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

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Abstract

This paper examines the impact of pension systems in economies with large informal labor markets using Peru as a case study. In these economies, mandatory participation in contributory pension systems can only be enforced on formal-sector workers impacting workers' decisions to take formal jobs. I develop a heterogeneous agent life-cycle, overlapping generations model where informality arises endogenously as workers choose their optimal working sector each period and face earnings and job separation risk. The government finances a non-contributory pension. Pension contributions impose a liquidity constraint on low-income workers, making them more likely to choose informal jobs. Removing these contributions increases formality and is welfare improving even after accounting for changes in the government budget.

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This study evaluates how the design of the pension system impacts workers' decisions about whether to pursue jobs in the formal or informal labor market. Informal jobs are, to a great extent, unregulated by the government, and for many workers, labor informality is not "residual" but, rather, a choice (Maloney, 2004; Perry et al., 2007; Packard, 2007; Williams, 2017). By choosing to work informally, workers avoid paying taxes and making mandatory contributions to the pension system, as well as other regulatory requirements. The International Labour Office (2018) estimates that around 60% of the world's total labor force is employed informally[1], with significant differences between high-income (18%), and low- and middle-income economies (70%).

This paper focuses on understanding the worker's trade-off between formality and informality, shedding light on the importance of liquidity in the decision to take a formal job. The liquidity mechanism has been overlooked in the literature when studying the factors affecting labor decisions under informality. Previous studies have focused on variables impacting workers' choices, such as income taxes (De Paula and Scheinkman, 2010), unemployment insurance (Cirelli et al., 2021; Bosch and Esteban-Pretel, 2015) or the privatization of the pension system (Joubert and Todd, 2022; McKiernan, 2021). However, the expansion of private individual-account pension systems in low- and middle-income economies, with no significant effects on formality rates (Mesa-Lago et al., 2021), exposes that a worker's preference for informality is highly driven by current liquidity needs against future benefits instead of the private nature of the pension scheme. From a worker's perspective, higher wages and the prospect of an old-age pension may not provide enough incentive to choose a formal job over an informal one when given the opportunity. Instead, a mandate to contribute a percentage of their salary towards their retirement could be a significant disincentive to entering the formal sector. Even with lower-paying jobs, workers might find the informal sector attractive because it allows them to avoid contributions to the pension system and, consequently, have higher liquid income available to consume.

To capture the liquidity channel, I use a two-asset economy following Kaplan and Violante (2014), where workers can save in liquid instruments and accumulate their pension as an illiquid asset. Following the hand-to-mouth literature, this paper is able to capture the impact of liquidity in the formality rate even with an individual-account system. This approach highlights the impact of all mandatory contributions in labor decisions, which differs from previous studies where only the PAYG system (payroll tax) was considered distortionary. Additionally, this study evaluates the role of liquidity by modeling informality rates that rise endogenously from consumption-saving decisions in contrast to previous

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

findings, where informality results from exogenous variables like unobservable heterogeneous preferences for informality, leisure or complete myopic behavior.

How responsive workers are to a tighter liquidity constraint is crucial to quantifying the effects of pension contributions on formality rates. Using household data from Peru, I measure the effect of increasing the pension contribution rates in the labor formality rate[2]. The empirical result for the elasticity is replicated by the theoretical model calibrated for Peru.

This paper also addresses a major concern for many countries: the lack of social protection resulting from high informal rates. Since pension systems are linked to workers' formality status, emerging economies are particularly vulnerable to having a large portion of the elderly population retiring without a pension (Frölich et al., 2014) and facing poverty risk. In response, a widespread government policy is providing a means-tested (or, in some countries, universal) social pension that is not based on contributions. These programs, mainly financed by the general budget, make the informal sector more attractive and further impact formality rates, adding pressure to increase income tax rates paid by formal workers.

In this paper, I quantify how the distribution of labor across formal and informal sectors is impacted by the structure of a contributive pension scheme through liquidity constraints, as well as the fiscal and welfare implications of alternative pension system arrangements in economies with large informal labor markets. This article focuses on answering specific questions, such as how the design of the pension system impacts workers' decisions to work in the formal versus informal sector? In particular, how important is the pension design for the overall size of the informal sector?, and What are the welfare implications of a contributory pension only mandated for formal jobs? Expanding on these questions, I evaluate the consequences of contributory pensions for workers' sector choices, the composition of the labor force, the government budget, and welfare.

For this analysis, I use Peru as a case study because it is representative of other developing economies in significant ways. First, Peru's economy has high levels of labor informality; more than 60% of the labor force in the country is informal. Second, formal workers in Peru must choose between the two most widespread types of contributory pension systems: individual-account (defined-contributions) and pay-as-you-go (defined-benefits). This powerful feature allows the framework and results of this study to be expanded to any economy in the region. Finally, Peru's pension design attempts to address the reduced coverage of the contributory system by including a non-contributory means-tested pension,

[2]In 2006, Peru increased contribution rates for workers enrolled in the private individual-account system, going from 8% to 10% of their monthly income.

financed from the government's general budget.

To quantify the impact of the pension system on a worker's decision between a formal or informal job, I build a heterogeneous agent life-cycle overlapping generations (OLG) model in which informal labor is endogenously determined by workers each period. In the model, an individual chooses between working as a formal worker, an informal worker, or an informal self-employed. Each sector has its own earning process and probabilities of job offer arrivals that increase with education. In the benchmark model, only formal workers pay income taxes and make contributions to the pension scheme of their choice. Additionally, the government provides a means-tested non-contributory pension for all qualifying poor elderly individuals, which acts as a consumption floor.

With this setup, I introduce a two-asset economy similar to that of Kaplan et al. (2014). Workers in all sectors can save in liquid assets and workers in the formal sector contribute to an illiquid asset, their future pensions. Contributions are mandatory for workers in formal jobs, which imposes a liquidity constraint during the working period. Mandatory contributions for retirement seek to insure workers against longevity risk at the expense of reducing current consumption and liquid precautionary savings. However, for some workers, the constraint these contributions impose on their consumption and liquid savings is binding, and they will be better off in an informal job.[3]

I discipline the model by incorporating detailed features of the Peruvian pension system design and targeting key labor market moments for the Peruvian economy estimated from two waves of 5-year panels, 2011–2015 and 2014–2018, from the Peruvian Household National Survey-ENAHO (INEI, 2018). I use a panel data regression to estimate the earning process for formal, informal, and self-employed individuals, and earnings shocks by sector. The model also includes the main features of the Peruvian pension system design, such as contribution requirements and payroll tax. The parameters used to model the pension system are obtained from the legislation and data for the period of study, precovid years 2011 to 2018. I estimate the wealth distribution for Peru, an additional empirical contribution of this paper, which is subsequently used to evaluate the model economy.

I calibrate the model to match the workers' transition matrix between these sectors for each education level, as well as the proportion of workers in each sector by education. In addition, I match moments corresponding to retirement behavior, such as the percentage of elderly individuals working and the proportion receiving a non-contributory pension. The calibration results show that the benchmark model does well, matching the distribution of workers according to the pension

[3]End-on-life liquidity preferences (Bairoliya et al., 2023) are not accounted for in this paper, yet it could further enhance the importance of the liquidity channel for formality.

system and reproduces the elasticity of the response of workers to changes to the pension contribution rate.

I find that when I remove the contributory pension system, the percentage of workers choosing formal jobs increases. Without any contributory system, the percentage of formal workers in the economy increases by $21pp$, from 33% to 54% of the workers. This effect is significant for a country with an initially low formality rate; however, it is bound by other factors affecting formality, such as income taxes, sectoral wage gap, job frictions and risk differential, and the presence of a social pension, which remained unchanged.

Considering both PAYG and individual-account systems, regardless of the design, contributory pensions generate disincentives to take formal jobs in an economy with a significant informal labor market. Contributing a percentage of your income to a pension system is not optimal for all workers, and some prefer informal jobs over higher-paying formal jobs in order to avoid contributions and keep more liquid income. Without a contributory pension system, a higher number of workers rely on non-contributory social pensions, going from 20% of all elderly individuals to 92% when the contributory system is removed, putting pressure on the government budget. However, the increased number of formal workers widens the taxable base, boosting government income. These two offsetting effects lead to small tax adjustments to keep the budget balanced, while the gains from formality are further. Removing the contributory system leads to an average increase of 4.1% in lifetime consumption compared to the benchmark economy.

The main contribution of this paper comes from understanding the liquidity mechanism and quantifying the impact that any mandatory pension contributions generate on the workers' formality decisions and welfare. While previous studies focused on firms' behavior under informality (Meghir et al., 2015; Ulyssea, 2010; Bosch and Esteban-Pretel, 2012; Erosa et al., 2023), this study adds to the recent literature that models informality as a function of workers' decisions over consumption, savings, and contributions to a pension system. A recent study by McKiernan (2021) finds long-run welfare gains from the privatization of the system in Chile. In contrast to McKiernan, my results suggest that both systems, public PAYG and private individual-account systems, create distortions in the labor market by only imposing contributions toward retirement on formal workers. This paper's two-asset approach allows the results to capture the impact of an individual-account system on informality. In this way, this paper introduces and evaluates a new mechanism impacting formality decisions, the *liquidity mechanism*, present for any contributory pension design.

Another close study using the Chilean private pension system was conducted

by Joubert (2015), finding that an increase in the contribution rate to individual accounts encourages informality and increases the size of the informal sector. I find consistent results using a complete heterogeneous agent model that broadens the analysis by incorporating both, the PAYG and individual accounts, systems under income and job uncertainty while considering the impact on the government budget, and expands the findings by exploring the welfare implications of this pension setup. In contrast to Joubert, this paper models informality endogenously for a small open economy and, matching the elasticity of response from workers found in the data, I successfully identify the role of the *liquidity mechanism* in the worker's formality decision, adequately quantifying the effects of changing contribution rates on labor formality choice, government budget, and welfare.

This study also contributes to the understanding of social security systems and the privatization of pension systems. The privatization of Social Security in the US has been evaluated, with studies finding evidence of long-run welfare gains (Feldstein, 1995), highlighting the importance of labor elasticity (Fuster et al., 2007) to achieve this result. Other studies suggest that those results are contingent on factors like the openness of the economy, the annuity market, matching programs, and idiosyncratic earning risks, among others (Nishiyama and Smetters, 2007). Evaluations of Latin American pension reforms mainly focused on Chilean privatization, a country with relatively low labor informality. Initial arguments supporting a fully funded private pension system in Latin America looked into potential gains in overall savings and economic growth (Corsetti and Schmidt-Hebbel, 1997) and an increase in formality (Holzmann, 1997). Current data contests these results for many countries and emphasizes the need to continue to study the dynamics of informal labor.

Following the mainstream literature on social security systems, this paper is consistent with the findings that contributions to the PAYG pension system are perceived by workers as a "tax" affecting their liquidity constraints and resulting in a distortion in the workers' allocation of consumption over the life cycle (İmrohoroğlu et al., 1995). Furthermore, I show that this distortionary effect also prevails in mandatory private individual-account systems, and the extent of the distortion is not restrained to consumption allocations but labor supply decisions, such as formal/informal sector choices, for workers in economies with informal labor markets. I show that an informal economy with only a non-contributory pension is welfare-improving and boosts formality more than a private fully-funded pension scheme.

The paper is organized as follows. Section 1 presents some facts about the Peruvian labor market. Section 2 covers the different pension system designs and discusses their impact on workers' decisions. Section 3 describes the model.

Section 4 shows estimation and calibration details. Section 5 presents the result and Section 6 concludes.

1 Case study of Peru

Peru provides a strong case study of a country with a high number of informal workers, estimated to account for 66% of the labor force; as well as, a pension system design with popular contributory and non-contributory features. Peru is located in Latin America, a region with similar highly informal labor markets, and from 2010 to 2019 showed an average real GDP growth rate of 4.5% and population growth of 1.2% (BCRP, 2021).

1.1 The data

This case study uses two types of data from the Peruvian National Household Survey (ENAHO), collected by the Peruvian National Statistics Institution (INEI, 2018), to examine trends and empirical facts about the Peruvian labor market and pension system. The first data set comprises quarterly survey results from 2011 to 2017 weighted to create nationally representative estimates.[4] In addition, to estimate the evolution of critical variables in the model, I use two waves of five-year panel survey results, where the first wave covers the years 2011 to 2015 and the second wave follows individuals from 2014 to 2018. Estimations and analysis of the workforce focus on the subsample of workers in the 20–65 age range because Peru's legal retirement age is 65. The employed workforce represents approximately 70% of the total population, while 90% of those employed are in the 20–65 age range.

