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

Carla Moreno [†]

November 1, 2021
Job Market Paper
(Latest version here)

Abstract

This paper studies the impact of pension systems in economies with informal labor markets. When the government can only regulate the formal sector, payments to social protection programs are mandatory for workers in formal jobs. Thus, contributions to a pension system impose a liquidity constraint only on formal workers. I develop a heterogeneous agent life-cycle OLG model where informality arises endogenously as workers choose their optimal working sector each period. Additionally, formal workers can choose to either contribute to a pay-as-you-go or an individual savings account pension system, while the government finances a non-contributory means-tested pension for the poor and uncovered elderly. In an economy with income uncertainty, workers with a binding liquidity constraint are better off choosing an informal job due to the required contributions formal workers must make to their chosen pension system. 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, regardless of the pension design. The number of elderly in the non-contributory social pension expands but the government has a bigger tax base of formal workers to offset financing this increase.

Keywords: Savings, Social Security, Pensions, Informal Labor, Latin America

JEL codes: E21 E26 E27 E60 H31 H55 J21 J46

[*]I am grateful to Kaiji Chen and Karen Kopecky for their guidance and valuable advice. Additionally, I would like to thank David T. Jacho-Chavez, Federico Mandelman, Toni Braun and participants of SEA 90^{th} conference for their helpful comments. I would also like to thank all workshop participants at FRB of St. Louis for their comments and questions that contribute to improve this paper. Responsibility for any errors is mine.

[†]Department of Economics, Emory University. E-mail: carla.moreno@emory.edu

1 Introduction

In this paper we evaluate how pension system designs impact workers' choices to be informal. Informal job are, to a great extent, unregulated by the government; thus, by choosing informal labor, workers avoid paying taxes, social security contributions, and requirements to comply with regulations. The ILO (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 situations where a large portion of the elderly population will retire without a pension (Frölich et al., 2014). However, from the workers perspective, pension systems do not provide enough incentives for them to choose formal jobs over informal jobs when given the opportunity. For some workers, a mandated income contribution for retirement could be considered a disincentive to enter the formal sector. Even with lower-paying jobs, in an economy with earning risk, workers might find informal labor attractive when avoiding contributions brings them higher liquid income available for current consumption or to icnrease liquid savings.

This study seeks to explain how much of the distribution of informal labor is driven by incentives originating from the structure of the pension scheme itself. In economies with informal labor, does the presence of contributory pension systems have an effect on the labor market composition? and if so, what is the mechanism through which they are affecting this decision? Expanding on these questions, we will then evaluate the consequences of different pension system designs in mediating workers decisions.

This paper uses Peru as a case study because it is representative of other developing economies in significant ways. First, Peru's economy holds high levels of labor informality. Second, it presents workers with a choice between two of the most widespread contributory pension systems: individual accounts (defined-contributions) and pay-as-you-go (defined-benefits). Finally, like many countries facing similar problems, 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.

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

To quantify the impact of the pension system in the worker's decision between a formal or informal job, we build a heterogeneous agent life-cycle overlapping generations (OLG) model where informal labor is endogenously determined by workers each period. In our model, an individual chooses between working as a formal worker, 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 in two categories (informal workers and informal self-employed) to account for the different motivations in job choice and dynamics observed in the informal labor market. This feature of the model will let us capture the impact of changing the design of the pension system on informal workers with comparable formal jobs and on self-employed workers that do not find formal jobs attractive initially. Our benchmark model considers income tax and contributions to the pension system only in the formal sector. In the mandatory contributory pension system, formal workers choose between enrolling in either an individual accounts system or a pay-as-you-go (PAYG) system. Additionally, The government provides a non-contributory pension for all qualifying poor elderly that works as a consumption floor. Thus, the model has the potential to evaluate effects on labor markets with informality in economies where both system are available, PAYG is the only system or when individual accounts system is the only option; as well as the effect of a complementary non-contributory pension. With this set up, we introduce a two-asset economy similar to Kaplan et al. (2014) where 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 that working period. Mandatory contributions for retirement seek to insure workers for longevity risk at the expense of reducing current consumption and precautionary savings. For some workers the liquidity constraint is binding and they will be better-off in an informal job. We discipline the model by targeting key labor market features 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).

The findings of this paper are organized in two parts. The first part, explores the outcomes of an economy without a contributory pension system and the second part compares the particular impacts of the two types of contributory pension system designs.
We find that when we remove the contributory pension system the level of workers choosing formal jobs increases. 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 preferred informal jobs over higher-paying formal jobs in order to avoid contributions and keep more liquid income. However, without a contributory pension system, a higher number of workers rely on non-contributory social pensions; thus, putting pressure on the government budget. In general equilibrium, this 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 balance. This yields gains in formality rates and welfare in general equilibrium.
Second, we show that the non-contributory pension system has limited distortionary effect on the labor composition. We demonstrate that, in economy with informal labor, a pension system that solely relays in non-contributory means-tested social pensions is welfare improving.
Third, in scenarios where workers do not have a choice over which pension system to choose, the formality rates in partial equilibrium are similar to the benchmark economy. This happens independently of whether the system is a PAYG only economy or an individual-accounts only. Demonstrating that the liquidity constraint mechanism is present in both types of contributory pension systems and is the main driver affecting the workers' sectorial choice. In general equilibrium, a PAYG system that is mandatory to all workers and has minimum and maximum levels of benefit, is prefer. It would include high-income workers that otherwise would not choose this system, collecting higher contributions. The government consolidated budget receives a significant increase: payroll taxes, as a proportion of income, are collected from all formal workers, but pensions paid are conditioned to requirements in years of contribution and capped at a maximum. This results in higher income towards the government budget and a reduction of income tax generating a more attractive formal sector. Thus, an economy with only a PAYG system produces higher formality rates and welfare gains in comparison to the benchmark economy.

This paper belongs to categories of literature regarding informal labor decisions and evaluation of social security systems. First, this study fits to the set of recent literature that uses microdata to model informality as a function of workers' decisions every period. A recent study by McKiernan (2021) uses a heterogeneous OLG model to study the effects of going from a PAYG to an individual accounts system in labor markets with informality. With Chile as the case study, she finds long-run welfare gains from the privatization of the system. However, her results also reveals that the PAYG payroll tax is

less distortionary in a labor market with informality, consequently reducing the welfare gains from the reform. Contrary to McKiernan, the results herein argue that both systems, public PAYG and private individual accounts, create distortions in the labor market by only imposing contributions toward retirement on formal workers. In order to capture the impact individual accounts on the labor market, we use a two-asset approach that accounts for contributions to the private pension system as savings towards an illiquid asset.

In a study more closely aligned to ours, Joubert (2015) models households' decisions in an individual accounts pension system. Both studies, ours and Joubert's, use Latin American countries with high informality, Peru and Chile respectively. Joubert shows that increasing the contribution rate encourages informality and increases the size of the informal sector. My paper expands on this framework by considering two types of informality: informal worker and informal self-employed. This allows us to incorporate exogenous job offer arrivals and job separation probabilities according to sector and type of worker. Thus, my results incorporate the difficulty of accumulating pension benefit in economies where workers face different degrees of job rationing and skills. Additionally, my findings distinguish effects between economies with only individual accounts system, PAYG or a combination; as well as the interaction of a non-contributory pension system.

Other frameworks that sought to explain the informal sector focus on firm's choices. Meghir et al. (2015), Ulyssea (2010) and Bosch and Esteban-Pretel (2012) find that firm's formal entry cost and government enforcement are leading informality factors modelling Brazil informal sector, while Almeida and Carneiro (2012) found that for lower paid jobs higher inspections might make formal benefit, like minimum wage, attractive. Amaral and Quintin (2006) explore the relevance of access to outside financing; while, Sarte (2000) modelled the effect of bureaucracies costs generated by rent-seeking officials on the firms decision. However, Galiani and Weinschelbaum (2012) argues that the informal sector should be modelled as a result of both households *and* firms making decisions over labor. This paper excludes from modelling the firm's decisions focusing in workers' decisions but incorporates labor demand with exogenous job probabilities to capture the potential effects of these factors in job rationing. The main contribution of the paper comes from understanding the mechanism and quantifying the impacts that mandatory contributions generate in formality and welfare. Nevertheless, we acknowledge that additional variables such as income taxes (De Paula and Scheinkman, 2010), unemployment insurance (Cirelli et al., 2021) (Bosch and Esteban-Pretel, 2015), and others, might be further reasons to pick working in one sector over the other.

