asses the impact of a contributory pension system in the worker's choice over informality. To evaluate the presence of the mechanisms through which the design of the pension system affects this decision, I study two main set ups. In the first set up, I remove the contributory pension system from the benchmark economy and evaluate two experiments on the treatment of the non-contributory pension. In the second set up, I keep a contributory system and evaluate between an economy with only a PAYG (defined-benefits) program or an only individual-accounts (defined-contributions) program. All result below are comparison of steady-states.

6.1 Impact of contributory pension systems

With all individuals starting their working life as informal workers, I remove the contributory pension system first. The non-contributory pension, that works as a means-tested program, is still in placed. Without mandatory contributions for retirement enforced in the formal labor market, workers in formal jobs receive more liquid earnings. In this case, I lift the liquidity constraint introduced by a contributory pension system.

6.1.1 Experiment 1: Number of non-contributory recipients adjust

I remove contributions to a pension system from the economy and let the number of non-contributory recipients adjust, if necessary. In the benchmark economy I calibrated the wealth threshold Ξ under which elderly receive a non-contributory

social pension (a means-tested transfer) to match the targeted 20% of the elderly population. In this experiment, I keep the same threshold level.

Impact on labor composition.– In an economy without a contributory pension system, the percentage of people working after reaching the retirement age significantly increases from 47% to 70% and the proportion of those age 65+ receiving the non-contributory social pension also jumps from 20% to 49%. These results reflect a more vulnerable elderly population. For the active workforce, I see that higher liquid earnings in the formal sector attracts more workers. Table 14 provides an overview of the labor force composition and shows that the proportion of formal workers increase in 3.5 percentage points, from 33.2% to 36.7% of the labor force for the economy with no contributory system in partial equilibrium. Results differ by education level. With a lower probability of job separation (lower unemployment risk) and higher returns from education in the formal sector, workers with more than a high school education will find the new setup in the formal sector more attractive. This group would see an increase in formality rates of 5.7 percentage points, from 44.0% to 49.7% of the workers.

Table 14: Labor force distribution across sector status, with and without a contributory pension system

Model	*Both systems*	*Removing contributory systems*			
	Benchmark	PE	%	GE	%
	(1)	(2)	Δ	(3)	Δ
		Overall			
Formal worker	33.2	36.7	*10.5*	36.5	*9.7*
Informal worker	35.0	33.6	*-4.0*	33.7	*-3.7*
Informal self-employed	31.7	29.6	*-6.6*	29.8	*-6.0*
		Less than high school			
Formal worker	24.3	25.5	*5.3*	25.3	*4.4*
Informal worker	38.1	37.8	*-0.6*	37.9	*-0.4*
Informal self-employed	37.7	36.6	*-2.8*	36.7	*-2.5*
		High school completed			
Formal worker	30.7	34.1	*10.8*	33.7	*9.7*
Informal worker	35.8	34.2	*-4.4*	34.4	*-3.7*
Informal self-employed	33.5	31.7	*-5.3*	31.9	*-4.9*
		More than high school			
Formal worker	44.0	49.7	*13.1*	49.5	*12.4*
Informal worker	31.5	29.1	*-7.5*	29.1	*-7.5*
Informal self-employed	24.5	21.2	*-13.7*	21.4	*-12.6*

Note: Distribution of workers' job status for (1) the benchmark economy, (2) the economy without a contributory pension system in partial equilibrium, and (3) the economy without a contributory system in general equilibrium. The first three rows correspond to the overall economy, and the subsequent rows provide results by education level. % Δ is the percentage change calculated with respect to (1).

The increase in workers choosing to take formal jobs when the contributory pension system is removed is more relevant at the beginning and end of one's working life, as shown in Figure 1. During the early working years, income is lower for all types of workers, leaving them more vulnerable to shocks and in higher need of liquidity. Thus, removing pension contributions in the formal sector will ease the entry for young workers with higher liquidity preferences. At the end of one's working life, productivity declines for all sectors and there is more prevalent need to enter retirement with savings. Formal jobs are still the higher paying jobs, and they also provide a greater possibility of accumulating liquid savings. In the benchmark economy, the percentage of workers taking formal jobs increases in this phase, effect that is enhanced in an economy without pension contributions.