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

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

and has higher rates of female workers compared to males.

This research focuses on non-agricultural labor to understand workers' behavior and sectoral decisions in markets with informality[5]. The main occupations in the non-agricultural informal sector are concentrated in services like commerce, transportation, and sales.

1.2 Labor Market Facts

This section describes informal labor markets based on previous literature and characterizes the Peruvian labor market for non-agricultural male workers. Prior studies on the informal labor force in Latin America used data to shed light on common misconceptions. For example, Maloney (2004) and Bosch and Maloney (2010) found that workers enter the informal labor force voluntarily, and informal jobs are not generally considered to be inferior to the formal workforce. The informal sector contains two types of workers: employees working for firms and self-employed individuals. The self-employed group is usually incorporated into the informal labor analysis as it is a highly unregulated workforce segment that avoids making pension contributions or fully reporting income. The self-employed share characteristics similar to those of the "entrepreneurial" worker found in other economies. For example, Perry et al. (2007) finds that informal self-employed earn more, value flexibility more, and express greater satisfaction than they would get working for a firm. Maloney (2004) shows that most entrepreneurs in Brazil and Mexico do not want a formal job. Earle and Sakova (2000) evaluate a set of transitional economies and find that self-employed workers have different characteristics than employees. Some may self-select into self-employment due to their comparative advantage as entrepreneurs. However, others may end up self-employed due to a lack of opportunities.

On the other hand, informal employees at firms have different motivations for entering the informal labor market than do the self-employed. Some informal workers seek opportunities to transition into a similar formal job (García and Badillo, 2018). Young workers may take informal jobs to gain experience and test qualifications (Perry et al., 2007). Consequently, informal work can also be understood as a screening mechanism to prove their skills (Cano-Urbina, 2015).

[5]Informal workers can be categorized according to the type of job between non-agricultural labor and agricultural labor. This distinction is usually made due to the lack of formal jobs in agriculture. In Peru, 97% of agricultural workers are classified as informal, accounting for 25.7% of all informal workers. In these cases, agricultural workers' options to transition to other industries or into formal jobs are very limited. Agricultural work is typically found in rural areas where there are fewer formal jobs offered and lower access to financial institutions.

Finally, formal jobs attract more productive and highly educated workers by providing a wage premium compared to the tax-free and contribution-free informal wage. These characteristics prevailed across many countries and are not the exception in the Peruvian labor force, as shown in Table 1.

Table 1: Employed labor force distribution by education

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

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

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

Table 2: Average real monthly income by type of worker

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

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

However, regardless of this wage premium in formal jobs, informal jobs are preferred for a group of workers. The income distribution for formal and informal workers employed by a firm (Figure B.1 in the appendix) shows significant

overlap for these two groups [6]. This overlap provides preliminary evidence of the presence of parallel labor markets with incentives and gains beyond just earnings. This finding aligns with prior research, which has found evidence of small or no wage premium for the formal sector for groups of workers in other Latin American countries (Pratap and Quintin, 2006). Oviedo et al. (2009) finds that in countries where the benefits that require a contribution from a formal wage are low perceived, a formal job does not have a clear advantage. Furthermore, the gains from the informal sector are not always monetary in nature. Packard (2007) cites factors such as moral hazard, a preference for present consumption, or favoring other types of savings as some reasons workers may want to avoid contributions and take informal jobs. Finally, Saavedra and Chong (1999) studied the Peruvian labor market after the 90s economic reforms and found a minimal difference in earnings for self-employed and formal workers, and a small wage gap for formal and informal jobs mainly attributed to a lower return from education from the informal sector.

[6]Figure B.1 also shows that the distribution of informal wages has wider ends, indicating that the informal workforce has a higher variance in earnings and contains a larger percentage of workers with very low earnings due to the lack of minimum wage requirement for these jobs. In contrast, in the more regulated formal sector, employers must abide by federal minimum wage laws Nevertheless, Boeri et al. (2011) show that in Brazil, changes in the formal minimum wage translate to changes in wages in the informal sector as well. This link between sectors' earnings, called the "lighthouse" effect, keeps the wage differential between sectors contained and can make an informal job competitive with formal employment.

Table 3: Peruvian transition matrix between sectors by education

Less than high school education

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

High school education

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

More than high school education

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

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

The different nature of the sectors and how they relate to one another can also be perceived in how often workers transition between these three types of work. Table 3 summarizes the results of the estimated annual transition probabilities between sectors for the Peruvian labor market. Across education levels, informal workers and the informal self-employed have distinctive probabilities of transitioning to formal jobs.

The lower probabilities of moving from self-employment to a formal job are consistent with the estimates for Argentina, Brazil, and Mexico by Bosch and Maloney (2010) and reinforce the argument to treat informal employees and informal self-employed as two categories of informal labor that exhibit different behaviors. Some informal workers are gaining experience and skills that will allow them to transition to a formal job when the opportunity arises. For self-employed individuals, the investment required (either on capital or abilities) makes transitioning out of the sector less attractive. Additionally, without a risk of getting fired, self-employed individuals have a higher level of stability in their activities.

1.3 Retirement Facts

When workers spend a long time of their working life in informal jobs, they do not contribute towards a social security or private pension system. As a result, data indicates very limited levels of coverage from contributory pension systems for the elderly population. Rofman and Apella (2020) calculate around 58% of the elderly population in Latin America does not receive a contributory pension.

In Peru, workers are eligible for retirement at 65 years old but due to the low pension coverage, it is common for retirees to continue working passed their retirement age. Table 4, shows the status of workers grouped into five-year cohorts after reaching retirement age. Whereas informal workers gradually transition into retirement, formal workers rapidly transition to informal positions or leave the labor force entirely.

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

Age cohort	Non working	Formal Worker	Informal Worker	Informal Self-employed
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)
Overall	0.584	0.053	0.135	0.228
	(0.009)	(0.004)	(0.007)	(0.008)

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

Workers are presented with two choices: if their savings and now-accessible pension generate an adequate income, they may choose to completely retire. For workers with smaller or insufficient pension benefits, an informal job provides a source of income during old age or offers additional liquid income to complement their pension benefits.
However, the probability of transitioning between sectors diminishes with age and most of the job transitions reflect older workers leaving the labor force[7]. As informal workers retain their jobs for longer, individuals who are not working are

[7]Refer to Table 16 in appendix B.2

unlikely to return to work. For the 65–69 age cohort, the probability of going back to work during the next period is 13.6%, dropping to 7.9% for the 70–74 age cohort.

2 Pension System Design

The literature generally defines informal workers as workers that are not covered or are insufficiently covered by formal arrangements, i.e., contracts, benefits, or social protection policies (OECD and ILO, 2019). Following this definition, this study identifies workers' formality status based on their contributions to a pension system that grants them access to formal social protection.

If a person is working and contributing to the pension system in the same period, they are considered a formal worker. Besides helping identify formality status, the country's pension system design could determine the worker's current formality choice, introducing forward-looking variables into their sector decision and budget constraint.

2.1 Peruvian Pension System

The Peruvian pension system has a contributory pillar that requires workers to contribute a percentage of their monthly salary towards retirement and no matching. Because enforcement of a mandatory savings policy is only possible in formal salaried jobs, the coverage of the pension system is restricted to formal workers.

Workers choose to enroll in one of the two available pension schemes. The first is a defined-benefit or pay-as-you-go (PAYG) pension plan that is managed by a public entity following the country's previous social security system. The second is a defined-contribution plan with individual accounts managed by private fund managers. Workers make a one-time decision to enroll in either the PAYG or individual-account pension system at the beginning of their first formal job[8], but the default option is the individual-account system. This distinctive characteristic of the Peruvian pension system allows us to examine how overall contributory pension schemes behave in an economy with a sizable informal labor force.

Contributing to the system is optional for self-employed and informal workers, the largest sector of the workforce. Consequently, only a small portion of the age 65+ population is covered by either of the two contributory plans. Table 5

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

summarizes the current coverage rate of the system and shows that more than half of the population age 65+ is not receiving a pension or monetary transfer from any system.

Table 5: Peruvian labor force and retiree coverage rates by pension scheme

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

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

The lack of pension coverage for a larger portion of the elderly population has driven reforms in several countries that face the informality challenge. In Latin America, the most popular means of extending coverage has been to implement non-contributory pensions, with at least 15 countries in the region introducing such programs (Bando et al., 2020). In 2012, Peru added *Pensión 65*, a non-contributory pension scheme that works as a mean-tested social program[9]. The program extended pension coverage to another 20% of the population older than 65 years; however, the benefit is only 27% of the minimum wage (about US$ 70), paid out once every 2 months.

2.2 Pension System Channels

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

2.2.1 Individual-account system (defined-contributions)

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

[9]It focused on people of retirement age who were living in extreme poverty, providing them with a monetary pension transfer and free access to the Integral Health Insurance Program (MIDIS, 2021)

account system hold retirement savings as illiquid assets.[10] The mandatory contribution of income toward an illiquid asset is not optimal for *all* households. For low-income households, a minimum contribution toward retirement savings reduces disposable income, negatively affecting the worker's utility. Households that are income-constrained would prefer a job in the informal sector with the risk of lower salaries but potentially higher disposable income each period.

Furthermore, it could impose a binding liquidity constraint on workers who initially took a formal job. For example, workers who accumulate significant levels of illiquid assets but are subject to negative income shocks would rather take an informal job in the next period to avoid making further contributions and hold more precautionary liquid savings instead.

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

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

2.2.2 PAYG (defined-benefits)

Workers enrolled in a PAYG pension system are also subject to a liquidity constraint and face the same trade-offs as those in an individual-account system. Nevertheless, the pension is not proportionate to their contributions. The primary requirement for collecting a pension in this system is to contribute for a minimum number of years. This requirement deters workers from taking informal

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

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

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

2.2.3 Non-contributory pension (social pension)

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

Additionally, a non-contributory pension also provides the protection of a pension for all informal workers that qualify for this means-tested pension. This program creates incentives to keep an informal job and reduces participation in the formal system (Attanasio et al., 2011). The impact of this effect is expected to be small given that many of the workers who 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, which is why a formal job offer is less attractive.

Finally, non-contributory pensions are financed from the general budget. Any modification to the non-contributory pension program will have an unintended effect on taxes that will only affect workers in formal jobs. For example, an expansion of this program (either in the transfer level or the number of people receiving the social pension) would lead to an increase in government expenses, resulting in a potentially higher income tax rate. This would tighten the liquidity constraint and make formal jobs even less attractive.

3 The Model

With interest in understanding the worker's choices in a context of high informality, this section presents a model incorporating the mechanisms affecting the labor formality decision. The framework is an extended Roy's model (1951) that can allow for endogenous choices between formal or informal occupations each period. To capture the main variables affecting the dynamics of the workers' decisions along their lives, the economy follows the two-asset approach from Kaplan et al. (2014) in an overlapping generations model with an incomplete market and a detailed pension system set up.

3.1 Model Description

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

Timing.— The time in the model is annually.

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

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

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

In the *individual-account* or defined-contribution system ($p = 1$), workers must contribute a percentage $\bar{x}_1$ of their income into their individual retirement account $\tilde{Y}_t$. The individual retirement fund is managed by private managers who

receive a management fee paid by the formal worker. The fee is calculated as a percentage of the formal worker's income η. The individual account $\tilde{Y}_t$ accumulates returns at an effective rate ρ each period, independent of the individual's labor status.

In the *PAYG* or defined-benefits system ($p = 2$), workers must contribute a percentage $\bar{x}_2$ of their income to the system. Because the PAYG system is a public system, the management fee is zero; however, access to pension benefits is conditional on a minimum number of years contributing to the system set for all workers as z_{min}.

The economy also presents a *non-contributory pension* or social pension that provides a means-tested monetary transfer $\bar{c}$ to guarantee a minimum level of consumption to the elderly.

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

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

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

Self-employed households have earnings based on $y^s = \theta k^\alpha\ \Omega^s(t, e, l, \varepsilon^i)$. This measure includes a production function that originates from their capacity to use assets, k, according to their ability θ[11] and the production parameter $\alpha \in (0, 1)$ and a deterministic earning process. Entrepreneurial ability is exogenously given and known by all at the beginning of their life. Higher ability corresponds to higher average and marginal returns from capital.

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

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

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

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

3.2 The Young's Problem

Individuals are heterogeneous in entrepreneurial ability θ and education e. Both variables are fixed and known to the individual. The individual enters each period with liquid assets a and accumulated retirement savings as illiquid assets $\tilde{Y}$ or years of contributions z in the PAYG system, depending on their choice of pension system p.