This work also contributes to the social security literature. The privatization of the Social Security in the US has been evaluated with studies supporting long-run welfare gains (Feldstein, 1995) (Fuster et al., 2007). Others contemplate that those results are contingent on factors like the openness of the economy, annuity market, matching programs, idiosyncratic earning risks and others (Nishiyama and Smetters, 2007) . Evaluations for Latin American, where pension reforms already took 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 by evaluating a country with both parallel systems; offering welfare comparisons between a private system, a PAYG system or no contributory system at all, in the context of high informality. 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, we show that this distortionary effect is also present in individual accounts systems and the extend of the distortion is not only restrained to consumption allocation but also formal/informal occupational choice along the life-cycle for workers in economies with informal labor markets. Our results follow Conesa and Krueger (1999) observations, PAYG systems are favor in economies with income uncertainty and heterogeneity due to its redistributional effects, this effect is stronger in markets with informal labor that adds heterogeneity in income processes. Finally, our results align with Braun et al. (2017) that found welfare benefits removing the contributions to social security and sustaining a means-tested social insurance programs for the old. This paper shows that, additionally, in economies with informal labor, formality rates increase enhancing the welfare gains of removing pension system contributions.

2 Case study of Peru

This paper uses Peru as the case study of a country with high informality levels, estimated as 66% of the labor force, and a pension system design with contributory and non-contributory features. Peru is located in Latin America with an average real GDP growth rate of 4.5% in the past decade and a population growth of 1.2% on average over the same period (BCRP, 2021).

2.1 The data

This paper uses two types of dataset 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. First, quarterly survey results from years 2011 to 2017 weighted for national representative estimates[2]. And the second source to estimate the evolution on critical variables in the model is two waves of five-year panel survey results, where the first wave covers the years 2011 to 2015 and second wave follows individuals from years 2014 to 2018.
Estimations and analysis of the working force sector will focus in the subsample of workers in a range age between 20 to 65 years old, with 65 as the retirement legal age in Peru. The employed workforce represents approximately 70% of the total population in the data and 90% of employed are in the age range 20-65

The identification of an informal worker in the data is process creating a binary variable for formality. This variable takes the value of 1 if the employed worker contributed to a pension system (private or public) in the previous or current month when the survey was taken. The variable takes the value of zero if there was no contribution, that corresponds to the definition of an informal worker. Workers differ in some key characteristics according to their formality status. Formal workers have in average higher education, higher income and are working more hours per week. Having higher education increases the likelihood of getting higher paid jobs; thus, higher income. While the proportion of self-employed and female workers is higher within the informal workers.

According to occupation, informal workers can be classify in two groups, non-agricultural labor or agricultural labor. This distinction is usually made given the lack of formal jobs in agriculture. In Peru, 97 % of agricultural workers are classified as informal, which correspond to 25.7% of the total informal workers. Likewise, agricultural labor is found in rural areas where there is less formal jobs offered and lower financial inclusion. To understand workers' behavior and decisions in markets with informality, the scope of this study centers non-agricultural labor. The main occupations in the no-agricultural informal sector are commerce, transport and sales force.

[2]The total number of individual observations is 576,066 across 28 quarterly period; nevertheless, statistics about savings behavior are available since 2015 (12 quarters).

2.2 Labor market facts

In this section we cover some labor market facts for non-agricultural male workers in the Peruvian economy. For these workers, Maloney (2004) and Bosch and Maloney (2010) find the existence of voluntary entry to the informal labor market where an informal job is not understood as a residual or inferior type of job. The informal sector encompassed informal workers for a firm and informal self-employed individuals a group that also avoids contributions and is highly unregulated. Workers with higher education are concentrated in formal jobs as shown in Table 1. We will see that formal jobs attract more productive workers providing a wage premium in comparison 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: Weighted average participation by sector across education from ENAHO panel survey INEI (2018) for sample of male workers within 20-64 years old in non-agricultural jobs. Waves correspond to years 2011-2015 and 2014 - 2018. Robust standard errors in parentheses

Perry et al. (2007) found that informal self-employed workers obtain higher earnings, value flexibility more and obtain higher satisfaction that what they would get working for a firm. Maloney (2004) shows that majority of entrepreneurs in Brazil and Mexico do not want a formal job. Earle and Sakova (2000) evaluated for a set of transition economies that self-employed have different characteristics than employees and might follow self-selection into self-employment given individuals comparative advantage as entrepreneurs. However, in some cases it might also be due to lack of opportunities. These motives to carry work in the informal sector differ from informal employees for a firm. Some formal job seekers are waiting in an informal job for an opportunity to transition into a similar formal job (García and Badillo, 2018). While, young workers look to gain experience and test qualifications in the informal

sector (Perry et al., 2007), as informal work can be understood as an screening mechanism to proof their skills (Cano-Urbina, 2015).

Using quarterly survey data (ENAHO) from 2011 to 2017 to study the Peruvian labor market, we find results consistent with findings in the literature (Pagés and Stampini, 2009), informal jobs have in average lower wages than formal jobs. Table 2 shows that this fact is present across education levels and for the two types of informal job. Meanwhile, 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: Bootstrap standar errors in parentheses. Average real monthly log income before taxes and deductions for non-agricultural males between 20 to 64 years old. ENAHO weighted quarterly survey from 2011 to 2017 (INEI, 2018).

Even with a wage premium in formal jobs, informal job offer are still competitive for a group of workers. Behind average income and wage differential. when observing the income distribution between formal and informal workers, both working as employees, we see that there is a significant overlap. This overlap expose the presence of more parallel labor markets with incentives and gains beyond just earnings. Evidence of small or no wage premium for the formal sector is also reported for other Latin American countries (Pratap and Quintin, 2006).
The income distribution in Section A.1 of the appendix presents distribution of informal wages with wider ends, where informal jobs contain higher number of workers with very low earnings. One factor contributing to the higher variance in informal jobs is the lack of a requirement for minimum wages in

these jobs. On the other hand, in the more regulated sector, formal workers' income obey a federal minimum law. Nevertheless, Boeri et al. (2011) show that for Brazil changes in the minimum wage law are translated in changes in the informal sector wages too. This link between sectors earnings, called the "lighthouse" effect, keeps the wage differential between sectors contained and can make an informal job offer competitive. This feature of the income distribution also supports the modern view of the informal sector as an attractive sector for a group of workers (Maloney, 2004). In countries where benefits that require a contribution from a formal wage are low perceived, a formal job does not have a regarded advantage (Oviedo et al., 2009). However, the gains from the informal sector are not always monetary. Packard (2007) includes factors as moral hazard, present for present consumption or favoring other type of savings as some reasons to skip contributions.

The different nature of the sectors and how they related to each other is also noted in the workers' transition between these three types of work. Table 3 summarizes the annual transition probabilities between sectors. First, across education levels informal workers and informal self-employed have distinctive probabilities of transitioning. The reduced probabilities of moving from a self-employment to a formal job are consistent with the estimates for Argentina, Brazil and Mexico by Bosch and Maloney (2010) and sustains the separation of informal labor into two types with different behaviors. Some informal workers are collecting experiences and skill to transition to a formal job when given the opportunity. For self-employed individuals, the investment required (either on capital or abilities) makes transitions out of the sector less attractive. Additionally, the lack of job separation for individuals working as self-employed provides 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 transition between sectors by education level estimated from ENAHO panel survey 2011-2015 and 2014 - 2018 INEI (2018) for weighted sample of male workers within 20-64 years old in non-agricultural jobs.

2.3 Retirement facts

With a limited social protection system and a risk of meager pensions, some individuals would rather extend their working life beyond retirement age. In Peru, workers are eligible for retirement at 65 years old; nevertheless, is a common practice for retirees to continue a working life as informal workers. In Table 4 we followed the status of workers in 5-year cohorts after reaching retirement age. As workers continue to age, those who were part of the formal labor force showed the most significant change in behavior after retirement. While workers who were previously informal showed a gradual transition into retirement, formal workers rapidly transitioned to informality or outside the

labor force. For this group of workers, the incentives to change status has two explanations linked to the pension system; first, the now available access to a pension generates a new source of income for individuals that accumulated this benefit over their working years. Second, for formal workers with smaller or insufficient pension benefits, an informal job would bring them higher liquid income to complement their pension benefits.