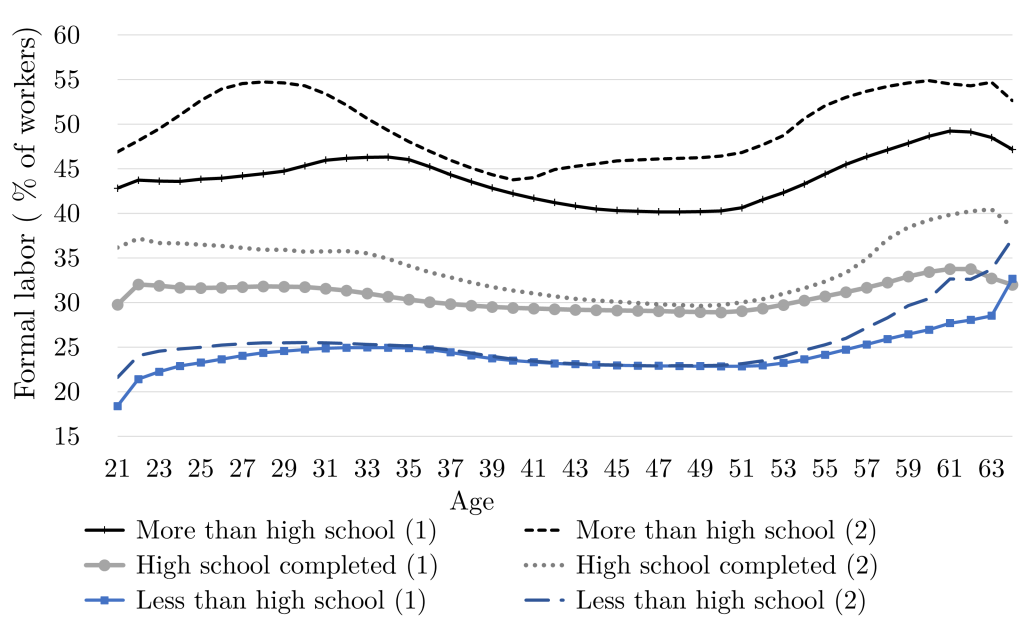

Figure 1: The figure shows the proportion of formal workers by each education level. The continuous lines show results for the benchmark model (1), and the dotted lines show percentages for the economy without a contributory pension system (2). For all education levels, removing the contributory pension system increases the proportion of formal workers.

Additionally, the probability of transitioning to the formal sector from an informal job also increases for all education levels. Table 26 in Appendix Section D.2 shows transition probabilities for informal workers by education level. When the contributory system is removed, workers also transition to formal jobs at a higher frequency.

Lower contributions makes formal offers more attractive for workers in both, informal jobs and self-employment. Given that the transition to the formal labor force is possible only for workers with an informal job, an informal job for a firm also becomes more attractive. Across all education levels, the change in the status of self-employed workers is the highest. In line with the findings of Mandelman and Montes-Rojas (2009), these individuals are better off in entrepreneurial activities and differ from informal workers that are waiting for an opportunity to enter the formal job, even given the current level of contributions. In this case, removing contributions and making the formal sector more attractive will have a weaker effect on informal workers who were already interested in moving to formality but will significantly increase the opportunity cost of being self-employed and encourage these individuals to transition to formal jobs. Similar results,

where a drop in self-employment is the main driver affecting formality rates, are obtained by Narita (2020) in experiments involving reduced taxes.

A complete removal of the contributory pension system has an important impact on the size of the formal labor. Individuals compensate the lack of a social protection system working after their retirement age and depending on government programs like the non-contributory social pension. These outcomes, higher number of formal workers and higher number of retirees receiving a non-contributory pension, impact the government budget. I find that the results of these indirect effects on government budget will further impact formality. Studying the general equilibrium results provides a comprehensive analysis of direct and indirect effects in the economy when the contributory system is removed.

General equilibrium analysis.– Besides a wealth Ξ, another condition to qualify to the means-tested non-contributory social pension $\bar{c}$ is to not receive a pension from any other source. Then, an economy without a contributory pension system would increase the number of elderly that can access to this means-tested transfer. The first two columns in Table 25 Section D.1 of the Appendix compares non-contributory social pension recipients in the benchmark economy with the counterfactual without a contributory pension system. The non-contributory social pension program is financed from the consolidated government budget. In experiment 1 the government budget perceives an increase in outlays due to the new number of elderly eligible to receive the non-contributory pension transfers.

There are two offsetting effects affecting the government budget. On one hand, the number of participants in the means-tested program more than doubled, increasing the cost of the program and expenses for the government. To keep the budget in equation (8) balanced, the government would need to increase taxes. However, in economies with informality, taxes will disproportionately affect workers on formal jobs, reducing the attractiveness of formal jobs that was gain when removing the contributory system.

On the other hand, removing the contributory system increase the proportion of the labor force in formal jobs, particularly of highly educated workers that sustain higher income levels. Therefore, the governments' tax base is greater in this economy. As a result the government's revenues from income tax collections also increases.

These two results from removing the pension system have opposite effects on the government consolidated budget. The pressure to raise taxes, created from the higher means-tested transfers, is compensated with a higher income tax col-

lection from the increased tax base. A slightly increase in income tax is still needed, that reduces the gains from removing contributions to the pension system. As a result, the labor force composition in general equilibrium is close to the partial equilibrium, as observed in Table 14. The percentage of worker in formal jobs has a modest reduction of 0.2 percentage points, once taxes are adjusted in general equilibrium.

The offsetting effects of an economy without a contributory pension system are summarized in Table 15. Taxes increase by a small percentage but gains from tax collections are significantly higher due to an increase in the tax base.

Table 15: General equilibrium effects of experiment 1

	Benchmark	*No contributory system*	
Model	(1)	(2) PE	(3) GE
Income tax	15.0%	15.0%	15.85%
Liquid Assets/Income ratio	1.54	1.70	1.69
Formal workers, %	33.2	36.7	36.5
Income tax collection, % Δ		15.7	21.1
Elderly			
working, %	46.7	70.0	70.8
with non-contributory pension, %	19.8	49.3	49.6

Note: Comparison between the benchmark economy (1), an economy without a contributory pension system in partial equilibrium (2), and an economy with no contributory system in general equilibrium (3). Percentage change (% Δ) is calculated with respect to the results in (1).