They start the period with a job in sector $j = \{f, i, s\}$, with job experience l[12], known probabilities of a job offer from each sector $\gamma^j(j, e)$ and observes current labor productivity shocks by sector ε^f and ε^i. Each individual chooses consumption c, liquid savings a', and self-employed capital k that maximizes their utility in each sector $V^j(\mathbf{s})$ based on their current state $\mathbf{s}$. The state space $\mathbf{s}$ is defined as a vector containing age-dependent variables and education e, entrepreneurial ability θ, and pension scheme p. It follows that $\mathbf{s} = (\theta, e, p, t, j, a, \tilde{Y}, z, l, \varepsilon^f, \varepsilon^i)$.

All working-age individuals make a discrete extensive-margin decision over their optimal labor sector (formal, informal, or informal self-employed) by selecting the sector that provides the highest utility. Thus, the worker's maximization

[12]Job experience refers to a worker's prior employment status, specifically whether they previously worked in the formal or informal sector. Empirical evidence shows that past status affects wages for up to three years after a sectoral transition. Motivated by this finding, the model tracks the most recent job transition within the past four years.

problem for ages $t < R$ exhibits the next structure each period:

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

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

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

3.2.1 Formal household problem

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

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

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

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

With probability $\gamma^f(f, e)$, a worker in the formal sector with a given education level receives a formal job offer with the possibility of keeping the formal job or

transitioning to an informal job. With probability $(1-\gamma^f(f,e))$, the worker is separated from her formal job. Once separated, the worker starts an informal job after a period of unemployment, accounted for by a decrease in their utility of $\nu_{f,e}$.

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

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

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

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

3.2.2 Informal household problem

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

Informal workers receive an offer to work in the formal sector in the next period with probability $\gamma^f(i,e)$ depending on their education e. The workers choose between taking the formal job, continuing in their informal job, or transitioning into self-employment. With probability $(1-\gamma^f(i,e))$, there is no offer from the formal sector and workers might receive an offer to continue their informal job with probability $\gamma^i(i,e)$. In this scenario, workers are able to choose

between keeping their informal job or transitioning to self-employment. Workers will transition to self-employment if a job offer from the informal sector does not arrive; this happens with probability $(1-\gamma^i(i,e))$ after experiencing a period of unemployment, reflected by a decrease in their utility $\nu_{i,e}$.

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

$$
\begin{aligned}
V^i(\mathbf{s}) = \max_{a'} \Big\{ u(c) + \beta \Big(& \gamma^f(i,e) \max \left\{ \mathbb{E}[V^f(\mathbf{s}')|\varepsilon^f], \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} \\
& + (1-\gamma^f(i,e)) \Big[\gamma^i(i,e) \max \left\{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} \\
& + (1-\gamma^i(i,e)) (\mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] - \nu_{i,e}) \Big] \Big) \Big\}, \qquad (3) \\
s.t. & \\
c + a' &= y^i + (1+r^*)a \\
\tilde{Y}' &= (1+\varrho)\, \tilde{Y} \quad \text{if } p = 1 \\
z' &= z \quad \text{if } p = 2 \\
a' &\geq 0.
\end{aligned}
$$

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

3.2.3 Self-employed household problem

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

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

$(1-\gamma^i(s,e))$, entrepreneurs will continue with their self-employed venture.

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

$$\begin{aligned} V^s(\mathbf{s}) = \max_{a',k} \Big\{ u(c) + \beta \Big(& \gamma^i(s,e) \max \left\{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i],\ \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \right\} \\ & + (1-\gamma^i(s,e))\, \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \Big) \Big\}, \qquad (4) \\ & s.t. \\ c + a' &= y^s + (1+r^*)(a-k) + (1-\delta)k \\ \tilde{Y}' &= (1+\varrho)\, \tilde{Y} \\ z' &= z \\ 0 \leq & \delta \leq 1 \\ 0 \leq & k \leq a \\ a' &\geq 0. \end{aligned}$$

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

3.3 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

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

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

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

3.3.1 Pension and transfers set-up

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

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

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

Individual-account (defined-contribution system).– Retirees who participated in the individual-account pension system $p = 1$ receive a pension in the form of an annuity. The pension is calculated using the market return rate r[13] 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 pension function adopts an ordinary annuity formula or the "money's worth" calculation (Brown et al., 2000). The annuity $\tilde{P}$ provides a constant pension until the individual's last possible period T such that the expected present discounted value of the annuity equals the fund at the time of retirement

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

PAYG (defined-benefit system).– Retirees who participate in the PAYG pension system $p = 2$ need at least 20 years of contributions, $z_{min} = 20$, to access their pension. The system has a minimum, ϑ_{min}, and a maximum, ϑ_{max}, pension level independent of how much the retiree contributed during her working life. The pension benefit b is calculated based on the average formal wage, for each

[13] Annuities are calculated using the risk-free interest rate, here approximated using the private savings return rate r.

education level, during the last five years before retirement $\tilde{w}_R$ and an exogenous replacement rate μ, given by the following formula:

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

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

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

With a minimum pension guarantee ϑ_{min} in the PAYG system, workers with very small average contributions to the system (that would be reflected in a small pension fund $\tilde{Y}$ in an individual accounts system) would be better off aiming for the minimum pension ϑ_{min}. On the other hand, workers with high average contributions to the system would be discouraged from contributing to the PAYG system, which imposes a maximum pension ϑ_{max}.

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

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

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

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

3.3.2 Retiree's problem

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

function:

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

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

3.3.3 Informal worker problem

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

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

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

3.4 The Government's Problem

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

government budget is balanced each period, such that

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

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 growth rate, n_t is normalized to 1 and decreases according to the mortality rate Γ_t after reaching retirement rate R. The indicator function $\mathbb{1}_{p=2}$ is 1 when the worker i is enrolled in the PAYG pension system, and $\mathbb{1}_{j=f}$ is 1 when current individual i is a worker in the formal sector $j = f$.

3.5 Small open economy

The model is a small open economy and has a competitive steady-state equilibrium. Comparisons of contrafactual policies in this paper are between steady-state economies. Appendix Section C provides a definition of production technology and equilibrium.

4 Estimation

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

4.1 Income Process

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

4.1.1 Formal and informal workers' income

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

$$\log y^j_t = \chi_t + \Lambda_t + \varepsilon^j_t.$$

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

The earning process controlled by workers' in-sector experience is estimated using panel data from Peruvian households. Results of the estimation are in Appendix Section D in Table 17. In addition to a wage premium in the formal sector, the results in Table 17 also show that returns to education are higher for formal workers. The earning processes will use the coefficients estimated for a log-linear transformation of the workers' wages.

4.1.2 Informal Self-employed income

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

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

I estimate the effects of the age variables χ and education e using a linear regression. The results are shown in Table 17 of Appendix D . I determine the return on capital and return on ability —the production function θk^{α}— using a percentage of the constant of this estimation as a proxy[14].

4.1.3 Earning risk

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

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

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 $\mathbb{E}\left[\varepsilon_t^f \varepsilon_t^i\right] = \rho_{fi}\, \sigma_f \sigma_i$.

[14]Details of self-employed production function estimation are found in Appendix Section D

Then, I let workers simultaneously withdraw the shocks in earnings in the formal work and for the informal sector from a multivariate normal distribution $\sim \mathcal{N}(0, \Sigma)$. The informal sector shock affects earning from both types of informal jobs: workers and self-employed. I estimate sectoral cross-correlated income shocks using the Generalized Method of Moments (GMM) with panel data from the Peruvian Household Survey (ENAHO). Empirical moments are computed using a mixed approach: residuals of salaried workers in formal and informal sectors are used for within-sector moments (variances and autocovariances). Cross-sector covariances are calculated only for individuals who switch between sectors using individual-level averages[15]. Details on the estimation of income shocks for the two-sector economy are provided in Appendix D.3.

The results of this estimation are summarized in Table 6 and follows trends observed in other countries with informal labor markets. Higher overall volatility of informal earnings is evidenced in the literature for Latin American countries(IMF, 2023), and found in estimations for cases like Chile Lopez Garcia (2015) and Brazil[16]. At the same time, a slightly higher persistent component is estimated for formal sectors in countries such as Chile (Lopez Garcia, 2015). These findings reveal the informal sector as one characterized by higher income volatility, but with shorter-lived shocks. In contrast, the formal sector is characterized by a more stable income with lower volatility but higher persistence.

Table 6: Earning shock parameters

	Formal	Informal
Autocorrelation (ρ_j)	0.7969	0.7735
Variance (σ_j^2)	0.1025	0.1968
Correlation	0.5499	

Source: Author's estimation using ENAHO panel waves 2011-2015 and 2014-2018 (INEI, 2018)

I use the discrete approximation of the Rouwenhorst method proposed by Kopecky and Suen (2010), which has proven to perform well with highly persistent processes. First, using the information in Table 6, I decompose the underlying process into a set of AR(1) processes, one that is independent (the formal sector) and the other that is perfectly correlated with the previous one in their error term

[15]Because observations of each worker-sector pair are observed once a year (not contemporaneous), the data allow only for the estimation of the correlated permanent shocks.

[16]Engbom et al. (2022) finds σ_f^2 =0.174 vs. σ_i^2 =0.449, Gomes et al. (2020) finds σ_f^2 =0.211 vs. σ_i^2 =0.533

(the informal sector). I then construct a two-state Markov chain with transition probability $\pi_{\varepsilon j}$ for each sector.

4.2 Calibration

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

4.2.1 Exogenous parameters

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

In the model demographics, the individuals are born at age 20, when they start their working life, and they can live to a maximum age of 100. They can retire when they reach 65 years old, following the legal retirement age in the Peruvian pension system (SBS, 2021). After 64 years old, the individuals are subject to a mortality risk Γ. The probability of survival at each age are obtained from the Peruvian mortality tables for males (Instituto Nacional de Estadistica e Informatica, 2019) available in Section C.2 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 liquid assets is obtained from the average annual interbank real interest rate in the local currency (PEN) from the last 10 years (2010 to 2019), 1% (BCRP, 2021). For simplicity, in the model, the same interest rate is available for formal and informal workers.[17] The interest rate for the

[17]The importance of the gap in interest rates by sector has a higher relevance in a model

illiquid assets is taken from the average annualized real return of the last 5 years pre-covid (2014 to 2019) for the moderate-risk pension fund, fund type 2, calculated at 4.5% (Super Intendencia de Banca, 2019). The income tax parameter in the model τ is a simple average of the first four income tax levels in the Peruvian economy, 15% (SUNAT, 2021). The highest open bracket is left outside of the calculation.

The pension system in the model incorporates the key institutional features of the Peruvian system, as summarized in Table 7.

Table 7: Peruvian Pension System parameters

Parameters		Values
1. *Individual accounts*		
Contribution rate	$x_{p=1}$	10%
Fund management fee	η	3%
2. *PAYG*		
Contribution rate	$x_{p=2}$	13%
Min years requirement	z_{min}	20%
Replacement rate	μ	45%
Min pension	ϑ_{min}	500 PEN
Max Pension	ϑ_{max}	893 PEN
3. *Non-contributory pension*		
Social pension	$\bar{c}$	125 PEN

Source: MIDIS (2021), ONP (2020), Super Intendencia de Banca (2019)

There is no widely available wealth distribution for Peru, and household surveys do not collect asset information. I approximate the initial urban wealth distribution, using information from two sources: an estimate by the Peruvian Central Bank (BCRP) (Carrera and Ordonez, 2023) of wealth shares by population quintile, and data from the World Inequality Database (Alvaredo et al., 2024), which indicates that the top 10% held about 67% of wealth in 2019. For a moderate scenario, I calibrate the distribution so that the top 10% holds 60% of total wealth, then compute the population share corresponding to each 20% wealth slice using a piecewise linear interpolation of the Lorenz curve between the quintile knots reported by the BCRP. Appendix D.5 contains the detailed explanation of the approximation process. Table 8 constitutes an additional contribution of this study, providing the first approximation of the wealth distribution for urban Peru.

with borrowing. Amaral and Quintin (2006) study the informal market in Brazil and find that the difference in access and the cost of borrowing in the informal sector is one of the potential arguments for the size of the informal economy.