Table 4: Elderly occupation by age group

Age cohort	Non-working	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: Weighted average from ENAHO panel survey INEI (2018) for sample of male retirees from non-agricultural sector. Waves correspond to years 2011-2015 and 2014 - 2018. Robust standard errors in parentheses.

The probability of transitioning between sectors is diminishing with age for the old generations as observe in Table 5. Furthermore, the major part of the changes are occurrences of old workers leaving the labor force. For individuals over 64 years old that are not working, returning back to work is unlikely. For the age cohort of 65 to 69 years old, their probability of going back to work next period is 13.6% and it reduces to 7.9% for the following cohort. As expected, this probabilities decrease rapidly with age.

Table 5: Probability of changing status after retirement age

Age cohort	For non-working 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: Probability of changing status next period conditioning on previous working status for elderly workers organized in 5-years cohort. Weighed average from ENAHO panel survey INEI (2018), 2011-2015 and 2014 - 2018.

3 Pension System Design

The definition of labor formality commonly followed in the literature categorizes workers as informal if they are not covered or insufficiently covered by formal arrangement i.e. contracts, benefits or social protection (OECD and ILO, 2019). Along this study we observe workers' formality status based on their contributions to the 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 understand the mechanisms impacting the formality decision, the following section first describes the pension system schemes we use in the study case to later expose the channels. The Peruvian system works with two parallel schemes serving as a baseline to study the impact of two most popular pension designs in Latin America on informal labor.

3.1 Peruvian Pension System

The Peruvian pension system has a contributory scheme enforcing mandatory contributions for retirement to formal workers. That is, 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 of the system is restricted to formal workers. The pension system provides to the workers with the option to choose one of the two available pension schemes. The first alternative 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, and the second is an individual accounts or defined-contribution plan that is managed by private managers. The one-time

decision to enrol into a public or private pension systems is perform at the worker's first formal job [3] where the default option is the private system. The two types of systems are popular and found in many countries around the world; however, both mandatory schemes working in parallel or competing for participants is rarely observed and particular to some countries in the Latin American region. This characteristic is helpful to examine individually the achievements of each scheme under labor informality.

The public system has younger generations financing the pension of the old generation following a PAYG. In the year 2020, 38% of the affiliates to the pension system are enrolled in the public system and only 45% made contributions that same year. Mandatory monthly contributions are 13% of the salary; however, there is no management fee. To have access to a pension the worker must reach the retirement age of 65 years and had contributed for at least 20 years. The pension is defined with a 40% replacement rate that considers the average of the salary from the last 5-years. Nevertheless, this system provides a minimum pension benefit as well as a maximum.

The second option in the contributory scheme is to contribute to the private system, where the pension is a function of the worker's monthly contributions to its individual account. Here 10% of the salary is deposit in the worker's individual retirement account. Besides the contribution, the workers 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 4 pension fund administrators or AFP (acronym in spanish). At 65 years the worker has access to his pension savings in one of three alternatives: to receive a monthly pension as schedule withdraws of their individual account, to buy an annuity, or to withdraw the 95.5% of their pension fund.[4] One characteristic that impact the attractiveness of this system specially for lower-income workers is the lack of a minimum pension guaranteed. In the defined-contribution system the pension level is a function of the worker's life-

[3]The decision is considered a one-time decision because a worker that chooses initially the PAYG system can later decide to transfer to the defined-contributions system but the reverse is not possible.

[4]Since May 2016 new retirees can withdraw up to 95.5% of their fund. In December 2019, the number of new retirees accessing a monthly pension was 115 while, for the same month, the flow of affiliates withdrawing up to 95.5% of their individual account was 6,418 (Super Intendencia de Banca, 2018).

time salary and financial market returns. The annualized real return rate was 4.5% in average for the last 5 years[5].

Contributing to the system is optional for self-employed and informal workers; which happens to be the largest sector of the working force. As result only a small portion of the elderly population is covered by either of the two contributory plans. Table 6 summarizes the current coverage rate of the system where more than half of the elderly population is not receiving a pension or monetary transfer from any system.

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

Pension scheme	Contributory		Non-contributory	
	Private	Public	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 the pension coverage to the rest of the elderly population drove reforms to the system in different countries. In Latin America the major extension to the coverage came from the implementation of non-contributory pensions with at least 15 countries in 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 in the people of retired age and living under extreme poverty providing them with a monetary pension transfer and free access to the Integral Health Insurance Program (MIDIS, 2021). The program extended the pension coverage to another 20% of the population older than 65 years; however, the benefit is only a 27% of the minimum wage (about US$ 70) paid out once every 2 months.

[5]Average real rate from the private system from January 2015 to December 2020 for Fund type 2, the most popular type of retirement fund with 91% of the affiliates.

3.2 Pension system channels

Each pension system design introduce different incentives affecting the worker's decision over an informal or formal job and the overall size of the informal labor. This study explores the different mechanisms and impact of these interactions in the three most extended types of pension schemes, individual accounts, PAYG and a non-contributory social pension.

3.2.1 Individual accounts (defined-contributions)

Every period, workers have to contribute a minimum percentage of their labor income towards their retirement. The accumulated retirement-savings are high-return assets; however, only available to the worker once she reaches the retirement age. Thus, following Kaplan et al. (2018) workers in an individual account system hold retirement savings as illiquid asset[6]. The mandatory contribution of income towards an illiquid asset is not optimal for all households. For low-income household, a minimum contribution towards retirement savings reduces disposable income affecting the worker's utility negatively. Household that are income-constrained would preferred a job in the informal sector with the risk of lower salaries but potential higher disposable income each period. Furthermore, a formal job with contributions towards an illiquid asset imposes also a liquidity constraint binding for workers that initially took a formal job. For example, workers that accumulated significant levels of illiquid asset but are subject to a lower income would rather take an informal job next period, avoiding further contributions.
Individual accounts for retirement keep accumulating returns even if the worker does not actively contributes. This feature benefit 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 more infrequent contributions translate into meager pensions for some workers in an individual account

[6]This definition for illiquid assets assumes that the transaction cost for withdrawing from their retirement accounts during working periods is high enough that precludes any household access to it before retirement.

system. In the presence of labor informality and without a minimum pension guarantee, an individual accounts system might failed to insure all enrolled workers. On the other hand, highly productive high-income workers would preferred to take advantage of the greater salaries in a formal job and the higher returns in their retirement savings. For these workers with a non-biding 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 to a pension system are also subject to a liquidity constraint and face the same trade-offs as the ones in an individual accounts system. Nevertheless, the pension is not proportionate to their contributions. Requirements for collecting a pension in this systems involve a minimum number of years contributing. This requirement deters workers from taking informal jobs before reaching the number of years, independently of income level. This system introduces a minimum pension benefiting low-income workers; however, the chance of getting no pension at all is still higher for low productivity workers. With lower probability of keeping or getting a formal job offer, these workers have a higher risk of not meeting the requirements at the end of their working life in order to get a pension.
High productivity workers face a different trade-off to be formal if enrolled in a PAYG system. In this case, the existences of a maximum pension level will discourage high-income workers to contribute as they could save a higher amount of assets to be use during retirement while working in an informal job.

3.2.3 Non-contributory pension (means-tested social pension)

Qualification for this non-contributory pension include not receiving other type of contributory pensions and living under a poverty (wealth threshold). Workers enrolled in an individual account system will not qualify; although, workers enrolled in the PAYG system that did not reach the requirements are able to qualify. In other words, having a social pension not only provides a minimum pension to elderly under poverty risk but also provides a safety net for low productivity workers that work for short periods in formal jobs. Having a non-contributory pension makes the PAYG system a more attractive option for low-income workers or workers with low probability of keeping a formal job.

Additionally, a non-contributory pension also provides protection with a pension for all informal workers that qualify for one. This social pension creates incentive towards keeping 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

A model incorporating the mechanisms affecting decisions over formality are postulated in this section. The framework is an extended Roy Model allowing 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 incomplete market and a contributory pension system.