Welfare analysis.– The impact on welfare from a complete removal of the contributory pension system differs by education level. The workers with higher education levels are the ones that benefit the most from a removal of the contributory system in partial equilibrium. They spend more periods of their working life in formal jobs, and their wages benefit from a higher premium in these jobs. As seen in Table 14 this group has the highest increase in formal participation in response. However, a higher formality rate implies that they will also be the most affected by changes in the income tax level.

Table 16 presents a summary of both effects on welfare, showing the partial and general equilibrium, for the average worker and by education level. Using

an estimation of welfare gains as the equivalent variation in consumption, I observe that consumption increases by 4% just with the removal of a contributory pension system. With more workers accessing formal wages, higher consumption is possible during their working life. More retirees have to keep working after reaching retirement age, but higher average disutility of elderly work does not offset the positive effects gained during the working life without contributing to a pension system.

Table 16: Welfare gains from removing contributory pension systems in experiment 1

Model	(2)PE	(3)GE
Average	4.03%	3.78%
by education level		
Less than high school	2.77%	2.60%
High school completed	4.00%	3.74%
More than high school	5.56%	5.21%

Note: Change in consumption in economy without contributory pension system in partial equilibrium (2) and general equilibrium (3). Percentage change calculated with respect to benchmark (1).

Welfare gains are still present but slightly affected in general equilibrium. To finance more non-contributory pensions, the income taxes increase. As discussed in last section, the increase is small due to the compensating effects of the larger tax base. This particular dynamic only present in labor markets with informality allows the overall positive welfare effects of removing contributory systems to extend to the general equilibrium. Results are slightly smaller than in partial equilibrium, 3.78%, with the greatest change in taxes felt by the most educated workers, a higher proportion of whom are formal tax payers.

6.1.2 Experiment 2: Number of non-contributory recipients is fixed

In the following experiment I remove the contributory pension system, while keeping a target on the non-contributory social pension as 20% of the elderly population. In this case, I recalibrate the wealth threshold Ξ in partial equilibrium. The aim is to study the effects of removing a contributory pension system, holding the same means-tested non-contributory pension level. The partial equilibrium results of this experiment will show how relevant is the non-contributory

pension in workers' decisions over formality. For the general the general equilibrium analysis I will evaluate two cases: an adjustment in the amount of the means-tested pension $\bar{c}$ and an adjustment in income taxes.

Impact on labor composition.– Similar to the previous case, a removal of contributory pension systems generates an increase in the proportion of workers taking formal job offers. when comparing the increase in formality to experiment 1, keeping the number of beneficiaries to the non-contributory social pension same as the benchmark (20% of the elderly) has a positive effect in formality in partial equilibrium. With a smaller probability to access this non-contributory pension, workers have to accumulate a higher level of savings. With higher paying jobs in the formal sector, I see a small increase in formality in comparison with experiment 1 (Table 14). The biggest increase comes from the less than high school workers, which is the group most likely to rely on the non-contributory pension. Formal jobs are riskier for less than high school workers because they have higher probability to being separated from their job and affected by unemployment, and their return on education in formal salaries is not as big as the ones obtained by more educated individuals. However, given a restrained non-contributory pension, they will be more likely to take formal jobs.

Table 17: Labor force distribution across sector status removing contributory system in experiment 2

Model	Bench mark (1)	*Removing contributory system* PE (4)	% Δ	GE, $\bar{c}$ (5)	% Δ	GE, τ (6)	% Δ
		Overall					
Formal worker	33.2	36.8	*10.7*	36.8	*10.8*	36.9	*10.9*
Informal worker	35.0	33.6	*-4.2*	33.6	*-4.2*	33.6	*-4.2*
Informal self-employed	31.7	29.6	*-6.7*	29.6	*-6.7*	29.6	*-6.8*
		Less than high school					
Formal worker	24.3	25.8	*6.2*	25.8	*6.3*	25.8	*6.2*
Informal worker	38.1	37.7	*-1.0*	37.7	*-1.1*	37.7	*-1.1*
Informal self-employed	37.7	36.6	*-2.9*	36.6	*-2.9*	36.6	*-3.0*
		High school completed					
Formal worker	30.7	34.1	*11.0*	34.1	*11.0*	34.2	*11.4*
Informal worker	35.8	34.2	*-4.4*	34.2	*-4.5*	34.1	*-4.7*
Informal self-employed	33.5	31.7	*-5.3*	31.7	*-5.4*	31.7	*-5.5*
		More than high school					
Formal worker	44.0	49.7	*13.0*	49.7	*13.0*	49.7	*13.0*
Informal worker	31.5	29.1	*-7.4*	29.1	*-7.4*	29.2	*-7.2*
Informal self-employed	24.5	21.2	*-13.7*	21.2	*-13.7*	21.1	*-14.0*

Note: Distribution of worker's job status for benchmark economy (1), economy without a contributory pension keeping fixed the number of beneficiaries to the non-contributory pension in partial equilibrium (4), adjustment to general equilibrium increasing non-contributory pension $\bar{c}$ (5), adjustment to general equilibrium with income taxes τ (6). First three rows correspond to the overall economy, the following rows provide results by education level. % Δ is the percentage change with respect to (1).