Table 8: Peru's wealth distribution, 2019

Wealth quintile (by share of wealth)	Cumulative population (% of total pop)	Population share (% of total pop)
Bottom 20% of wealth	45.53	45.53
2nd 20% of wealth	80.00	34.47
3rd 20% of wealth	95.56	15.56
4th 20% of wealth	98.89	3.33
Top 20% of wealth	100.00	1.11

Source: Author's estimations

4.2.2 Targeted parameters

The subjective discount factor β is calibrated to match the capital-output ratio in Peru, calculated as the output-side real GDP (in millions of 2017 US dollars) over capital stock (in millions of 2017 US dollars) using estimates from the Penn World table (Feenstra et al., 2015). As this ratio has increased over time, I will use the estimate for 2019 as my target. In the model, capital is defined as the stock of liquid assets plus the illiquid assets in the economy, and income from all sectors is added up to determine the output in the model.

The percentage of retirees still in the labor force after retirement is obtained from the overall calculations in Table 4 of those age 65+ who are working. This parameter is matched in the model by calibrating the disutility of work (ϕ). This value is linearly increasing with age to replicate the decline in participation observed. 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*. Results for this set of calibrated parameters for the baseline economy are compile in Table 22 in Section D.7 of the Appendix.

The parameters governing the job separation cost $\nu(j, e)$ by sector and education level are set such that the average distribution of the labor force across sectors and education levels matches the estimated distribution from the Peruvian labor market in Table 1. Table 21 in Appendix Section D summarizes the values for the parameters ruling the labor market structure in the model.

The labor demand is characterized using the arrival of a job offer $\gamma(j, e)$ by sector j and education e referred to in Appendix Section D. This calibration is obtained by targeting the transition matrix between sectors by education for the Peruvian labor market. For tractability and due to the reduced probability of the event (less than 5%), the model exempts decisions from formal workers to become self-employed and self-employed to transition into formal jobs. For calibration

purposes, I adjust the transition matrix estimated from the data to examine the transition opportunities presented in the model. The targeted transition matrix incorporates these cases by assigning a zero probability to these specific transitions and adding the residual probability from the data into the informal sector. Computing the probabilities in this way ensures that the matrix of probabilities adds up to one and that the transitions correspond to the choices available in the model. Table 9 presents the results of the targeted labor transition matrix for the Peruvian economy along with the benchmark model results.

Table 9: 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	0.57	0.16	0.26	-	-
Informal Worker	0.21	0.43	0.63	0.52	0.20	0.23
Informal Self-employed	-	-	0.21	0.21	0.80	0.77

High school education, $e = 2$

Previously / Currently	Formal		Informal		Self-employed	
	Data	Model	Data	Model	Data	Model
Formal Worker	0.76	0.62	0.20	0.32	-	-
Informal Worker	0.24	0.38	0.62	0.50	0.18	0.19
Informal Self-employed	-	-	0.18	0.18	0.82	0.81

More than high school education, $e = 3$

Previously / Currently	Formal		Informal		Self-employed	
	Data	Model	Data	Model	Data	Model
Formal Worker	0.80	0.72	0.27	0.39	-	-
Informal Worker	0.20	0.28	0.53	0.47	0.23	0.21
Informal Self-employed	-	-	0.19	0.14	0.77	0.79

4.3 Goodness of fit

4.3.1 Matched moments

The calibrated model reproduces key moments well, as shown in Table 10, particularly the initial labor force distribution between sectors by education. These two elements characterize the labor force in the model and provide fifthteen (five for each education type) parameters that must be disciplined in the model simultaneously. The calibrated model captures key features of the Peruvian labor

market under the current pension system that are used as a benchmark for contrafactual analysis.

The simultaneous calibration of parameters governing the transition matrix and composition of the labor force by education provides one degree of freedom. The overall fraction of labor force by sector resulting from this calibration matches the data very closely.

Table 10: Moments targeted in the calibration

Moments targeted	Parameters	Description	Data	Model
Capital-output ratio	β	Discount factor	3.7	3.6
Fraction of elderly:				
working	ϕ	Disutility of work	41.6	41.5
with non-contributory pension	M	Means-tested threshold	20.0	20.4
Labor force distribution	γ	Job offer probabilities		
by education:	$\nu^f; \nu^i$	and separation cost		
Less than high school, $e = 1$				
Formal worker			24.4	23.8
Informal worker			38.4	38.7
Informal self-employed			37.2	37.5
High school completed, $e = 2$				
Formal worker			30.5	30.2
Informal worker			35.9	35.1
Informal self-employed			33.6	34.7
More than high school, $e = 3$				
Formal worker			44.6	44.8
Informal worker			30.8	30.7
Informal self-employed			24.6	24.6

Other sets of untargeted moments are shown in Appendix Section D.8 Table 24 and prove the predictive power of the model. A relevant untargeted moment is the fraction of workers enrolled in PAYG versus individual accounts. Since pension reforms have altered the overall distribution over time, the distribution of new enrollees in 2019 provides a more accurate comparison. In the model, workers optimally choose their pension system, and the benchmark economy closely replicates the data: 37.5% in Peru versus 37.8% in the model (25.4% choosing PAYG and 67% individual accounts).

"Finally, the average log income ratios of the informal and self-employed sectors relative to the formal sector closely match the corresponding averages from

the Peruvian household panel survey data presented in the Appendix, as do the average log monthly incomes (Table 11) and life-cycle income profiles (Figure 1).

Table 11: Average log monthly income

Formal		Informal		Self-employed	
Data	Model	Data	Model	Data	Model
7.28	7.33	6.75	6.78	6.67	6.82

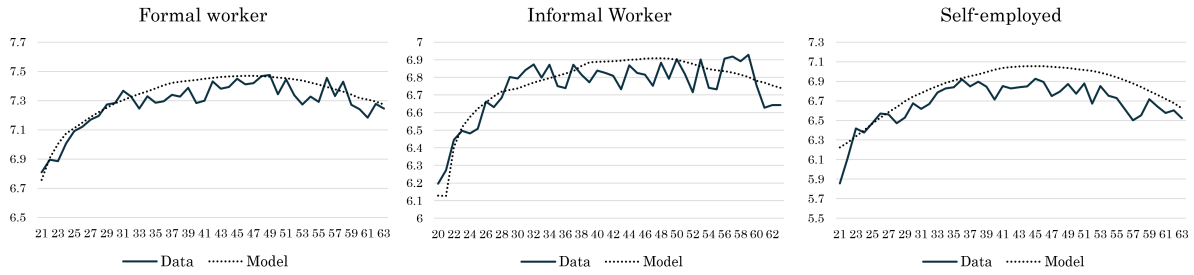


Figure 1: The figure shows the average log monthly wage by sector over the life cycle. The dotted line represents the benchmark model, while the continuous line shows the average log monthly wage by age from the ENAHO household survey weighted panel data for the periods 2011–2015 and 2014–2018. Appendix D.8 desagregates graphs by education levels.

4.3.2 Goodness-of-fit test

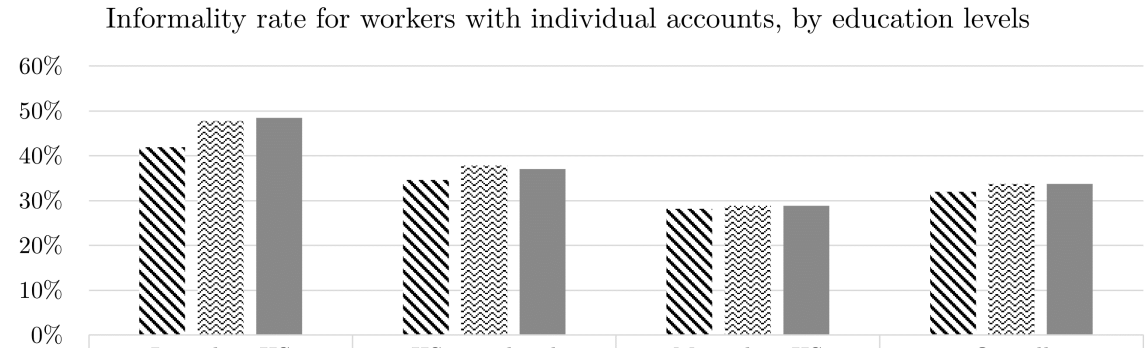
The impact of a contributory pension system on informal labor markets relies on the responsiveness of workers to the pension scheme. To test the goodness-of-fit of the calibrated model, I use an exogenous change in the pension contribution rate to calculate the elasticity of workers' formality status.

In January 2006, The Peruvian private pension system increased the contribution rate to the individual accounts for retirement from 8% to 10% of the workers' wages, a policy that remains to date (Seminario et al., 2018). During this decade until the 2008 crisis, Peru experienced sustained economic growth, and formality rates increased in the labor market overall.

Using the Peruvian National Household Survey (ENAHO), I studied workers enrolled in the private pension system before and after the increase in the contribution rate (2005-2007). Even though formality rates increased over these years, the proportion of workers enrolled in an individual account system that kept formal jobs went down by 1.8 percentage points after the change in policy. The policy had a bigger impact on workers with the lowest education levels, as the informality rate increased from 42% to 47.8% right after the rise in contribution rates. This is an increase of informality of 5.8 percentage points for workers

with the lowest education levels. These results align with the liquidity channel explored in Moreno (2020) and the scope of this study; contribution pension systems impose a liquidity constraint in workers who might opt out from formal jobs into informal jobs to avoid contributions.

Due to the difference in response to a change in policy by education level, I estimate the response of an average worker in the private pension system to a change in their contribution rate.



	Less than HS	HS completed	More than HS	Overall
2005	42.0%	34.6%	28.2%	32.0%
2006	47.8%	37.8%	28.8%	33.8%
2007	48.5%	37.1%	28.9%	33.8%

Figure 2: The figure shows informality rates for non-agricultural workers under 64 years with individual accounts (private pension system) by education level for 2005, 2006, and 2007 in Peru using balanced ENAHO (INEI, 2018). Education levels are: Less than Highschool, Highschool completed, and More than Highschool

Workers in the PAYG system were not affected by the policy; their rate of contribution remained unchanged. With this natural control group, I estimate the informality rate for workers registered in the PAYG system. These workers did not show an increase in informality; furthermore, the overall labor formality rate increased between 2005 and 2007 (see Appendix D.9).

Table 12 shows the elasticity of the formality rate in response to changes in the rate of contribution to the pension system for Peru's private pension system in 2006.

The marginal effects show that increasing the contribution rate from 8% to 10% for the private pension system decreased the probability of being formal by 3.1 percentage points. This can be understood as for each percentage point increase in the contribution rate, the formality rate decreases by 1.55 percentage points or an elasticity of -1.55.

Table 12: Probit, Logit and LPM Estimates of Labor Formality Rate

Dependent Variable: *Formality Rate*

Variables	Probit (MLE)	Marginal Effects (dx/dy)	Logit (MLE)	LPM (OLS)
Education	0.260***	0.096***	0.420***	0.099***
	(0.017)	(0.006)	(0.028)	(0.006)
Age	-0.009***	-0.003***	-0.014***	-0.003***
	(0.001)	(0.000)	(0.002)	(0.000)
Policy	-0.084***	**-0.031****	-0.137***	-0.031***
	(0.028)	(0.011)	(0.046)	(0.010)
Pension System	-0.240***	-0.089***	-0.389***	-0.092***
	(0.033)	(0.012)	(0.053)	(0.012)
Constant	0.385***		0.630***	0.647***
	(0.071)		(0.115)	(0.027)
Observations	16,740	16,740	16,740	16,740
R-squared				0.047

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Note: Annual data from ENAHO, years 2005-2007 for a weighted sample of male workers less than 65 years old.

To assess the model's goodness of fit, I simulate an economy with a private pension contribution rate of 8% and compare it to the benchmark case of 10%. Since workers choose their pension scheme only once in their lifetime and rarely switch thereafter, I evaluate both simulations using the pension scheme distribution from the benchmark model. The model simulation shows that increasing the contribution rate from 8% to 10% in the private system reduces the overall formality rate by 2.44 percentage points. This implies an elasticity of 1.22 (in absolute value), which is close to the empirical estimate of 1.55. The model therefore reproduces the responsiveness of formality to contribution rates with reasonable accuracy through liquidity-driven mechanisms. The subsequent analysis evaluates the implications of this mechanism for the government budget, overall labor formality, and workers' welfare.

5 Results

I use the calibrated model as a benchmark to assess the impact of a contributory pension system on the worker's choice over informality. To evaluate the mechanisms through which contributions towards a pension system affect this decision, I study two counterfactual economies. In the first counterfactual, I remove the contributory pension system from the benchmark economy without adjustment

to the government budget, focusing only on the impact on the labor supply. In the second counterfactual, the government budget is balanced by an income tax adjustment, exploring the pension system's unintended consequences on this economy. This evaluation will not account for transition periods; all results below are steady-state comparisons.