4.1 Model Description

Demographics.— The economy is occupy 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 up to one. Households have two stages in their life: Young and Old. Young households are composed by working individuals with ages from $t = 1, 2, ..., R-1$. Old households are made by 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 accumulates with a return given by the parameter ϱ. Illiquid assets yield a higher return but they are only available at the end of the working life in the form of a pension. Returns are exogenous in the model and borrowing is not allow.

Pension system.— The economy has a contributory pension system where, 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 accounts.
In the *individual accounts* or defined-contributions 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, independently of the individual's labor status.Workers in this private system receive a pension in 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 to all workers by z_{min}.The pension is calculated with a replacement rate μ over the average income of the last 5 working periods in the formal sector but subject to a 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 elderly 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; each working 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 face in labor markets with informality. The worker's probability of finding or keeping a formal job $\gamma^f(j, e)$ or an informal job $\gamma^i(j, e)$ are 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.

Giving 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.— 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 for efficiency unit of labor services, w, independent of the workers 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. This also depends on the workers age t, education e, sector experiences (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 according $y^s = \theta k^\alpha\ \Omega^s(t, e, l, \varepsilon^i)$. This 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 correspond to higher average and marginal returns from capital.

Uncertainty.— Individuals face two type of risks during their life. While working they are subject to earning uncertainty and upon retirement age, they endure survival uncertainty.

Earning risks exist 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. The earning shocks ε^j follows an age-invariant

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

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 their age and is specify 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. They enter each period with liquid assets a and accumulated retirement savings as illiquid assets $\tilde{Y}$ or years of contribution z in the PAYG system , accordingly to 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 observe current labor productivity shocks by sector ε^f and ε^i. Every 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 make a decision on the optimal labor sector (formal, informal or work as informal self-employed) by choosing the sector that provides the higher 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 time of the model for young households at each age is divided in two steps: first, workers solve each household problem 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.

Formal Household Problem

As noted in Levy and Schady (2013), formal workers are the ones covered by social protection. In the model, the social protection layout is featured in the pension system. All workers start their working-life without a default pension system, $p = 0$. At their first formal job, workers preform a one-time decision choosing to enrol in one of the two pension systems: the defined-contributions system (privately managed individual accounts) $p = 1$, or the defined-benefits system (public managed PAYG) $p = 2$. The timing for this decision might be different between 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 of the pension system p the worker enrolled in.
Thus, the value function for a formal worker is set accordingly to 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 an 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 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 next period follows the law of motion for $\tilde{Y}'$ as 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 possibility of keeping the formal job or transition to an informal job. For tractability purposes, we simplify this decision with the assumption that given the offer from a formal job, formal workers will continue in their formal job. With $(1 - \gamma^f(f, e))$ the worker is separated from her formal job. Once separated the worker starts an informal job after a period of unemployment accounted by a decrease in their utility of $\nu_{f,e}$.

Therefore, workers of age $t < R$ with $p = \{1, 2\}$ face the following opti-

mization problem in the formal sector

$$\tilde{V}^f(\mathbf{s}) = \max_{a'} \Big\{ u(c) + \beta \Big(\gamma^f(f,e) \left(\mathbb{E}[\tilde{V}^f(\mathbf{s}')|\varepsilon^f] \right) + (1-\gamma^f(f,e)) \left(\mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i] - \nu_{f,e} \right) \Big) \Big\}, \tag{2}$$

$$\begin{aligned} & s.t. \\ c + a' &= (1-\tau-x_p)\, y^f - \mathbb{1}_{p=1}\{\eta y^f\} + (1+r)\, a \\ \tilde{Y}' &= (1+\varrho)\, \tilde{Y} + x_1 y^f \quad \text{if } p=1 \\ z' &= z+1 \quad \text{if } p=2 \\ a' &\geq 0. \end{aligned}$$

The formal sector is extra 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 offer is also increasing with education, then the risk of being affected by unemployment is smaller for this group. Additionally, the high income group would be less constraint and could take advantage of a individuals account pension system with higher returns over this illiquid asset.

Informal Household Problem

The informal sector pays a wage of y^i without enforcing workers to pay taxes τ, nor contributions to the pension system x. Even thought this sector has lower wages compare to the formal sector, they 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 over 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 next period with probability $\gamma^f(i,e)$ depending on their education e. Given a job offer form the formal sector, workers choose between taking the job offer, continuing in their informal job, or to transition 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 endure their informal job with probability $\gamma^i(i,e)$. In this scenario workers are able to choose between keeping their informal job or to transition 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 in unemployment, reflected by a

decrease in their utility $\nu_{i,e}$.

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

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

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

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 rate according to the worker's sector status opens another channel affecting the worker's decision on labor choice. To focus on the mechanism impacting the workers decisions linked to the pension system design, in this study we will close the interest rate gap channel assuming the interest rate for liquid assets is the same across sectors.

Self-Employed Household Problem

Self-employed workers are not subject to contributions to the pension system x, and evade payroll taxes τ. Income is also more liquid in this sector but the income gap between self-employment and the formal sector will now depend also in the worker's entreprenurial ability θ. Self-employed individuals that are enrolled in the individual accounts system $p = 1$ continue to gain returns ϱ over their pension fund $\tilde{Y}$. Nevertheless, if 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 individuals in self-employment choose an 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 next period, a'. Then, the utility maximizing problem for the self-employed 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, this financial constraint to the entrepreneurs is evidenced in Bianchi and Bobba (2013). 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 avoiding taxes and contributions, thus; a greater opportunity to 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 possibility of returning to the labor market in subsequent periods. In which 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 probability of surviving an extra year given by Γ_t. All individuals at the retirement age R or older have access to pension benefits according to the pension system they contributed to: a benefit b if enrolled in the PAYG public system $p = 2$; otherwise, if enrolled in the private system $p = 1$, the pension is calculated with an annuity from the individual's retirement account balance $\tilde{Y}_R$.

Pension and transfers set-up

A person over the retire age R might be eligible for a pension or a monetary transfer given by the pension system design.

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

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

Individual accounts (defined-contributions) .– Retirees who participated in the private pension system $p = 1$ perceive a pension in the form of an annuity. The pension is calculated by the function $\zeta(.)$, that considers the markets 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-benefits).– Retirees who participate in the public pension system $p = 2$ need at least 20 years of contributions, $z_{min} = 20$, to access

to their pension. The system has a minimum, ϑ_{min}, and a maximum, ϑ_{max}, pension level independently on how much the retiree contributed during her working life. The pension benefit b is calculated based on the average wage of the last 5 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 years, they earn a 2% increase in their pension benefit for each additional year. Thus, the pension receive from the public PAYG system follows:

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

With a minimum pension guarantee ϑ_{min} in the PAYG system, workers with very small average contribution 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 discourage to contribute to the PAYG system that imposes a maximum pension ϑ_{max}.

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

Retirees might qualify to be recipients of a non-contributory social pension $\bar{c}$. The non-contributory pension is a mean-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. This 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.

Retiree's Problem

An individual retired from the labor force chooses next period liquid asset level a' to maximizes her utility, considering her future periods outside the labor

force and mortality probability. The decision is given by the following value function:

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

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

Informal Problem

A retiree that works in the informal market receives an income y^i but suffers disutility of working understood as a fix cost ϕ_t increasing in age . The worker maximizes utility choosing it's optimal liquid savings level a, with a value function as follows:

$$
\begin{aligned}
W^i(\mathbf{s}) &= \max_{a'} \left\{u(c) - \phi_t + \beta\, \Gamma_t \max\left\{W^r(\mathbf{s}'), \mathbb{E}[W^i(\mathbf{s}')|\varepsilon^i]\right\}\right\} \qquad (7)\\
&\quad s.t.\\
c + a' &= y^i + \tilde{P} + \bar{c}\,[\mathbb{1}_{(\Xi<M)}\mathbb{1}_{(\tilde{P}=0)}] + (1+r)a\\
a' &\geq 0
\end{aligned}
$$

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 to the non-contributory pension $\bar{c}$. The informal workers is still subject to an income risk from the informal sector ^{i} and a mortality risk with no access to borrowing. We assume that the informal workers always has an informal job available after retirement ($\gamma^i(i,e) = 1$), until they completely exit the labor force and this probability turns 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 finances 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

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

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 one when the worker i is enrolled in the PAYG pension system and $\mathbb{1}_{j=f}$ is one when current individual i is a worker in the formal sector $j = f$. Given that payroll taxes, and PAYG contribution rate and benefit levels are set to legislation and data in the country, we 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 produce 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 factors productivity and is fixed. All capital depreciates at a constant rate $\delta \in (0, 1)$ We 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:

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

that determines the liquid asset returns rate r and the wage per efficient unit of labor services,

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

4.6 Definition of Equilibrium

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

5 Estimation

To replicated key features in the Peruvian economy, we use sectorial income processes estimated from the Peruvian data and the model is parametrized to match a set of moments in this economy.