General Equilibrium.– With a restricted increase on non-contributory pensions, the consolidated government budget experiences an increase in collections due to the bigger tax base of formal workers. I proposed two transitions to general equilibrium. In counterfactual economy (5) an increase in the benefits of the non-contributory pension $\bar{c}$ and in counterfactual economy (6) a reduction on income tax τ.

Table 18: General equilibrium effects of experiment 2

Model	Benchmark	*No contributory system*		
		PE	GE, $\bar{c}$	GE, τ
	(1)	(4)	(5)	(6)
Income tax	15.0%	15.0%	15.0%	14.80%
Liquid Assets/Income ratio	1.54	1.72	1.72	1.72
Formal workers, %	33.2	36.8	36.8	36.9
Income tax collection, % Δ		16.1	16.1	14.7
Elderly				
working, %	46.7	70.2	65.5	70.0
with social pension, %	20	20	22	20
Social pension	$\bar{c}$	$\bar{c}$	1.25 $\bar{c}$	$\bar{c}$

Note: Comparison between benchmark economy (1), e economy without a contributory pension keeping fixed the number of beneficiaries to the non-contributory pension in partial equilibrium (4), adjustment to general equilibrium increasing non-contributory pension $\bar{c}$ (5), adjustment to general equilibrium with income taxes τ (6). Percentage change (% Δ) is calculated with respect to results in (1).

The first case, an increase of the non-contributory pension transfer by 25% balance the government budget. The general equilibrium effects on the composition of the labor force are not significantly different from the partial equilibrium results. The main effect observe is a reduction on the working elderly population. This points in the direction that a non-contributory social pension program (as means-tested programs) have limited distortionary effects on the formality rate of an economy while effectively increasing the well-being of the elderly population. These results replicate the conclusions found in empirical studies of non-contributory pension program. Bando et al. (2020) evaluated the impact of the introduction of the non-contributory pension for Peru and calculated a relevant reduction in elderly work as the main effect. The result in other indicators is summarized in Table 25 in Appendix Section D.1.

Table 19: Welfare gains from removing contributory pension systems in experiment 2

Model	PE (4)	GE, $\bar{c}$ (5)	GE, τ (6)
Average	4.01%	4.03%	4.07%
by education level			
Less than high school	2.75%	2.77%	2.79%
High school completed	3.99%	4.00%	4.05%
More than high school	5.54%	5.55%	5.62%

Note: Change in consumption in economy without contributory pension system in partial equilibrium (4), general equilibrium through higher $\bar{c}$ (5) and general equilibrium through taxes τ (6). Percentage change calculated with respect to benchmark (1).

The second case, the government keeps the same level of non-contributory pension $\bar{c}$ and adjusts income taxes instead. Reducing income tax, has a higher impact on labor composition than a change on the $\bar{c}$. In terms of welfare gains, this options generates the highest increase in consumption to all workers as observed in Table 19.

Findings from the quantitative exercise show that the non-contributory pension is a program with minimal impact in the workers decision over formal jobs in partial equilibrium. Results from an adjustment in taxes in general equilibrium are expected to affect formality rate in similar way as previously observed.

6.2 Analysis of the Design: PAYG or Individual-Account

In the benchmark economy, workers decide which pension designed is best for them. The following exercise uses as counterfactual economies with a default and single pension scheme. The results in Table 27 in Appendix section D.3 show that the impact of each pension design on the composition of the labor force is very small in partial equilibrium. This result follows the argument that almost all of the impact of the contributory pension system in the formal labor market is coming from its effect on liquidity and not in the particular features of the design. The liquidity mechanism is the dominant channel and is present in both types of pension systems, individual-account and PAYG.

I also observe a positive small increase in formality if the economy offers

only a PAYG system. This effect is amplified in general equilibrium when the government budget and taxes are adjusted, as shown in Table 20.

Table 20: Labor force distribution across sector status based on a contributory pension scheme in general equilibrium (GE)

Model	*both*	*only*		*only*	
	Benchmark (1)	Individual accounts(7)	% Δ	PAYG (8)	% Δ
		Overall			
Formal worker	33.2	32.4	*-2.5*	36.3	*9.2*
Informal worker	35.0	35.5	*1.4*	33.4	*-4.7*
Informal self-employed	31.7	32.1	*1.2*	30.3	*-4.5*
		Less than high school			
Formal worker	24.3	24.0	*-1.1*	25.3	*4.5*
Informal worker	38.1	38.2	*0.3*	37.6	*-1.1*
Informal self-employed	37.7	37.8	*0.4*	37.0	*-1.7*
		High school completed			
Formal worker	30.7	30.1	*-2.2*	33.3	*8.4*
Informal worker	35.8	36.1	*1.0*	34.5	*-3.4*
Informal self-employed	33.5	33.8	*1.0*	32.2	*-4.0*
		More than high school			
Formal worker	44.0	42.4	*-3.5*	49.4	*12.2*
Informal worker	31.5	32.4	*3.0*	28.3	*-9.9*
Informal self-employed	24.5	25.2	*2.5*	22.3	*-9.2*

This table shows the distribution of workers' job status in a benchmark economy where workers choose a PAYG or individual-account pension system (1), an economy with only an individual-account pension system in general equilibrium (4), and an economy with only a PAYG pension system in general equilibrium (5). The first three rows correspond to the overall economy, the other rows provide results by education level. % Δ is the percentage change with respect to (1).