Removing the pension system changes the number of workers eligible to receive the social pension program. I let the number of non-contributory recipients adjust if necessary. In the benchmark economy, I calibrated the wealth threshold Ξ under which the elderly receive a non-contributory social pension (a means-tested transfer) to match the targeted 20% of the elderly population. In this experiment, the benchmark threshold level is kept.

5.1 Impact of contributory pension systems on labor composition

With all individuals starting their lives as informal workers, I removed the contributory pension system and explored their decision between formality status. The non-contributory pension, which works as a means-tested program, remains in place. Without mandatory retirement contributions enforced in the formal labor market, workers in formal jobs receive more liquid earnings. This counterfactual lifts the liquidity constraint introduced by a contributory pension system.

In an economy without a contributory pension system, the percentage of people working after reaching the retirement age significantly increases from 41.5% to 84.0% and the proportion of those age 65+ receiving the non-contributory social pension also jumps from 20.4% to 92.0%. These results reflect a more vulnerable elderly population.

Higher liquid earnings in the formal sector attract more workers to formal jobs. Table 13 provides an overview of the labor force composition and shows that the proportion of formal workers increased by about 21 percentage points, from 33% to 54% of the labor force for the economy with no contributory system. The new benefits of the formal sector differ by productivity, as formal sector provides higher returns in education; thus we see the biggest impact in workers with more than high school education. Workers with high school completed or less, are on the margin of taking formal jobs. When they receive job offers from the formal sector, they weigh the impact of pension contributions on their liquidity. Once this constraint is removed, they are also more likely to take formal offers.

Table 13: Labor force distribution across sector status, with and without a contributory pension system

Model	*Both systems*	*Removing contributory systems*			
	Benchmark	no τ adjustment		τ adjusted	
	(1)	(2)	Δ	(3)	Δ
Overall					
Formal worker	33.2	54.5	*21.3*	56.8	*23.6*
Informal worker	34.7	26.2	*-8.5*	25.4	*-9.3*
Informal self-employed	32.1	19.3	*-12.8*	17.8	*-14.3*
Less than high school					
Formal worker	23.8	37.4	*13.6*	40.9	*17.1*
Informal worker	38.7	34.4	*-4.3*	32.7	*-6.0*
Informal self-employed	37.5	28.2	*-9.3*	26.4	*-11.1*
High school completed					
Formal worker	30.2	48.9	*18.7*	51.5	*21.3*
Informal worker	35.1	28.7	*-6.3*	27.8	*-7.2*
Informal self-employed	34.7	22.3	*-12.4*	20.7	*-14.1*
More than high school					
Formal worker	44.8	75.7	*30.9*	76.6	*31.8*
Informal worker	30.7	16.2	*-14.5*	16.2	*-14.5*
Informal self-employed	24.6	8.1	*-16.4*	7.2	*-17.4*

Note: Distribution of workers' job status for (1) the benchmark economy, (2) the economy without a contributory pension system, and (3) the economy without a contributory system and a balanced government budget through income tax adjustment. The first three rows correspond to the overall economy, and the subsequent rows provide results by education level. Δ is the change in percentage points calculated with respect to the benchmark (1).

Without contribution to a pension system, formality is higher across all ages and education levels. The change in the fraction of formal workers across ages is found in Appendix section E.1. However, the magnitude of the increase of workers taking formal jobs varies along the lifecycle, and by education level. Figure 3 summarizes the change in formality between the benchmark economy (with a pension system) and the counterfactual economy (without pension contributions).

At the beginning of their working life, with lower income levels, workers are more vulnerable to shocks and in higher need of liquidity. Thus, removing pension contributions in the formal sector will ease the entry for young workers with higher liquidity preferences. This is observed for workers with education levels of high school or less, responding to the liquidity mechanism. For workers with higher education, the increase in formality is higher later in life as their returns in education increase with age, making the formal sector more attractive.

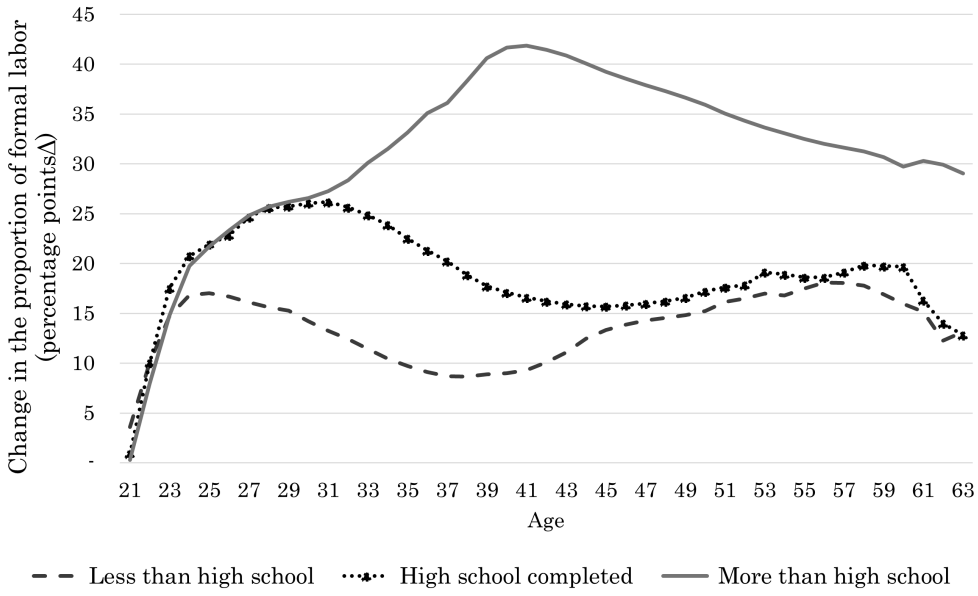


Figure 3: The figure shows the change in the proportion of formal workers by each education level across their working life when removing the contributory pension system. Benchmark (1) vs counterfactual (2).

Additionally, the probability of transitioning to the formal sector from an informal job also increases for all education levels; the same is observed for the probability of remaining formal. Table 25 in Appendix section E.2 shows transition probabilities to formality by education level.

Lower contributions make formal offers more attractive for workers in informal jobs and self-employment. Given that the transition to the formal labor force is possible only for workers with an informal job, an informal job for a firm also becomes more attractive. Across all education levels, once the contributory pension system is removed, the decrease in the number of self-employed workers is greater than that of informal workers. In line with the findings of Mandelman and Montes-Rojas (2009), these individuals are better off in entrepreneurial activities and differ from informal workers who wait for an opportunity to enter a formal job. In this case, removing contributions and making the formal sector more attractive will have a weaker effect on informal workers who were already interested in moving to formality but will significantly increase the opportunity cost of being self-employed and encourage these individuals to transition to formal jobs. These results align with findings by Narita (2020) that, using experiments involving reduced taxes, identify that a drop in self-employment is the main driver affecting formality rates.

Finally, to shed light on the importance of the contributory design versus the pension payouts design (individual account or PAYG), I compared the labor force composition in an economy without a contributory system against the benchmark economy when workers only have one pension design. Results of a comparison between the benchmark economy versus only the PAYG system and only individual-accounts are presented in the Appendix Section E.3. There are no significant differences in the labor composition[18], confirming that the main mechanism affecting labor supply decisions is the level of contributions as a percentage of the worker's income (*liquidity mechanism*) and not the nature of the pension scheme.

A complete removal of the contributory pension system has an important impact on the size of the formal labor. Individuals compensate for the lack of a social protection system by working after retirement and relying on government programs like the non-contributory social pension. These outcomes (a higher number of formal workers and a higher number of retirees receiving a non-contributory pension) impact the government budget. However, the results indicate that the indirect effects of both results on the budget have a limited net impact on formality, since they partially offset each other.

5.2 Impact of contributory pension systems on the Government Budget

When the contributory pension system is removed, unintended consequences impact the government budget. The first one affects government outlays. To qualify for the means-tested non-contributory social pension $\bar{c}$, workers should be below a wealth threshold and not receive a pension from any other source. In an economy without a contributory pension system, the second requirement is redundant, increasing the number of elderly that can now access the means-tested transfer. The number of elderly receiving a non-contributory pension increases from 92%. The non-contributory social pension program is financed from the consolidated government budget. As a result, the government budget perceives an increase in outlays due to the new number of elderly eligible for transfers.

The second effect is a consequence of the change in the composition of the labor force. As formality increases, the taxable base increases. The government's

[18]Formality rate for PAYG-only scheme is 33.7% while for only individual-account scheme formality is 33.6%.

revenues from income tax collections are higher in the counterfactual economy without a pension system.

These two results from removing the pension system have opposite effects on the government's consolidated budget. The pressure to raise taxes, created from the higher means-tested transfers, is compensated by a higher income tax collection from the increased tax base. To keep the budget in equation (8) balanced, the government would need a small adjustment in taxes. Reducing income taxes increases the attractiveness of formal employment, reinforcing the gains from removing the contributory pension system.

Therefore, in a second counterfactual, I reevaluate the overall effects on the economy once the government budget is balanced. The new income tax (τ_2) sets the formal labor force at 56%, a level that is 23 percentage points higher than the benchmark economy. The gains in formality further, as observed in the last column of Table 13.

The offsetting effects of an economy without a contributory pension system are summarized in Table 14. The tax adjustment relaxes income tax from 15% to 13.5%; reducing gains from tax collections; while, still expanding the tax base.

Table 14: Impact on Government budget

	Benchmark	*No contributory system*	
Model	(1)	(2)	(3)
Income tax (τ)	15.0%	15.0%	13.5%
Liquid Assets/Income ratio	0.92	0.96	0.97
Formal workers, %	33.2	54.5	56.8
Income tax collection, % Δ		53.2	42.6
Elderly			
working, %	41.5	84.1	82.8
with non-contributory pension, %	20.4	92.0	92.0

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

5.3 Impact of contributory pension systems on welfare

There is a positive impact on welfare from a complete removal of the contributory pension system, which differs by education level. Workers with higher education levels are the ones who benefit the most from the removal of the contributory

system. With a higher probability of job offers arriving from formal jobs, they will spend more periods of their working life in formality, and their wages benefit from the higher education premium in these jobs.

As seen in Table 13 the highly educated group has the highest increase in formal participation. However, a higher formality rate implies that they are also the group most affected by changes in the income tax level. Table 15 summarizes both effects on welfare for the average worker and by education level. Using an estimation of welfare gains as the equivalent variation in consumption, results show an increase in lifetime consumption by 4.1%, removing the contributory pension system. More workers accessing formal wages make higher consumption possible during their working life. However, without a contributory pension, retirees must keep working after retirement. Still, the higher average disutility of elderly work does not offset the positive effects gained during a working life without contributing to a pension system.

Table 15: Welfare gains from removing contributory pension systems

Model	(2) same τ	(3) τ adjusted
Average	4.1%	4.6%
by education level		
Less than high school	2.6%	3.0%
High school completed	3.8%	4.3%
More than high school	5.9%	6.6%

Note: Results are in comparison to the benchmark economy (1). (2) shows lifetime consumption gains keeping the same (τ) income tax. (3) shows results with the government budget balanced through τ adjustment.

The partially offsetting effects on the government budget of removing contributory pension systems(higher tax collection but higher outlays to social pension) let the counterfactual economy keep welfare gains even after accounting for the fiscal impact of this intervention. This particular dynamic is only present in labor markets with informality, where the tax base changes based on formality rates.

6 Conclusion

In economies with an informal labor market, contributions to a pension system are not enforced equally for all workers. In fact, when the formal labor market requires workers to contribute a percentage of their income, those with preferences for current liquidity may be discouraged from accepting formal jobs. To

study the impact of this incentive on formality, I develop a heterogeneous agent life-cycle OLG model of an economy with informal labor markets and the two most popular contributory pension systems —PAYG and individual-account— and calibrate it to Peru.

I find that removing the contributory pension system increases formality rates in the economy and provides welfare gains to workers. This is true independent of whether workers have a preference for PAYG systems (defined-benefits) or individual-account systems (defined contributions). The increase in formality has an unintended positive effect on the government budget because it provides a higher tax base. In this setup, the percentage of individuals relying on non-contributory social pensions also increases; increasing government expenses. However, the government is able to meet the higher number of transfers without significantly affecting taxes due to the increased size of the tax base.

Comparing the benchmark economy to a setup with only a PAYG or only individual accounts, I showed that the design of the system is not the main driver of the results on formality. Instead, this study shows that the contributory burden of the pension system is the main channel impacting workers' formality decisions.