5.1 Income process

The income process for each sector was estimated using an weighted two waves panel data from the Peruvian national household survey (ENAHO) for years 2011-2015 and 2014-2018 (INEI, 2018), with representation at the national level. The data collected is annually and the sample is restricted to men between 20 to 64 years with non-agricultural jobs.

5.1.1 Formal and Informal workers income

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

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

Age profile χ consider also interactions between age and education, that in the informal sector signals experience. Informal jobs have a higher return in age with jobs that require higher in-job experiences rather than training. The individual specific effects Λ_t contemplate two main variables, education level and sector experience.

With a panel regression we are able to control the earning process in each sector by their 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 we find a positive effect in the wage of informal workers if the individual previous job experience was in a formal job. This expose a level of knowledge that is carried and valued in the informal job for workers with experience in the formal sector. We run external test and determined that the effect of coming from the formal sector had a lasting effect in the informal workers' wage until their third year. We also observed the opposite effect in workers transitioning from informal jobs into formal ones. They are affected from a lower wage in comparison with workers with same age profile and qualifications, exposing that experience accumulated in the formal sector

is more valuable in for both sectors.

Additionally of the existence of a wage premium in the formal sector, Table 7 shows 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

Our earning processes will use the coefficients here estimated for a log-linear transformation of the earning process. Some adaptations are made during the calibration. First, we 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

Self-employed production function contemplates entrepreneurial ability and physical capital as complementing 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}. Following McKenzie and Woodruff (2006) profit equation for entrepreneurs, that includes ability θ , total income comes from its return to capital and its age-education profile, such that

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

We estimated the effects of age variables χ and education e with a linear regression with results in Table 7. The estimation for the returns on capital and ability where obtained using a percentage of the constant of this estimation as a proxy.

First, we assume that the capital share in the self-employed production function α is 0.2 and depreciation δ is set to 10%. Second, we set two potential levels of entrepreneurial ability: high θ_H and low θ_L. We assume that individuals with θ_H are able to earn 20% over the average self-employed production earnings and individuals with θ_L will have earnings 20% below the average. Then we estimate that the earnings produced by the self-employed production function account for 20% of the constant estimated in column three of Table 7. Finally, we solved for the ability values $\theta = \{\theta_H, \theta_L\}$ that, given the optimal level of capital at 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

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

5.1.3 Earning risk

Income in any jobs is subject to earning risk that will vary according to their formality status. Earning risk follow a first-order autoregressive process, such that for each sector j the shock can be expressed as :

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

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

Then, we let workers withdraw simultaneously the shocks for 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 type of informal jobs: workers and self-employed. Lopez Garcia (2015) estimates this numbers with similar income process for formal and informal workers in Chile, that we will borrow for our model. They 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)

We use the discrete approximation of the Rouwenhorst method proposed by Kopecky and Suen (2010), that has proven to preform well with highly persistent processes. First, using the information in Table 9 we decomposed 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). We then construct a 2-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 statistics used to characterize the moments of the Peruvian labor economy is restricted to the sample of male non-agricultural workers using averages from years 2011 to 2018. We used an initial guess on relevant parameters and compare them to the data estimated targeted. The process

for calibration is done by updating parameters values until the differences between model moments and targeted values is significantly small. Other group of parameters are set using direct estimates from historic averages for the same time period or obtained from previous literature. This section will cover both type of parameters: non-targeted and targeted.

Non-targeted parameters

Individuals are born in one of the three education levels e: Less than high school $e = 1$, Highschool completed $e = 2$ or More than high school $e = 3$, this includes any instruction after high school, technical, college, university complete or incomplete. Education is distributed following the average distribution of education level in 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 can live to a maximum age of 100. They can retire when they reach 65 years old, following the legal age for old-age retirement in the Peruvian pension system (SBS, 2021). After 64 years old the individuals are subject to a mortality risk Γ. The probability of survivable at each age are obtained from the Peruvian mortality tables (Instituto Nacional de Estadistica e Informatica, 2019) for males. The abbreviated mortality tables for 2015-2020 are available in 5-years cohorts and mortality is 1 when the individual reaches 100 years old. Using a linear interpolation, we estimated the annual survivable probability for individuals age 65 until the person reaches 100 and use it to provide the mortality probabilities 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 correspond 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%

[9]The importance of the gap in the interest rate by sectors has a higher relevance in a model with borrowing. Amaral and Quintin (2006) studied the informal market in Brazil finding the difference on access and cost of borrowing in the informal sector as a one of the potential arguments for the size of the informal economy.

(Super Intendencia de Banca, 2018).

The pension system design in the model gathers the most important features of the Peruvian pension system. In the PAYG system, contributions x_{public} to the system are 13% of the salary and pensions are calculated with a replacement rate μ of 40% after 20 years of contributions and a 2% pension increase for every extra year. The average wage $\tilde{w}_R$ used for the replacement rate 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 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 the salary. The AFP's management fee has fluctuated over the period of study around this value. A benefit of keeping a 3% management fee in the model is that both systems display a level of contribution that represents 13% of the disposable income each period. The current set up of this parameter helps to compare both system designs beyond their effect over current liquidity income. 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 the calculation.

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 mil. 2017 US dollars) over Capital stock (in mil. 2017 US dollars) using estimates from the Penn World table (Feenstra et al., 2015). As this ratio is increasing over time, estimate for 2019 is chosen as target. In the model capital is accounted as the stock of liquid assets plus the illiquid asset in the economy and income from all sectors

[10]The law requires to use the average salary for the last 5 years of contributions

are added up to determined the output in the model.
The percentage of retirees still in the labor force after retirement is obtained from the overall elderly working in table 4. The number is match in the model adjusting the disutility of working after reaching 64 years ϕ. This value is linearly decreasing with age to replicated the decline in participation observed in table 4. The means-target eligibility criteria 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 sector and education 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 targeting the labor force distribution. Job offer arrivals by sector use transition matrix as 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 model, the arrival of a job offer $\gamma(j, e)$ by sector j and education e in table 10 are calibrated targeting the transition matrix between sectors by education for the Peruvian

labor market. For tractability and due to the reduce 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 we adjusted the transition matrix estimated from the data to contemplate the transition opportunities presented in the model. The targeted transition matrix incorporates these cases 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 form ensures that the matrix of probabilities adds up to one and the transitions correspond to the choices available in the model. This simplification also let us 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 transited out of formality if they do not receive a job offer to continue (an exogenous separation). Table 11 describes the result of the the targeted labor transition matrix for the benchmark economy and 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 observed in Table 12, in particular the initial labor force distribution by education and as well as the transition matrix shown in Table 11. These two elements characterize the labor force in the model and provide 15 (5 for each education type) parameters that have to be discipline in the model simultaneously. The model is able to capture the key feature 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. We 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

We 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, we study two main set ups. In the first set up, we 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, we 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, we 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 formal jobs, formal workers receive more of their earnings in liquid. In this case, we are lifting the liquidity constraint introduced by a contributory pension system.

6.1.1 Experiment 1: Number of non-contributory recipients adjust

We remove contributions to a pension system from the economy and let the number of non-contributory recipients adjust if necessary. In the benchmark economy we 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, we keep the same threshold.