Two main feature of the PAYG-only system generates the positive direct effect in partial equilibrium. First, in the PAYG system workers must reach a minimum number of years of contribution in order to qualify for benefits. Therefore, receiving a pension depends on the periods a worker spends in formal jobs. This generates an incentive to remain in formality or take formal jobs, specially when a worker is close to completing that requirement.

An economy with only an individual accounts system deters some workers from taking formal jobs in comparison with a PAYG system. Low-income workers

will make smaller contributions; consequently, their individual-account balances will be lower, leading to smaller pensions compared to the minimum pension provided in a PAYG system. For this group, taking a formal job will make them liquidity-constrained and provide them with meager pensions. Some will be better off relying on the non-contributory pension and working in the informal sector. The effect is the opposite in a PAYG system with a minimum pension guarantee. This system incentivizes entry for low-income workers. This results point that adding a minimum pension to an individual accounts pension system would also likely increase formal labor force participation rates, as Todd and Vélez-Grajales (2008) show using data from Chile.

Which pension system is optimal for an individual worker will depend on that worker's potential income level. From the benchmark model, we observe that the average income level of formal workers enrolled in an individual accounts system is higher than for workers who find the PAYG optimal. PAYG encourages the entry of low-income workers with a pension floor, but it inhibits high-income workers from choosing this system because they could achieve higher pension savings in individual accounts. Figure 2 shows that the average workers' income according to the pension system selected is significantly different at the beginning of one's working life, when this decision is usually made.

An economy that provides workers with a choice between both pension systems introduces a selection problem that affects the solvency of the PAYG system. With high-income workers choosing to enrol in an individual-account system, the PAYG system relays only on contributions from low-income workers that are smaller and more scarce, as they transition out for formal jobs with higher probability. Because the PAYG is public managed, this effect is translated to the government consolidate budget that has to secure the PAYG benefits and non-contributory pensions with taxes. A context where both systems are available reduces the risk-sharing nature of the PAYG system.

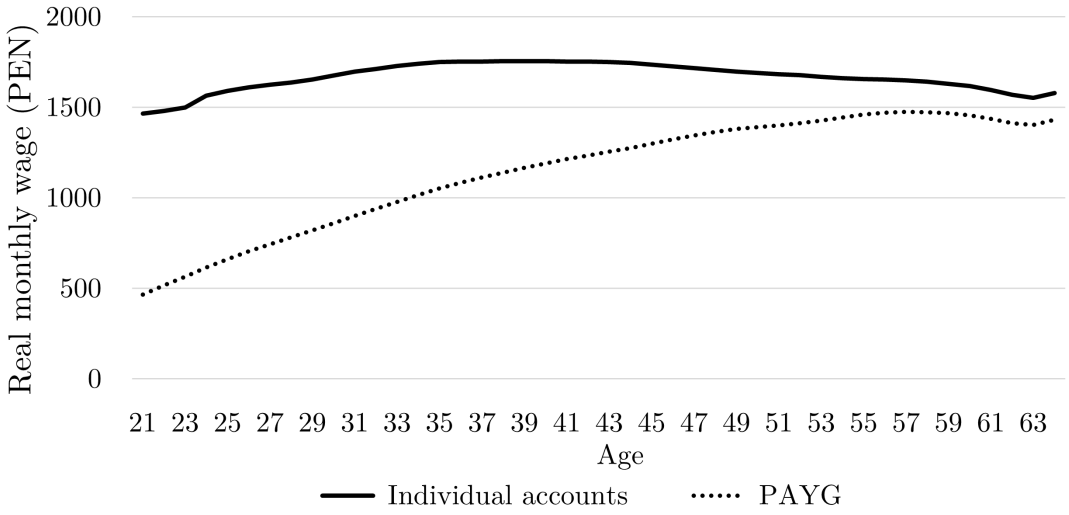

Figure 2: The figure shows average monthly income (in PEN) of formal workers by the pension system they contribute to. The individual-account system is more attractive to high-income workers, who can make bigger contributions to their future self-financed pension. PAYG is preferred by low-income workers who rely on the PAYG minimum pension or non-contributory pension.

In find that in general equilibrium, having an economy with only a PAYG system provides further increases in formality. With a mandatory PAYG-only system, the net effects on the government consolidated budget are positive. First, high-income workers that take formal jobs will contribute a percentage of their income to the PAYG system. This increases government revenues in comparison to the benchmark economy, where both systems are available.