Finally, similar to findings in Braun et al. (2017) for the US, I find welfare benefits from removing contributions to social security and sustaining only a means-tested social insurance programs for the old. This paper shows that, additionally, in economies with large informal labor, formality rates increase, enhancing the welfare gains of removing contributions to the pension system. Building on these results, this study underscores the policy relevance of liquidity constraints imposed by contributory pension systems and provides a framework to evaluate contribution rates and retirement policies that promote formalization while maintaining fiscal sustainability.

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Appendices

A Peruvian Pension System details

The contributory pension system in Peru provides the workers with two pension schemes options: a government-run system or a privately managed system.

The public system is administrated by the Oficina de Normalizacion Previsional (ONP), working as a PAYG system where younger generations finance the pensions of the older generations. In 2020, 38% of the affiliates to the pension system were enrolled in the PAYG system, and only 45% made contributions that year. Workers are required to make mandatory monthly contributions of 13% of their salary, and they pay no management fee. To have access to a pension, the worker must reach the retirement age of 65 and have contributed for at least 20 years. The pension is defined with a replacement rate between 30% and 45% replacement rate of the worker's last five years' average wage. This system provides a minimum pension benefit as well as a maximum.

The private system follows an individual-account system, where the pension is a function of the worker's monthly contributions to an individual account. Here, 10% of the worker's salary is deposited into his or her individual retirement account. In addition to this contribution, the worker has to pay a management commission to the fund administrator as well as an extra fee of around 1.5% to the insurance company. The worker chooses a private fund manager to invest their accumulated savings in financial markets. The fund manager can be changed at any time and without cost; however, currently there are only four pension fund administrators or AFPs (acronym in Spanish). At age 65, the workers gain access to their pension savings and must choose one of three alternatives: to receive a monthly pension as a scheduled withdrawal from their individual account, to buy an annuity, or to withdraw the 95.5% of their pension fund.[19] One characteristic that impacts the attractiveness of this system, especially for lower-income workers, is the lack of a minimum guaranteed pension. In the defined-contribution system, the pension level is a function of the worker's lifetime salary and financial market returns. The annualized real return rate was 4% on average from January 2015 to December 2020.[20]

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

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

B Empirical facts

B.1 Income distribution

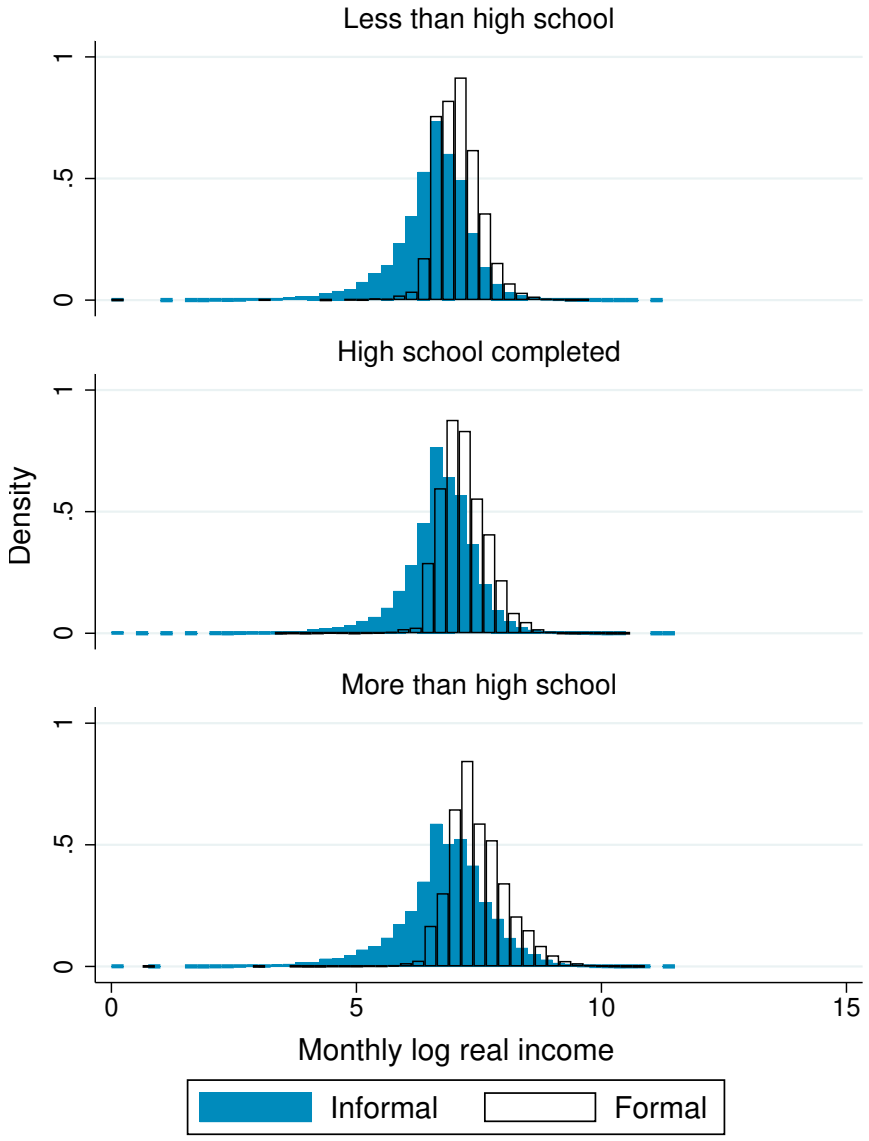


Figure 4: The figure shows the proportion of monthly log real income for workers in formal jobs and in informal jobs, excluding self-employed. Income is calculated before taxes and deductions for non-agricultural males between 20 to 64 years old from ENAHO INEI (2018).

B.2 Retirement facts

Table 16: Probability of changing work status after retirement age

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

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

C Model Features

C.1 Production Technology

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

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

where L is the sum of informal and formal labor $L = L^f + L^i$ firms hire, and A is the total factor productivity and is fixed. All capital depreciates at a constant rate $\delta \in (0, 1)$. Following the case study of Peru, the model considers a small open economy with access to international capital markets, providing the model with an exogenous interest rate and; therefore, exogenous wages. Financial returns for liquid and illiquid assets are also exogenous. In equilibrium, capital per worker is given by

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

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

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

C.2 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 $\{r, \varrho\}$ 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 Estimation and Calibration moments

D.1 Income Estimation

Income is estimated from the Peru Household Survey (ENAHO) using combined panel data from the 2011–2015 and 2014–2018 waves. The sample is restricted to male workers aged 20–65 who report income and work in non-agricultural sectors. The income variable aggregates self-reported earnings from the main and secondary jobs, expressed in real terms and deflated using Peru's Consumer Price Index (BCRP, 2021). A worker is classified as formal if they report pension contributions for the current or previous month of the survey. Education is grouped into three levels based on years of schooling: less than high school, high school

completion, and more than high school.

The variable *Sector change* calculates the relative importance of the previous sector in the current sector wage. I find a positive effect on the wages of informal workers if the individual's previous job experience was in the formal sector. This formal sector experience signals a level of knowledge carried and valued in the informal job. This variable is not significant for self-employed workers. In secondary estimations, I found that this positive effect lasts until the informal workers' third year in the informal sector. I also observed the opposite effect on workers transitioning from informal to formal jobs, indicating that experience accumulated in the formal sector is more valuable in both sectors. In contrast, informal sector experience is negatively valued, which can be understood as a wage penalty.

Finally, I controlled for year fixed effects and region. Region is determined by the Peruvian Institute of Statistics according to representative geographic areas, such as: Metropolitan Lima, the rest of the urban coast, the urban highlands, the urban jungle, the rural coast, the rural highlands, and the rural jungle. This captures different costs of living and other regional fixed effects.

Estimates of monthly log income are obtained from an OLS panel regression with survey weights. Results are summarized below.

Table 17: Determinants of income by sector

	Salaried worker	Formal worker	Informal worker	Informal Self-employed
Education level	0.081***	0.088***	0.064***	-0.196***
	(0.008)	(0.010)	(0.012)	(0.062)
Age	0.076***	0.074***	0.074***	0.102***
	(0.004)	(0.005)	(0.006)	(0.008)
Age^2	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Sector change (same year)	0.060**	-0.088***	0.321***	
	(0.028)	(0.029)	(0.053)	
Change sector 1 year ago			0.150**	
			(0.073)	
Change sector 2 years ago			0.291**	
			(0.114)	
High school # Age				0.007***
				(0.001)
More than High school # Age				0.012***
				(0.003)
Status	-0.489***			
	(0.013)			
Controlled by year	✓	✓	✓	✓
Controlled by region	✓	✓	✓	✓
Constant	5.752***	5.308***	4.896***	4.570***
	(0.084)	(0.105)	(0.109)	(0.209)
Observations	16,393	8,141	7,613	8,744
R-squared	0.234	0.090	0.087	0.064

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

Some adjustments are introduced during calibration. First, the coefficient capturing the effect of sectoral transitions on wages is applied only to formal and informal salaried workers, excluding the self-employed, for whom it is not statistically significant. Consistent with empirical evidence, the wage penalty from a sector change is assumed to persist for three periods among informal workers, with the average effect over those three years applied. For formal workers transitioning from informal jobs, only the contemporaneous effect is retained. Second, the constant term for the informal sectors is reduced by 0.3, improving

the alignment between the model's sector-specific mean of log earnings and the corresponding data in the benchmark economy for the informal/formal wage gap.

D.2 Self-employed production function

First, I assume that the capital share in the self-employed production function α is 0.2 and depreciation δ is set to 6% following Cagetti and De Nardi (2006). Second, I set two potential levels of entrepreneurial ability: high θ_H and low θ_L. I assume that individuals with θ_H are able to earn 20% over the average self-employed production earnings and that individuals with θ_L will have earnings 20% below the average. I then estimate that the earnings produced by the self-employed production function account for 20% of the constant estimated in column 3 of Table 17. Finally, I solve for the ability values $\theta = \{\theta_H, \theta_L\}$ that, given the optimal level of capital in first year of working life, will provide this difference in production earnings θk^{α} for the high school education level ($e = 2$).[21]

Table 18: Parameters in self-employed production function

	$\tilde{\beta}_0$	θ_H	θ_L	α	δ
Value	3.6	0.65	0.45	0.2	0.06

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

D.3 GMM Estimation of Income Shocks in the two-sector economy

The estimation of the income shocks follows a standard two-sector model setup, such that a worker chooses between the formal and the informal sector in each time period. This section details the model setup and GMM procedure.

Model Setup

In order to characterize the dynamics of labor income, I distinguish between two sectors of employment: the formal sector ($s = f$) and the informal sector ($s = i$). Let the observed (log) income of individual j in period t be:

$$y_{jt}^s = f_s(X_{jt}) + \varepsilon_{jt}^s$$

where $s \in \{f, i\}$ is the sector, $f_s(X_{jt})$ is a deterministic component (e.g., age, education, formal previous experience) and ε_{jt}^s is the idiosyncratic income shock.

In each sector, workers are subject to persistent income shocks that follow autoregressive processes of order one (AR(1)). Formally, I assume

$$\varepsilon_t^s = \rho_s \varepsilon_{t-1}^s + \epsilon_t^s, \quad s \in \{f, i\},$$

where ε_t^s denotes the sector-specific shock at time t, ρ_s is the persistence parameter, and ϵ_t^s is the sector-specific innovation. The innovations are mean-zero and normally distributed, with variances $\sigma_{\epsilon f}^2$ and $\sigma_{\epsilon i}^2$.

Crucially, the innovations across the two sectors are contemporaneously correlated:

$$\text{Cov}(\epsilon_t^f, \epsilon_t^i) = \rho_\epsilon \, \sigma_{\epsilon f} \sigma_{\epsilon i},$$

where $\rho_\epsilon \in [-1, 1]$ captures the degree of cross-sector dependence.

In the current ENAHO Peruvian Household Survey panel data (INEI, 2018), observation for individual-sector pairs are only available once a year, so contemporaneous cross-sector covariances cannot be reliably estimated. I therefore focus on the *permanent* correlation of the AR(1) shocks, which captures the persistent comovement of income shocks across sectors. This approach isolates long-run correlations while filtering out transitory, idiosyncratic variation that the annual data cannot capture. Moreover, it aligns naturally with the AR(1) model structure, for which the unconditional covariance of the permanent components is well-defined and directly interpretable. Using permanent correlations thus provides a robust and meaningful measure of cross-sector shock dependence under the data constraints.