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 elderly receiving the non-contributory social pension also jumps from 20% to 49%. These results reflect a more vulnerable elderly population. Nevertheless, in terms of the working force, we see that higher liquid earnings in the formal sector attracts more workers. In table 14 we find a summary of the labor force composition showing an increase of 10.5% in the proportion of formal workers in an economy with no contributory system in partial equilibrium. Results differ by education level. With lower probability of job separation (lower unemployment risk) and higher returns from education in the formal sector, workers with more than high school education will find the new set up in the formal sector more attractive. Formality rates go from 44% to 49.7% of workers with more than high school education.

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

Model	*Both systems*	*Removing contributory system*			
	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 worker's job status for (1) benchmark economy, (2)PE economy without contributory pension system in partial equilibrium and (3)GE economy without contributory system in general equilibrium. First three rows correspond to the overall economy, the following 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 the working life, as shown in Figure 1. In early working years, income is lower for all types of workers leaving them more vulnerable to shocks and in higher need for liquidity. Thus, removing pension contributions in the formal sector will ease the entry for young workers with higher liquidity preferences. At the end of the 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, they provide higher possibility to accumulate liquid savings too. 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.

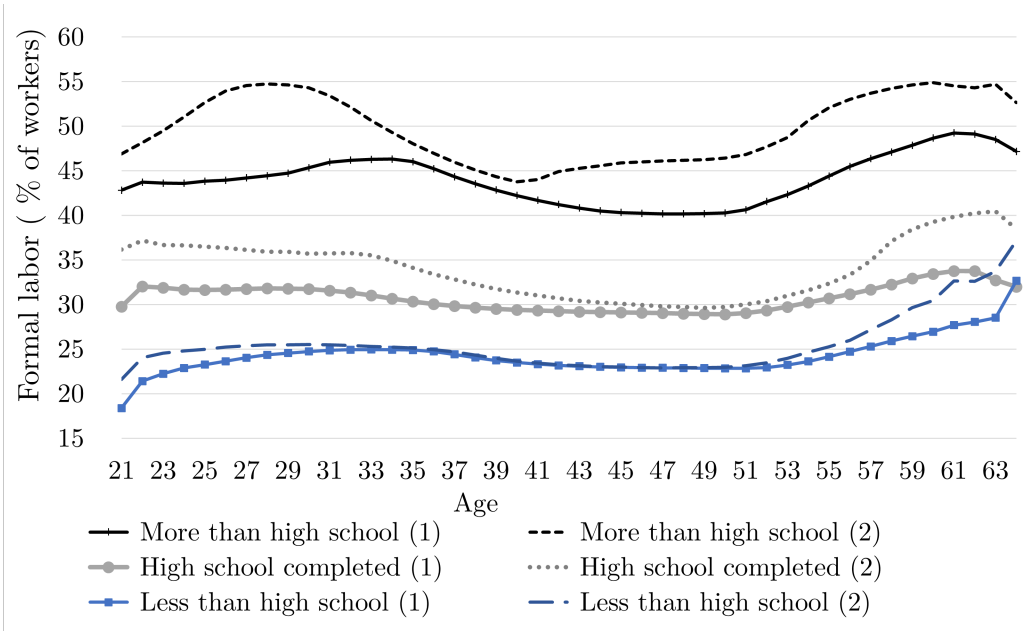

Figure 1: The figure shows the proportion of formal worker for each education level. The continuous lines show results for the benchmark model (1) and dotted lines show percentages for the economy without a contributory pension system in partial equilibrium (2). For all education levels, removing the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

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

Lower contributions makes formal offers more attractive for both, workers in informal jobs and self-employed individuals. Given that the transition to formality 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 self-employed worker is the highest. Following Mandelman and Montes-Rojas (2009) findings, these individuals are better off in entrepreneurial activities and differ from informal workers that are waiting for an opportunity to enter the formal job. In this case, removing contributions and making the formal sector more attractive will have lower effect in informal workers that were already

interested in moving to formality but will significantly increase the opportunity cost of being self-employed and encourage these individuals to transit to formal jobs. Similar results, where a drop in self-employed is the main driver that affects formality rates, are obtained by Narita (2020) for experiments reducing income tax.

A complete removal of the contributory pension system has an important impact on the size of the informal labor. Workers compensate the lack of social protection system with higher rates of elderly work and depending on government programs like the non-contributory social pension. These outcomes impact the government budget with further effects on formality; thus, the general equilibrium case is needed to provide a comprehensive analysis of the implications 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 benchmark economy with counterfactual without a contributory pension system. The non-contributory social pension program is financed from the consolidated government budget; then, in experiment 1 the government budget perceive an increase in transfers due to the new number of elderly accessing this transfers.

There are two offsetting effects affecting the government budget. On one hand, the number of participants in the social program more than doubled, increasing the cost of the program and expenses to the government. To keep the budget in equation (8) balanced, government should increase taxes. However, in economies with informality, taxes will disproportionately affect workers on formal jobs.

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 creating an increase in the level of income tax collections. These two effects compensate each other, such that the pressure to raise taxes, because of the higher means-tested transfers, is loosen and results in labor force composition in general equilibrium are close to the partial equilibrium results. A small increase in income tax is still needed, that reduces the gains from

removing contributions to the pension system. The results of this adjustment are observed in Table 14, where the percentage of worker in formal jobs has a modest reduction 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 in small percentage but gains from tax collection are significantly bigger 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 social pension, %	19.8	49.3	49.6

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

Welfare analysis

The impact of welfare from a complete removal of the contributory pension system differs by education level. The workers with higher education level 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 we observed in Table 14 this group has the highest increase in formal participation in response. However, higher formality rate implies that they will also be the most affected by changes in the tax level.

Table 16 provides a summary of both effects on welfare, partial and general equilibrium, for the average worker and by education level. Using the definition of welfare consumption equivalent variation, we 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 the 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 is 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 bigger tax base. This particular dynamic only present in labor markets with informality let the overall positive welfare effects of removing contributory systems extend to the general equilibrium. Results are slightly smaller than in partial equilibrium, 3.78%, with the higher change present in the most educated workers, that are in higher proportion formal tax payers.

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

In the following experiment we remove the contributory pension system, while keeping a target on the non-contributory social pension as 20% of the elderly population. In this case, we recalibrate the wealth threshold Ξ in partial equilibrium. The aim is to study the effects in an economy with a small means-tested non-contributory pension. We also extend the general equilibrium analysis to two cases: with changes in the amount of the means-tested

pension $\bar{c}$ and with changes 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, we 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. We 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 accounts

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

individual accounts or PAYG.

However, we observe a positive small increase in formality if the economy followed only a PAYG system. This effect is amplify in general equilibrium when the government budget and taxes are adjusted, shown in table 20.

Table 20: Labor force distribution across sector status according to 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*

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 GE (7), and economy with only a PAYG pension system in GE (8). 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).

An economy with only an individual accounts system deters some workers into taking formal jobs in comparison with a PAYG system. Poor low-income workers will have smaller contributions to their individual accounts balances and smaller pensions, in comparison to the minimum pension provided in an PAYG system. For this group, taking a formal job will make them liquidity

constraint and provide them with meager pensions. For some, they will be better off taking 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 incentives the entry for poor low-income workers. The addition of a minimum pension for an individual accounts pension systems is expected to increase formality rates. This exercise was executed by Todd and Vélez-Grajales (2008), proving that adding this feature to the pension system has a positive impact in formality for the case of the Chilean pension system.

The workers optimal pension system depends on the workers potential income level. From the benchmark model we observe that the average income level in formal workers enrolled in an individual accounts system is higher than for workers that find the PAYG optimal. The PAYG encourage the entry of low-income workers with a pension floor but inhibits high-income workers to choose this system because they could achieve higher pensions saving in individual accounts. In Figure 2 we can see that the average income according to pension system selected is significantly different at the beginning of the working life, when this decision is made for most workers.