Second, the PAYG system has two features that limit the expenses of the program. The requirement of a minimum years of contributions in order to obtain a pension will restrain the number of workers accessing to the benefits. While the capped maximum pension, limits the level of the benefit paid to the retirees. At the end, the payment of benefits in the PAYG system are not higher that the increase in collections. In an economy with only a PAYG system, the government has higher revenues while pension transfers remain control resulting in the potential lower income taxes in general equilibrium. This further increases the attractiveness of formal work for low-income and low-asset workers that benefit the most from the PAYG system.

Welfare analysis.– General equilibrium results on welfare are different by pension system. I find that providing workers with the option to choose their

optimal pension system is not welfare improving. Because the PAYG system is publicly managed, an economy with only a PAYG system has a significant impact on the government budget. Thus, the following analyses of an economy with only PAYG and an economy with only an individual-account system evaluate the welfare effects in general equilibrium.

With lower income taxes in general equilibrium, an economy with a mandatory contributory PAYG-only system increases consumption by 2.4% in comparison to an economy where both systems are available, as shown in Table 21. Even thought, a PAYG-only system might not provide attractive features for high-income workers in comparison to the individual-account system, the effect of having all workers contributing to the PAYG program on the government's budget provide a welfare improving equilibrium for all workers.

Table 21: Welfare gains from only one pension system

Model	Individual accounts (7)	PAYG (8)
Average	-0.8%	2.2%
by education level		
Less than high school	-0.6%	1.5%
High school completed	-0.8%	2.1%
More than high school	-1.1%	3.1%

Note: Change in consumption in economy with only an individual accounts system (7) and an economy with only a PAYG (8) evaluated in general equilibrium. Change calculated with respect to benchmark (1).

Table 21 shows a small but negative change in welfare from an economy with only an individual-account system for retirement. In an individual-account setup, workers do not have a minimum pension guarantee and by contributing to this pension system they will not qualify to the non-contributory means-tested pension. In this case, this economy negatively impact the attractiveness of formal jobs for low-income workers and negatively impacts their potential ability to qualify to a non-contributory pension when retired.

A PAYG only economy with lower income taxes in general equilibrium provides an increase in lifetime consumption of 2.2% for all workers; unlike an economy with only individual-accounts, that results in a decrease in welfare. However,

an economy without all contributory pension systems, like the one explored with experiment 1 or 2, continues to provide the highest welfare gains increasing lifetime consumption by 4%.

7 Conclusion

With an informal labor market, contributions to a pension system are not enforced equally for all workers. In fact, when the formal labor market requires workers to contribute a percentage of their income, those with preferences for current liquidity may be discouraged from accepting formal jobs. To study the impact of this incentive on formality, I develop a heterogeneous agent life-cycle OLG model of an economy with informal labor markets and the two most popular contributory pension systems —PAYG and individual-account— and calibrate it to Peru.

I find that removing the contributory pension system increases formality rates in the economy and provides welfare gains to workers. This is true independent of whether workers have a preference for PAYG systems (defined-benefits) or individual-account systems (defined contributions). The increase in formality has an unintended positive effect on the government budget because it provides a higher tax base. In this set up, the percentage of individuals relying on the non-contributory social pensions also increases; increasing government expenses. However, the government is able to meet the higher number of transfers without significantly raising taxes due to the increase size of the tax base.
My findings that there are large welfare gains from removing the contributory pension system while keeping the non-contributory pension (means-tested program) extends on Braun et al. (2017) results for the US. I also show that the non-contributory pension has little impact on the composition of the labor market. This result is in contrast to my finding that the contributory system has a significant effect on formality.

Finally, this paper shows that in the benchmark economy, where workers can choose which pension system they contribute to, low-income workers prefer a PAYG system. An individual-account system is the optimal choice for middle- and high-income workers who can self-finance their retirement with individual savings. As a result, running both pension systems and allowing workers to choose which one they participate in negatively impacts the financial stability of the PAYG system and the government budget. With high income workers contributing to individual accounts, the PAYG system loses its redistributional nature. On the other hand, an individual-accounts-only system does not incen-

tivize low-income workers to take formal jobs. My analysis reveals that in markets with high informality, a PAYG-only system, with minimum and maximum pension benefits and with an eligibility requirement based on years of contributions, increases formality and welfare in general equilibrium as compared to an individual-accounts-only system or both. Including high-income workers in the PAYG system increases collections and reduces the overall income tax, making the formal sector more attractive to workers of all income levels.