This specification allows for two key features of the data: (i) persistence of income shocks within each sector, governed by ρ_s, and (ii) permanent comovement of shocks across the formal and informal sectors, governed by ρ_ϵ. The implied variance and covariance structure of the AR(1) processes ε_t^s are therefore functions of the innovation variances $(\sigma^2_{\epsilon f}, \sigma^2_{\epsilon i})$, the persistence parameters (ρ_f, ρ_i), and the cross-sector long-run correlation ρ_ϵ.

Estimation Strategy

Using ENAHO panel data waves 2011-2015 and 2014-2018, I estimate income equations separately for salaried workers in the formal and informal, and use the estimated residuals to construct empirical moments. Due to the annual frequency of the data, cross-sector moments are computed using individual-level averages of the residuals.

Table 19: Empirical Moments of Sectoral Income Shocks

Moment	**Value**	**Description**
$m_1 : \text{Var}(\varepsilon_t^f)$	0.2728	Variance of shocks in the formal sector
$m_2 : \text{Var}(\varepsilon_t^i)$	0.5110	Variance of shocks in the informal sector
$m_3 : \text{Cov}(\varepsilon_t^f, \varepsilon_{t-1}^f)$	0.2337	Lag-1 autocovariance of shocks in the formal sector
$m_4 : \text{Cov}(\varepsilon_t^i, \varepsilon_{t-1}^i)$	0.3704	Lag-1 autocovariance of shocks in the informal sector
$m_5 : \text{Cov}(\varepsilon_t^f, \varepsilon_t^i)$	0.1984	Cross-sector permanent covariance of shocks
$m_6 : \text{Cov}(\varepsilon_t^f, \varepsilon_{t-1}^i)$	0.1864	Cross-sector lagged covar(formal now, informal lagged)
$m_7 : \text{Cov}(\varepsilon_t^i, \varepsilon_{t-1}^f)$	0.1500	Cross-sector lagged covar(informal now, formal lagged)

Model-Implied Moments

The model delivers closed-form expressions for the same set of moments. Under stationarity,

$$
\begin{aligned}
m_1^{\text{model}} &= \frac{\sigma_{\epsilon f}^2}{1-\rho_f^2}, \\
m_2^{\text{model}} &= \frac{\sigma_{\epsilon i}^2}{1-\rho_i^2}, \\
m_3^{\text{model}} &= \rho_f \, \frac{\sigma_{\epsilon f}^2}{1-\rho_f^2}, \\
m_4^{\text{model}} &= \rho_i \, \frac{\sigma_{\epsilon i}^2}{1-\rho_i^2}, \\
m_5^{\text{model}} &= \frac{\rho_\epsilon \, \sigma_{\epsilon f} \sigma_{\epsilon i}}{1-\rho_f \rho_i}, \\
m_6^{\text{model}} &= \rho_i \, \frac{\rho_\epsilon \, \sigma_{\epsilon f} \sigma_{\epsilon i}}{1-\rho_f \rho_i}, \\
m_7^{\text{model}} &= \rho_f \, \frac{\rho_\epsilon \, \sigma_{\epsilon f} \sigma_{\epsilon i}}{1-\rho_f \rho_i}.
\end{aligned}
$$

Thus, each empirical moment has a corresponding theoretical counterpart that depends directly on the parameters $\theta = \{\rho_f, \rho_i, \sigma_{\epsilon f}, \sigma_{\epsilon i}, \rho_\epsilon\}$.

Estimation Procedure

I denote by m^{data} the vector of empirical moments and by $m^{\text{model}}(\theta)$ the corresponding vector of model-implied moments. The GMM estimator solves

$$
\hat{\theta} = \arg\min_{\theta} \left[m^{\text{data}} - m^{\text{model}}(\theta) \right]' W \left[m^{\text{data}} - m^{\text{model}}(\theta) \right],
$$

where W is a positive semi-definite weighting matrix. In practice, I begin with an identity matrix and iterate toward the optimal weighting matrix defined by the inverse of the covariance matrix of the moments.

Since the number of empirical moments (seven) exceeds the number of parameters (five), the model is over-identified. This allows me to conduct a Hansen J-test of over-identifying restrictions. The model failed to reject the null hypothesis, meaning empirical moments are not statistically inconsistent with the 5-parameter AR(1) two-sector model; thus, shocks are correctly captured by the model.
Results of the parameters estimation are summarized in Table 6 of the paper

This estimation strategy recovers the persistence of shocks in each sector, the innovation variances, and the degree of correlation between formal and informal sector innovations. By focusing on the cross-sector covariance of the AR(1) processes, the approach isolates the long-run comovement of income shocks across sectors rather than short-run transitory variation.

D.4 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 20: 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)

The abbreviated mortality tables for 2015–2020 are available in five-year cohorts, and mortality is 1 when the individual reaches 100 years old. Using linear interpolation, I estimate the annual survival probabilities for individuals aged 65 to 100 years and incorporate them into the model.

D.5 Wealth distribution approximation

There is no official wealth distribution for Peru, as household surveys do not include questions about financial assets, savings, or other assets. To approximate the wealth distribution of the country for the urban area, I will use two pieces of available information on wealth. First, an estimate by Carrera and Ordonez (2023) published by the Peruvian Central Bank (BCRP)[22] that provides the share of total wealth held by each population quintile. I use this to construct a Lorenz representation consistent with those knots. To refine the tail of this calibration, I use information from the World Inequality Database (Alvaredo et al.) for Peru, where the top 10% of the population holds about 67% of the wealth in 2019. For moderate estimates, I impose the additional calibration that the top 10% of the population holds 60% of total wealth, and compute the population fraction that corresponds to each 20% slice of wealth.

Data and objective

The wealth shares for each population quintile are estimated by the Peruvian Central Bank as follows,

$$Q_1 = 1.4\%,\ Q_2 = 12.6\%,\ Q_3 = 21.7\%,\ Q_4 = 28.0\%,\ Q_5 = 36.3\%.$$

From these I build the cumulative Lorenz knots (population p vs. cumulative wealth $L(p)$) at the standard quintile population points:

Population p	0	0.2	0.4	0.6	0.8	1.0
$L(p)$	0	0.014	0.140	0.357	0.637	1.000

The objective of the estimations is to compute, for each wealth threshold $w \in \{0.20, 0.40, 0.60, 0.80, 1.00\}$, the cumulative population $p(w)$ such that $L\big(p(w)\big) = w$. The population in each wealth quintile equals successive differences of $p(w)$.

Tail calibration

To match a similar distribution at the tail that characterized the levels of inequality of Peru, I add the constraint that the top 10% hold 60% of total wealth based on the World Inequality Data estimates. Thus,

$$1 - L(0.9) = 0.60 \quad \Longrightarrow \quad L(0.9) = 0.40.$$

This transformation means that $L(0.8) = 0.637 > 0.40$; the original knots are inconsistent with the target. Therefore, I perform a transformation at the 80% knot that respects the original quintile information as closely as possible. I consider the following conversion approach:

[22] Using numbers calculated for the Lima metropolitan area, as a reference of urban area

1. Keep the original cumulative knots at $p = 0, 0.2, 0.4, 0.6$ unchanged:

$$L(0) = 0,\ L(0.2) = 0.014,\ L(0.4) = 0.140,\ L(0.6) = 0.357.$$

2. Impose $L(0.9) = 0.40$ (Top-10 = 60%). This forces $L(0.8) \leq 0.40$. I adopt the minimal clipping

$$L(0.8) \leftarrow \min\{L(0.8),\ 0.40\} = 0.40,$$

   Where $L(0.6) = 0.357 < 0.40$, monotonicity is preserved.

3. From $p = 0$ up to $p = 0.9$ I use piecewise linear interpolation between the knots:

$$(p_i, L_i) = (0, 0), (0.2, 0.014), (0.4, 0.140), (0.6, 0.357), (0.8, 0.400), (0.9, 0.400).$$

4. For the top tail $p \in [0.9, 1]$ I adopt a Pareto conditional tail to generate a smooth, monotonically increasing Lorenz segment that concentrates the remaining 60% of wealth across the final 10% of the population. I used a moderate Pareto shape parameter $\alpha = 2.0$

Functional form and inversion formulas

Piecewise linear segments (general formula)

On any interval $p \in [p_i, p_{i+1}]$ with endpoints (p_i, L_i) and (p_{i+1}, L_{i+1}) define

$$L(p) = L_i + \frac{L_{i+1} - L_i}{p_{i+1} - p_i}\,(p - p_i).$$

If a wealth threshold w lies in $[L_i, L_{i+1}]$, the inverse (population at which cumulative wealth equals w) is

$$p(w) = p_i + \frac{w - L_i}{L_{i+1} - L_i}\,(p_{i+1} - p_i).$$

Pareto tail on $[0.9, 1]$

Let $p_0 = 0.9$, $L_0 = L(0.9) = 0.40$, $\Delta_p = 1 - 0.9 = 0.1$ (tail population), and $\Delta_L = 1 - L_0 = 0.60$ (tail wealth). For a Pareto tail with shape parameter $\alpha > 1$ the conditional Lorenz on the tail (in terms of u, the fraction of the tail) is

$$L_{\text{tail}}(u) \ = \ 1 - (1 - u)^{\beta}, \qquad \beta \equiv 1 - \frac{1}{\alpha}, \quad u \in [0, 1].$$

The global Lorenz on the tail is therefore

$$L(p) \ = \ L_0 + \Delta_L \cdot L_{\text{tail}}\Big(\frac{p - p_0}{\Delta_p}\Big).$$

Given a target cumulative wealth w with $w \in [L_0, 1]$ the tail inversion is obtained by solving

$$\frac{w - L_0}{\Delta_L} \;=\; 1 - (1-u)^{\beta}$$

for u; hence

$$(1-u)^{\beta} \;=\; 1 - \frac{w - L_0}{\Delta_L} \quad\Longrightarrow\quad u \;=\; 1 - \Big(1 - \frac{w - L_0}{\Delta_L}\Big)^{1/\beta},$$

and finally

$$p(w) \;=\; p_0 + \Delta_p \cdot u \;=\; p_0 + \Delta_p \left[1 - \Big(1 - \frac{w - L_0}{\Delta_L}\Big)^{1/\beta}\right]. \tag{11}$$

For $\alpha = 2.0$, $\beta = 1 - 1/2 = 0.5$ and $1/\beta = 2$.

Results for Peru

(i) Bottom 20% of wealth, $w = 0.20$

This lies in the interval $[p_2, p_3] = [0.4, 0.6]$ because $L(0.4) = 0.140$ and $L(0.6) = 0.357$. Using formula (11):

$$\begin{aligned} p(0.20) &= 0.4 + \frac{0.20 - 0.140}{0.357 - 0.140} \times 0.2 = 0.4 + \frac{0.06}{0.217} \times 0.2 \\ &= 0.4 + \frac{12}{217} \approx 0.45530. \end{aligned}$$

Hence the bottom 20% of wealth is held by approximately 45.53% of the population.

(ii) First 40% of wealth, $w = 0.40$

By construction $L(0.8) = 0.400$, so $w = 0.40$ coincides with $p = 0.8$. Thus

$$p(0.40) = 0.800.$$

(iii) First 60% of wealth, $w = 0.60$

Now $w > L(0.9) = 0.40$, I invert inside the Pareto tail using (11). Take

$$L_0 = 0.40, \quad \Delta_L = 0.60, \quad p_0 = 0.9, \quad \Delta_p = 0.1, \quad \beta = 0.5.$$

Compute the tail fraction:

$$\frac{w - L_0}{\Delta_L} = \frac{0.60 - 0.40}{0.60} = \tfrac{1}{3}.$$

Then

$$u = 1 - \left(1 - \tfrac{1}{3}\right)^{1/\beta} = 1 - \left(\tfrac{2}{3}\right)^{2} = 1 - \tfrac{4}{9} = \tfrac{5}{9}.$$

Thus

$$p(0.60) = 0.9 + 0.1 \times \tfrac{5}{9} \approx 0.95556,$$

(iv) First 80% of wealth, $w = 0.80$

Analogously:

$$\frac{w - L_0}{\Delta_L} = \frac{0.80 - 0.40}{0.60} = \tfrac{2}{3}.$$

Hence

$$u = 1 - \left(1 - \tfrac{2}{3}\right)^{1/\beta} = 1 - \left(\tfrac{1}{3}\right)^{2} = 1 - \tfrac{1}{9} = \tfrac{8}{9},$$

and

$$p(0.80) = 0.9 + 0.1 \times \tfrac{8}{9} \approx 0.98889,$$

(v) Total wealth, $w = 1.00$

Trivially $p(1.00) = 1.00$.