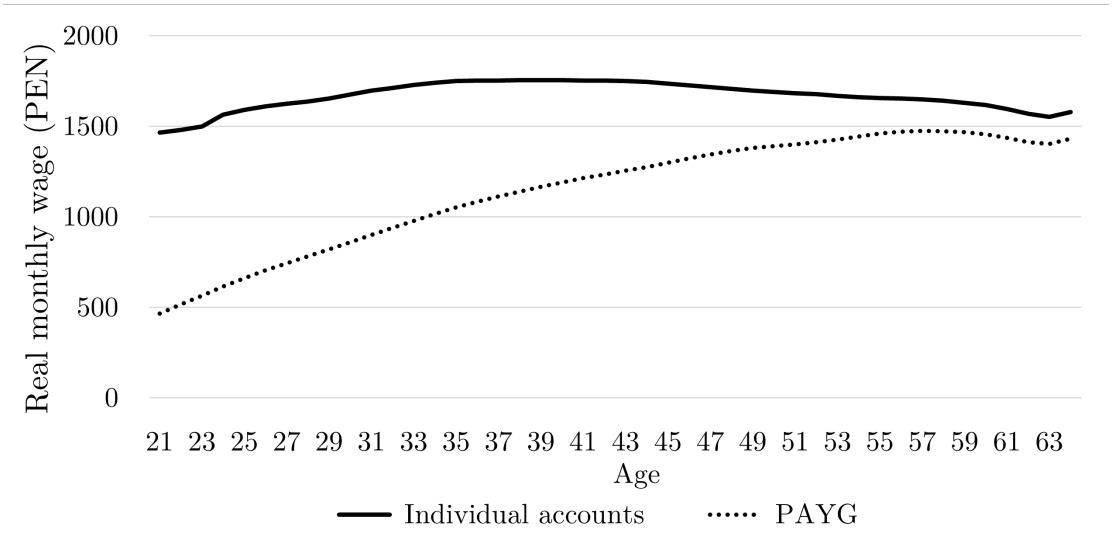

Figure 2: The figure shows average monthly income (in PEN) in the benchmark economy (1) for formal workers according to the pension system they contribute to. Individual accounts system are more attractive for high-income workers, with bigger contributions to their future self-financed pension. PAYG is preferred for low-income workers that rely on the PAYG minimum pension or social pension.

Welfare analysis

Welfare is also affected when workers are not given the capacity to choose their optimal pension system. Given the PAYG system is public managed, an economy with only a PAYG system has significant differences in the composition of the government budget. Thus, the following analysis for a case of an economy with only PAYG and an economy with only an individual accounts system is preform evaluating welfare effects in general equilibrium.

The risk-sharing and progressive nature of the PAYG system encourage more workers to enter to formality and increases consumption in 2.4% in an economy with a mandatory contributory PAYG system.

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 very small but negative change in welfare from an economy only with individuals account for retirement. In the benchmark economy most workers where choosing individual account system and high income worker self-selected into this system, limiting the potential redistributive attributes of the PAYG system for the benchmark economy. Gains from a PAYG only system, shown in column two, come mostly from their effect over taxes. Higher amount of contributions to the PAYG system are possible for two reasons: a bigger formal sector and the integration of high-income workers to the system.

With a requirement in the years of contributions in order to obtain a pension in the PAYG program and a capped maximum pension benefit, the payment of benefits of this program are not higher that the increase in collections.

In an economy with only a PAYG system, the government has higher collections while pension transfers are low resulting in the posibility to reduce 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.

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, a policy without a contributory pension system, like the one explored with experiment 1 or 2, provided higher welfare gains with an increase of consumption by 4%.

7 Conclusion

With an informal labor market, contributions to a pension system are not enforced equally to all workers. In fact, having to contributed a percentage of your income in formal jobs might discourage workers that have preferences for current liquidity to take formal job offers. To study the impact of this incentives on formality, we develop an heterogeneous agent life-cycle OLG model for an economy with informal labor markets and the two most popular contributory pension systems available (PAYG and individuals accounts), and calibrated it to Peru.

This paper finds that removing a contributory pension system increase formality rates in the economy and provides welfare gains to workers. This is true independently if workers have a preference for PAYG systems (defined-benefits) or individual accounts systems (defined-contributions). The increase in formality has an unintended positive effect in the government budget because it provides a higher taxable base. In this set up, the level of individuals relaying in non-contributory social pension also increases; generating an increase on government expenses from the higher number of transfers for the program. However, thanks to the increase on the number of formal workers, the government is able to collect more from income tax and balance the consolidated government budget without significant increases in income taxes.

Removing the contributory system would expand the taxable base due to the higher number of formal workers. When keeping fixed the number of elderly eligible to qualify to non-contributory mean-tested pension, the gov-

ernment is provided with an opportunity to increase the benefit of this non-contributory transfer or reduce income taxes with welfare gains for all. The model also demonstrates that non-contributory pension schemes have little influence in the structure of the labor market. They achieve their goal with limited disruption in formality.

Finally, this paper shows that in the benchmark economy, where workers can choose a pension system to contribute to, low-income workers preferred a PAYG system. An individual accounts system are chosen by middle and high income workers that can self-financed their retirement with individual savings. An economy where a worker can choose their system negatively impacts the financial stability of the PAYG system deteriorating the government budget. With high income workers contributing to individual accounts, the PAYG system looses its redistributional nature. On the other hand, an individual-accounts-only system do not generate incentives for low income workers to take formal jobs. This paper reveals that in markets with high informality a PAYG-only system increases formality and welfare in general equilibrium. Including high income workers to the PAYG system would increase collection and reduce the overall income tax, making the formal sector more attractive for all income-level workers.

References

Almeida, R. and Carneiro, P. (2012). Enforcement of labor regulation and informality. *American Economic Journal: Applied Economics*, 4(3):64–89.

Amaral, P. S. and Quintin, E. (2006). A competitive model of the informal sector. *Journal of monetary Economics*, 53(7):1541–1553.

Attanasio, O., Meghir, C., and Otero, A. (2011). Formal labor market and pension wealth: evaluating the 2008 chilean pension reform. *Institute for Fiscal Studies. Working paper.*

Bando, R., Galiani, S., and Gertler, P. (2020). The effects of noncontributory pensions on material and subjective well-being. *Economic Development and Cultural Change*, 68(4):1233–1255.

BCRP (2021). Series estadisticas. Report, Gerencia Central de Estudios Economicos.

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

Boeri, T., Garibaldi, P., and Ribeiro, M. (2011). The lighthouse effect and beyond. *Review of income and Wealth*, 57:S54–S78.

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

Bosch, M. and Esteban-Pretel, J. (2015). The labor market effects of introducing unemployment benefits in an economy with high informality. *European Economic Review*, 75:1–17.

Bosch, M. and Maloney, W. F. (2010). Comparative analysis of labor market dynamics using markov processes: An application to informality. *Labour Economics*, 17(4):621–631.

Braun, R. A., Kopecky, K. A., and Koreshkova, T. (2017). Old, sick, alone, and poor: A welfare analysis of old-age social insurance programmes. *The Review of Economic Studies*, 84(2):580–612.

Brown, J. R., Mitchell, O. S., and Poterba, J. M. (2000). Mortality risk, inflation risk, and annuity products. *NBER Working Paper*, (w7812).

Cagetti, M. and De Nardi, M. (2006). Entrepreneurship, frictions, and wealth. *Journal of political Economy*, 114(5):835–870.

Cano-Urbina, J. (2015). The role of the informal sector in the early careers of less-educated workers. *Journal of Development Economics*, 112:33–55.

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

Conesa, J. C. and Krueger, D. (1999). Social security reform with heterogeneous agents. *Review of Economic Dynamics*, 2(4):757–795.

Corsetti, G. and Schmidt-Hebbel, K. (1997). Pension reform and growth. *The Economics of Pensions: Principles, Policies, and International Experience*.

De Paula, A. and Scheinkman, J. A. (2010). Value-added taxes, chain effects, and informality. *American Economic Journal: Macroeconomics*, 2(4):195–221.

Earle, J. S. and Sakova, Z. (2000). Business start-ups or disguised unemployment? evidence on the character of self-employment from transition economies. *Labour Economics*, 7(5):575–601.

Evans, D. S. and Jovanovic, B. (1989). An estimated model of entrepreneurial choice under liquidity constraints. *Journal of Political Economy*, 97(4):808–827.

Feenstra, R. C., Inklaar, R., and Timmer, M. P. (2015). The next generation of the penn world table. *American Economic Review*, 105(10):3150–82.

Feldstein, M. (1995). Would privatizing social security raise economic welfare? Report, National Bureau of Economic Research.