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Appendices

A Empirical facts

A.1 Income distribution

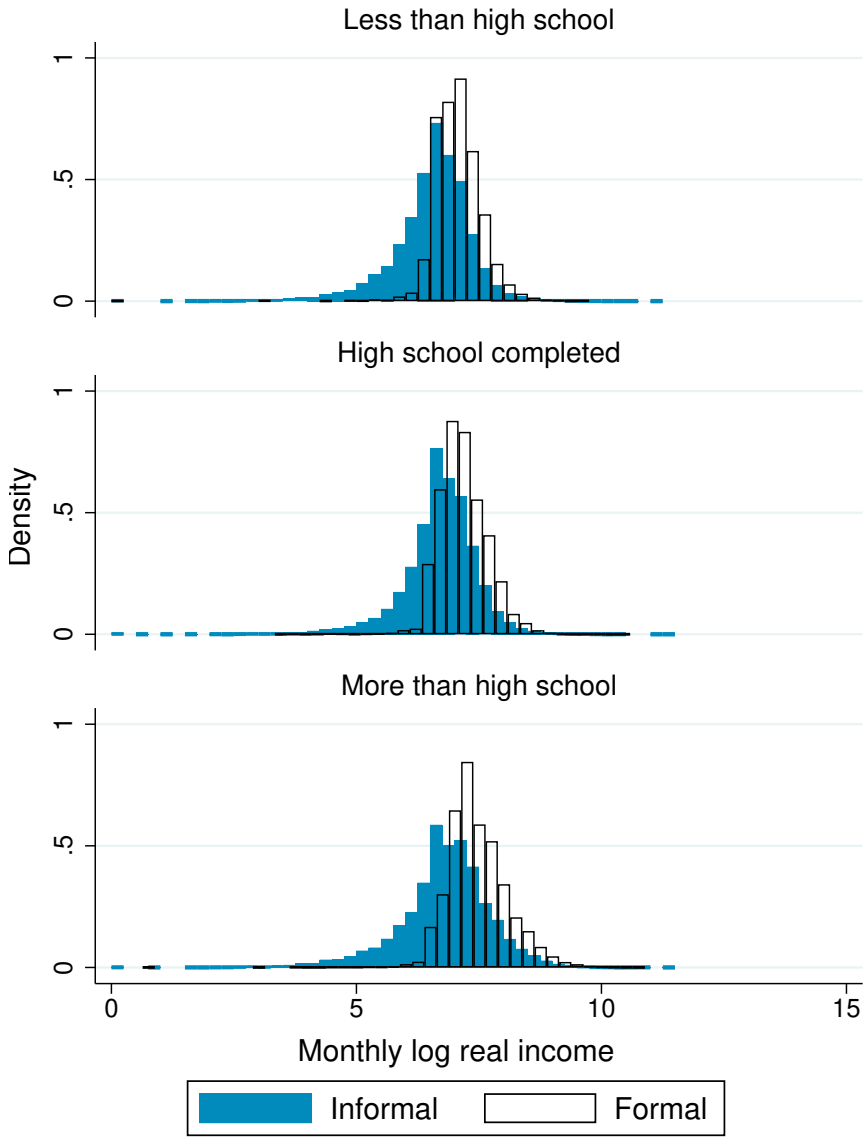

Figure 3: The figure shows the proportion of monthly log real income for workers in formal jobs and in informal jobs, excluding self-employed. Income is calculated before taxes and deductions for non-agricultural males between 20 to 64 years old from ENAHO INEI (2018).

B Calibration moments and data

B.1 Mortality Table

Mortality risk Γ_t is obtained directly from the Peruvian mortality tables for males provided by the INEI (Instituto Nacional de Estadistica e Informatica, 2019), where q(x,n) is the probability of a person from age x to die before reaching x+n.

Table 22: Mortality Table, summary 2015-2020 for males

Age (x)	n	q(x,n)	Age (x)	n	q(x,n)
0	1	0.0140	50	5	0.0302
1	4	0.0038	55	5	0.0427
5	5	0.0029	60	5	0.0625
10	5	0.0019	65	5	0.0926
15	5	0.0057	70	5	0.1567
20	5	0.0086	75	5	0.2359
25	5	0.0108	80	5	0.3593
30	5	0.0109	85	5	0.5189
35	5	0.0125	90	5	0.6664
40	5	0.0162	95	5	0.7854
45	5	0.0212	100	-	1.0000

Source: INEI (2019)

B.2 Other parameters

Table 23: Calibrated parameters for the economy

Parameter	Value	Target
Discount factor, β	0.89	capital-output ratio
Desutility of working at age 65, ϕ	0.0013	% elderly work
Non-contributory pension threshold, M	1660	% of beneficiaries

Table 24: Non-calibrated parameters

General: Parameters	Value
Risk aversion, γ	2
Capital utilization, α	0.2
Capital depreciation rate, δ	0.1
Payroll tax, τ,	15%
Pension system	
Contribution rates:	
individual accounts, $x_{p=1}$	10%
PAYG, $x_{p=2}$	13%
Fund management fee, η	3%
PAYG years requirement, z_{min}	20

C Model Features

C.1 Definition of Equilibrium

For defining the equilibrium we use the compact way to express the household state into a vector $\mathbf{s} = (\theta, e, p, t, j, a, \tilde{Y}, z, l, \varepsilon^f, \varepsilon^i)$ which contains the households entreprenurial ability, education level, type of pension system, age, sector, liquid asset, illiquid asset, years of contribution to the system, sector experiences (transitions) in past 3 years, earning shock in formal job and earning shock in informal job.

DEFINITION. Given a fiscal policy $\{\tau, \bar{c}, M, \mu, \vartheta_{max}, \vartheta_{min}, \bar{x}_2\}$ and real interest rates for liquid and illiquid assets $\{r, r^*, \varrho\}$ a steady-state competitive equilibrium consists of households policies of consumption, savings, entreprenurial investment and occupational choice $\{c(\mathbf{s}), a'(\mathbf{s}), k(\mathbf{s}), j(\mathbf{s})\}_{t=1}^{T}$ and associated value functions
$\{V^f(\mathbf{s}), V^i(\mathbf{s}), V^s(\mathbf{s})\}_{t=1}^{R-1}$, $\{W^r(\mathbf{s}), W^i(\mathbf{s})\}_{t=R}^{T}$, government purchases and prices $\{G, w, r\}$, per capital stocks $\{k, \tilde{Y}\}$ and a constant distribution of people Ψ_t over the state variables $\mathbf{s}$ such that

1. At the given prices and tax rates, household policy functions $c(\mathbf{s})$, $a'(\mathbf{s})$, $k(\mathbf{s})$ and $j(\mathbf{s})$ solve household's decision problems in equations (1), (2), (3), (4), (5), (6) and (7) in the paper.

2. At the given prices, firms maximize profit choosing their inputs, with a rental rate r exogenously given and a wage given by equation (10) in the paper.

3. Total liquid savings in the economy equal the sum of total capital employed in nonentrepreneurial and entrepreneurial sector.

4. Self-employed use their own labor. The sum of labor supplied by workers in formal and informal workers L equals the total labor employed in the nonentrepreneurial production.

5. Goods and factor markets are cleared.

6. The government's budget stated in Equation (8) is balanced.

D Results continuation

D.1 Other economic indicators

Table 25: Summary of indicators for counterfactual economies

Indicators	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
capital-output ratio	3.66	1.70	1.69	1.72	1.72	1.72	4.43	1.57
Fraction of elderly								
working	46.7	70.0	70.8	70.2	65.5	70.0	47.1	49.8
with social pension	19.8	49.3	49.6	19.6	21.5	19.6	3.9	32.7
Fraction of workers in								
Individual accounts	19.19	-	-	-	-	-	32.40	-
PAYG	14.06	-	-	-	-	-	-	36.31

Note: Economic indicators for benchmark economy (1), economy without contributory pension system experiment 1: in partial equilibrium (2), no pension system in general equilibrium (3). Experiment 2: in partial equilibrium (3), no pension system in general equilibrium increasing benefits of non-contributory system (4), no pension system in general equilibrium reducing income tax (5). Economy with only an individuals account pension system in general equilibrium (7), economy with only a PAYG pension system in general equilibrium (8).

D.2 Summary of transition matrix

Table 26: Transition probabilities into formal jobs from informal workers by education level

Model	Benchmark	*No contributions*		Individual accounts	PAYG
		PE	GE		
	(1)	(2)	(3)	(7)	(8)
Less than high school					
Formal worker	14.4	15.2	15.1	14.2	15.2
Informal worker	62.8	62.1	62.2	63.0	62.1
Informal self-employed	22.8	22.7	22.7	22.8	22.7
High school completed					
Formal worker	16.3	18.7	18.4	15.8	18.2
Informal worker	65.5	63.1	63.4	66.0	63.6
Informal self-employed	18.2	18.2	18.2	18.3	18.2
More than high school					
Formal worker	21.2	25.7	25.5	20.0	26.2
Informal worker	65.2	60.9	61.1	66.5	60.4
Informal self-employed	13.6	13.4	13.4	13.6	13.4

Note: Transition probability to transition to formal jobs from an informal job by education level for benchmark economy (1), economy without contributory pension system in partial equilibrium (2) and general equilibrium (3), economy with only an individuals account pension system in GE (4), economy with only a PAYG pension system in GE (5)

D.3 Results from the analysis of the design

Results of changes in labor force composition by pension system in partial equilibrium.

Table 27: Labor force distribution across sector status according to contributory pension scheme in partial equilibrium

Model	*both*	*only*		*only*	
	Benchmark (1)	Individual accounts(7)	% Δ	PAYG (8)	% Δ
		Overall			
Formal worker	33.2	33.2	*-0.3*	33.6	*1.0*
Informal worker	35.0	35.1	*0.1*	34.8	*-0.6*
Informal self-employed	31.7	31.8	*0.1*	31.6	*-0.3*
		Less than high school			
Formal worker	24.3	24.2	*-0.1*	24.3	*0.2*
Informal worker	38.1	38.1	*0.1*	38.0	*-0.1*
Informal self-employed	37.7	37.7	*0.0*	37.6	*-0.1*
		High school completed			
Formal worker	30.7	30.6	*-0.5*	31.0	*0.9*
Informal worker	35.8	35.9	*0.3*	35.6	*-0.6*
Informal self-employed	33.5	33.5	*0.1*	33.4	*-0.3*
		More than high school			
Formal worker	44.0	43.9	*-0.2*	44.6	*1.4*
Informal worker	31.5	31.5	*0.0*	31.1	*-1.3*
Informal self-employed	24.5	24.6	*0.3*	24.3	*-0.8*

Distribution of worker's job status for benchmark economy where workers choose a PAYG or individual accounts system (1), economy with only an individuals account pension system in PE (7b), and economy with only a PAYG pension system in PE (8b). First three rows correspond to the overall economy, the following rows provide results by education level. % Δ is the percentage change with respect to (1).