Frölich, M., Kaplan, D., Kaplan, D. S., Pagés, C., Rigolini, J., and Robalino, D. (2014). *Social insurance, informality, and labour markets: how to protect workers while creating good jobs*. Oxford University Press.

Fuster, L., İmrohoroğlu, A., and İmrohoroğlu, S. (2007). Elimination of social security in a dynastic framework. *The Review of Economic Studies*, 74(1):113–145.

Galiani, S. and Weinschelbaum, F. (2012). Modeling informality formally: households and firms. *Economic Inquiry*, 50(3):821–838.

García, G. A. and Badillo, E. R. (2018). Rationing of formal sector jobs and informality: The colombian case. *Journal of International Development*, 30(5):760–789.

Holzmann, R. (1997). Pension reform, financial market development, and economic growth: Preliminary evidence from chile. *IMF Econ Rev*, 44(2):149–178.

ILO (2018). Women and men in the informal economy: a statistical picture (third edition). *International Labour Office – Geneva*.

INEI (2018). Encuesta nacional de hogares,enaho. https://webinei.inei.gob.pe. Accessed on 06/04/2018.

Instituto Nacional de Estadistica e Informatica, I. (2019). *Peru: Estimaciones y Proyecciones de Poblacion, 1950-2070*. Economic Commission for Latin America and the Caribbean, Lima, Peru.

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

Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary policy according to hank. *American Economic Review*, 108(3):697–743.

Kaplan, G., Violante, G. L., and Weidner, J. (2014). The wealthy hand-to-mouth. Report, National Bureau of Economic Research.

Kopecky, K. A. and Suen, R. M. (2010). Finite state markov-chain approximations to highly persistent processes. *Review of Economic Dynamics*, 13(3):701–714.

Kuhn, M. and Ríos-Rull, J.-V. (2016). 2013 update on the u.s. earnings, income, and wealth distributional facts: A view from macroeconomics. *Quarterly Review*, (April):1–75.

Levy, S. and Schady, N. (2013). Latin america's social policy challenge: Education, social insurance, redistribution. *Journal of Economic Perspectives*, 27(2):193–218.

Lopez Garcia, I. (2015). *Human Capital and Labor Informality in Chile: A Life-Cycle Approach*. RAND Corporation.

Maloney, W. F. (2004). Informality revisited. *World Development*, 32(7):1159–1178.

Mandelman, F. S. and Montes-Rojas, G. V. (2009). Is self-employment and micro-entrepreneurship a desired outcome? *World Development*, 37(12):1914–1925.

McKenzie, D. J. and Woodruff, C. (2006). Do entry costs provide an empirical basis for poverty traps? evidence from mexican microenterprises. *Economic development and cultural change*, 55(1):3–42.

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

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

MIDIS (2021).

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

Nishiyama, S. and Smetters, K. (2007). Does social security privatization produce efficiency gains?*. *The Quarterly Journal of Economics*, 122(4):1677–1719.

OECD and ILO (2019). *Definitions of informal economy, informal sector and informal employment*.

Oviedo, A. M., Thomas, M. R., and Karakurum-Özdemir, K. (2009). *Economic informality: causes, costs, and policies-a literature survey*. The World Bank.

Packard, T. G. (2007). *Do Workers in Chile Choose Informal Employment? A Dynamic Analysis of Sector Choice*. The World Bank.

Pagés, C. and Stampini, M. (2009). No education, no good jobs? evidence on the relationship between education and labor market segmentation. *Journal of Comparative Economics*, 37(3):387–401.

Perry, G. E., Arias, O., Fajnzylber, P., Maloney, W. F., Mason, A., and Saavedra-Chanduvi, J. (2007). *Informality: Exit and exclusion*. The World Bank.

Pratap, S. and Quintin, E. (2006). Are labor markets segmented in developing countries? a semiparametric approach. *European Economic Review*, 50(7):1817–1841.

Sarte, P.-D. G. (2000). Informality and rent-seeking bureaucracies in a model of long-run growth. *Journal of Monetary Economics*, 46(1):173–197.

SBS, S. I. d. B. S. y. A. (2021).

SUNAT (2021). Superintendencia nacional de aduanas y de adminsitracion tributaria. *Ministry of Economy and Finance of Peru*.

Super Intendencia de Banca, S. y. A. (2018). Estadisticas. http://www.sbs.gob.pe/estadisticas/sistema-privado-de-pensiones. Accessed on 03/28/2019.

Todd, P. and Vélez-Grajales, V. (2008). How pension rules affect work and contribution patterns: a behavioral model of the chilean privatized pension system. *Michigan Retirement Research Center Research Paper*, (2008-193).

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

İmrohoroğlu, A., İmrohoroğlu, S., and Joines, D. H. (1995). A life cycle analysis of social security. *Economic Theory*, 6(1):83–114.

Appendices

A Empirical facts

A.1 Income distribution

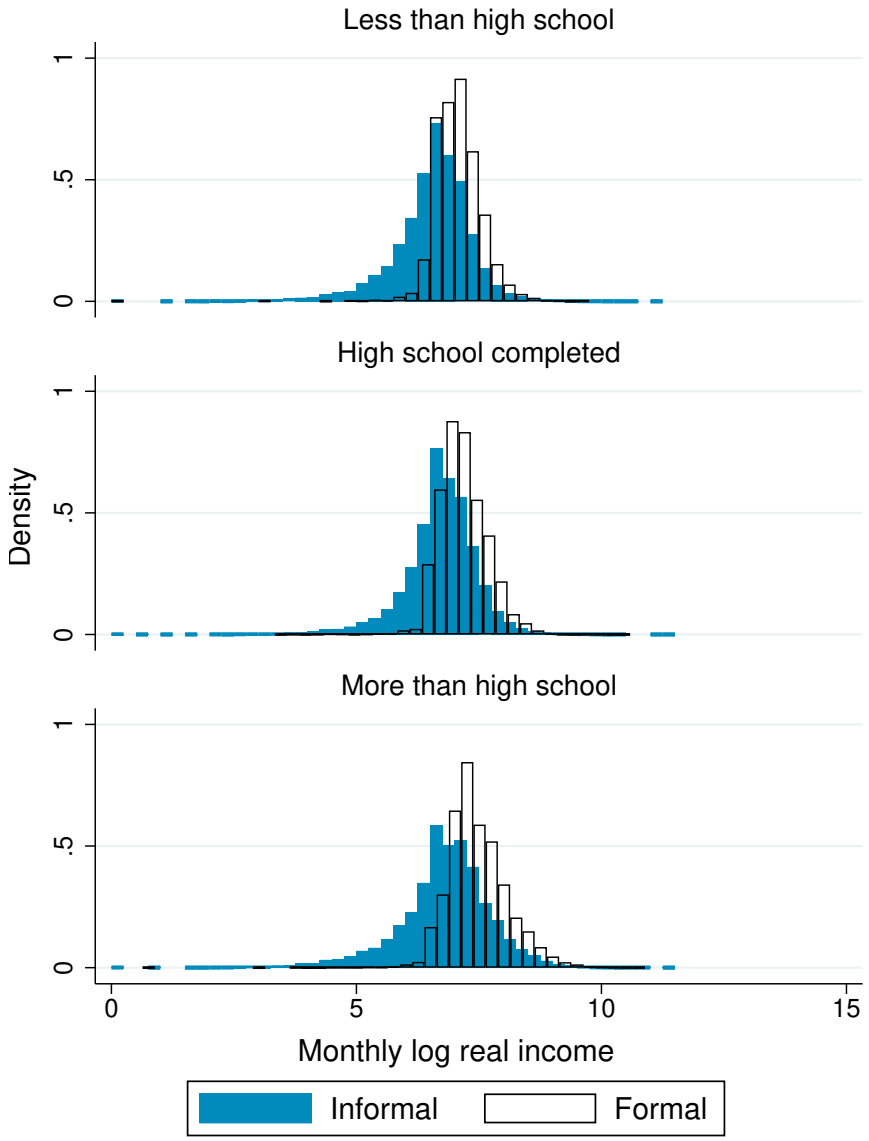

Figure 3: The figure shows the proportion of monthly log real income for workers in formal jobs and in informal jobs, excluding self-employed. Income is calculated before taxes and deductions for non-agricultural males between 20 to 64 years old from ENAHO INEI (2018).

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).