Final results: population shares by wealth quintile

The population share in each 20% slice of *wealth* equals successive differences of the $p(w)$ values computed above. Results summarized in Table 8 in the paper.

Under this construction, the bottom 20% of wealth is owned by roughly 45.5% of people whereas the richest 20% of wealth is held by only about 1.1% of people. This reflects the strong concentration implied by the requirement that the top decile hold 60% of wealth.

D.6 Labor market calibrated parameters

Table 21: Calibrated labor market parameters across education levels

Labor market parameters	Education levels, e		
	1	2	3
Separation cost:			
From formal job, ν^f	0.0005	0.0007	0.0013
From informal job, ν^i	0.0015	0.0024	0.0058
Job offer arrival:			
Formal offer for formal worker, γ_f^f	0.76	0.8	0.87
Formal offer for informal worker, γ_f^i	0.43	0.52	0.64
Informal offer for informal worker, γ_i^i	0.68	0.72	0.79
Informal offer for self-employed, γ_i^s	0.41	0.43	0.49

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

D.7 Other parameters

Table 22: Calibrated parameters for the economy

Parameter	Value	Target
Discount factor, β	0.85	Capital-output ratio
Desutility of working at age 65, ϕ	0.0008	Elderly work (41%)
Non-contributory pension threshold, M (monthly income plus wealth)	2,300	Program beneficiaries (20%)

Table 23: Non-calibrated parameters

General: Parameters	Value
Risk aversion, γ	2
Capital utilization, α	0.2
Capital depreciation rate, δ	0.06
Average 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

D.8 Untargeted parameters

Table 24: Untargeted Moments

Moment	Data	Model
Fraction of workers enrolled to PAYG / individual accounts	0.375	0.378
Overall Fraction of total labor force		
Formal	33.4	33.2
Informal worker	35.0	34.7
Informal self-employed	31.6	32.1
Average log income of formal workers/ informal workers	1.08	1.08
Average log income of formal workers/ self-employed	1.09	1.07

Note: Data for fractions of workers by pension system are estimated from the distribution of new enrollments by pension system for the year 2019 (Super Intendencia de Banca, 2019)

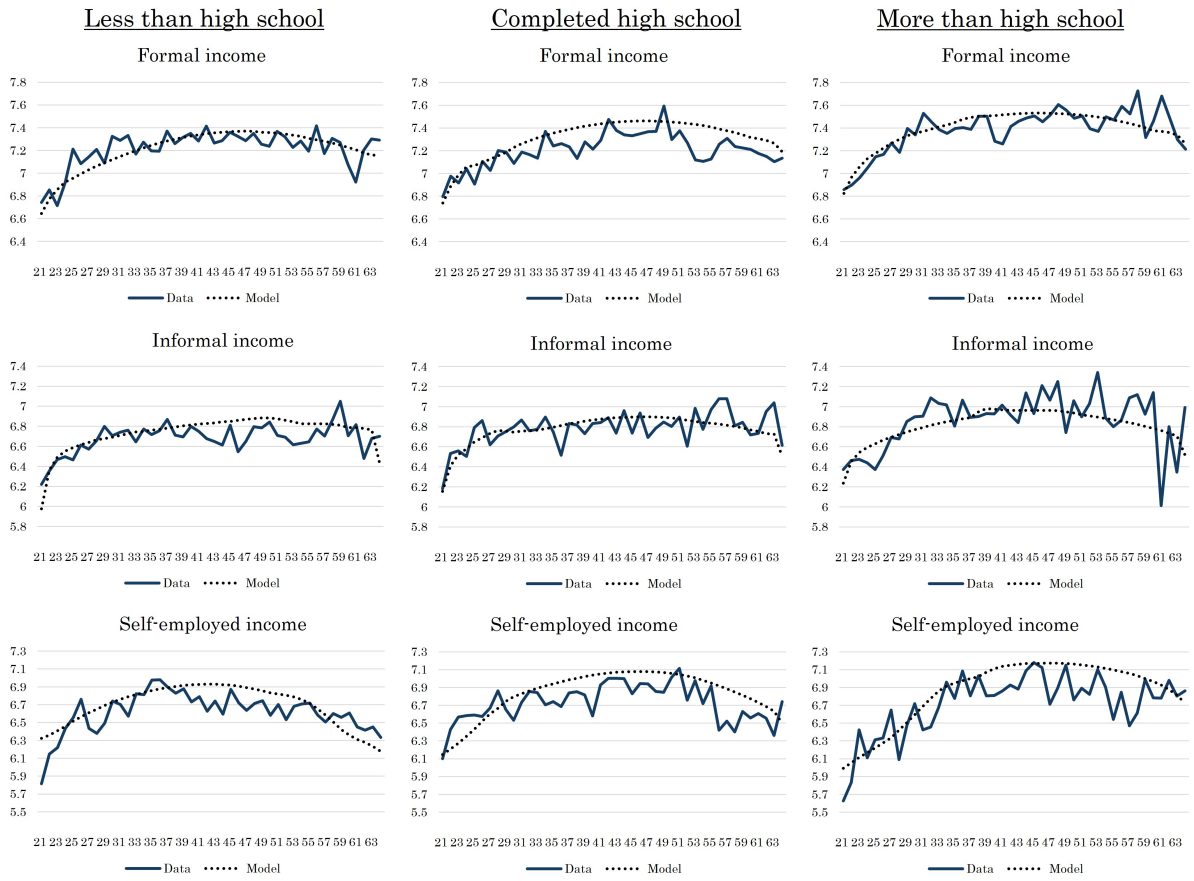
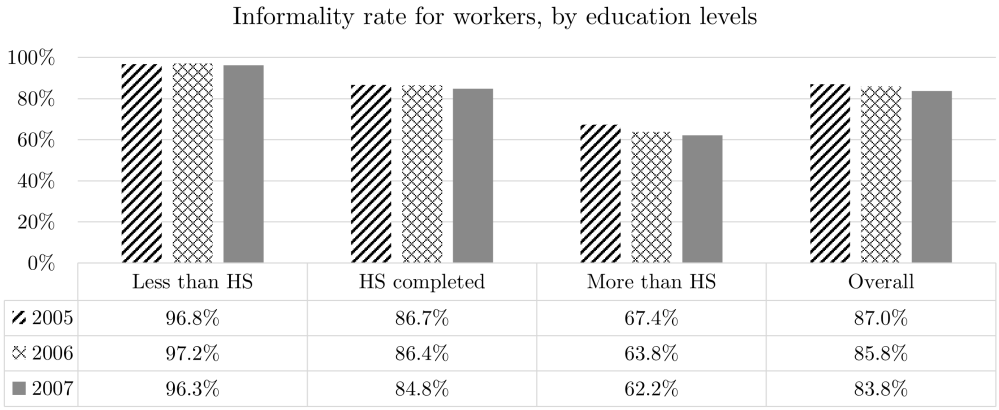


Figure 5: The figure shows the average log monthly wage by sector over the life cycle. The dotted line represents the benchmark model, while the continuous line shows the average log monthly wage by age from the ENAHO household survey weighted panel data for the periods 2011–2015 and 2014–2018.

D.9 Goodness-of-fit



	Less than HS	HS completed	More than HS	Overall
2005	96.8%	86.7%	67.4%	87.0%
2006	97.2%	86.4%	63.8%	85.8%
2007	96.3%	84.8%	62.2%	83.8%

Figure 6: The figure shows the informality rates by education level for 2005, 2006, and 2007 in Peru. Overall and across education levels, informality rates decreased from 2005 to 2007 for non-agricultural workers under 64 years old from ENAHO (INEI, 2018).

E Results continuation

E.1 Impact on the labor force

Removing a contributory pension system, while keeping a non-contributory means-targeted pension, increases formality rates for all education levels.

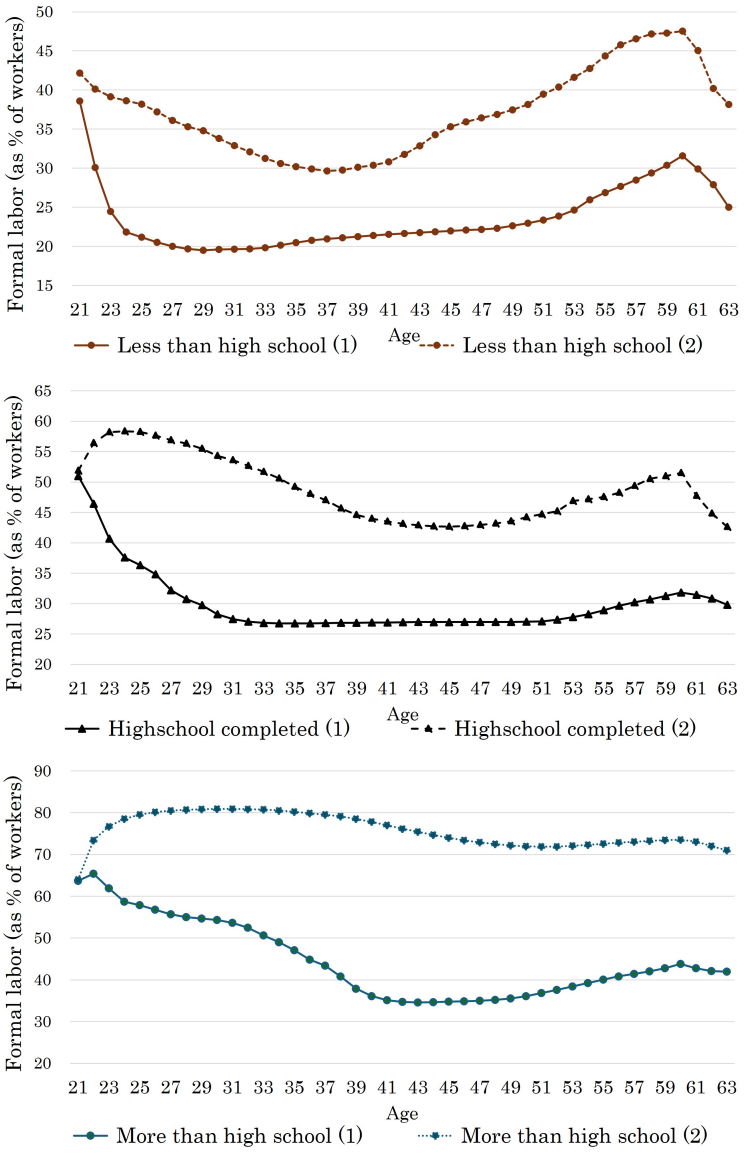


Figure 7: The figure shows the proportion of formal workers by each education level across their working life. The continuous lines show results for the benchmark model (1), and the dotted lines for the economy without a contributory pension system (2).

E.2 Summary of transition matrix

Table 25: Transition probabilities from informal workers and formal workers, by education level

	From informal workers			From formal workers		
	Benchmark	No contributions		Benchmark	No contributions	
	(1)	(2)	(3)	(1)	(2)	(3)
			Less than high school			
Formal worker	0.26	0.34	0.36	0.57	0.69	0.72
Informal worker	0.52	0.46	0.45	0.43	0.31	0.28
Self-employed	0.21	0.20	0.20	-	-	-
			High school completed			
Formal worker	0.32	0.42	0.44	0.62	0.76	0.77
Informal worker	0.50	0.42	0.41	0.38	0.24	0.23
Self-employed	0.18	0.16	0.16	-	-	-
			More than high school			
Formal worker	0.39	0.62	0.63	0.72	0.87	0.87
Informal worker	0.47	0.27	0.27	0.28	0.13	0.13
Self-employed	0.14	0.11	0.10	-	-	-

Note: Transition probability of transitioning to formal jobs by education level for benchmark economy (1), an economy without a contributory pension system (2), and an economy without a contributory pension system with a government budget balanced (3)

E.3 Results from the analysis of the design

Results of changes in labor force composition by pension system, without general budget (taxes) adjustments.

Table 26: Labor force distribution across sector status according to the contributory pension scheme in partial equilibrium

Model	*both*	*only*		*only*	
	Benchmark	Individual-accounts		PAYG	
	(1)	(4)	Δ	(5)	Δ
		Overall			
Formal worker	33.2	33.6	*0.4*	33.8	*0.6*
Informal worker	34.7	34.7	*-0.1*	34.5	*-0.2*
Informal self-employed	32.1	31.8	*-0.3*	31.7	*-0.4*
		Less than high school			
Formal worker	23.8	24.9	*1.1*	23.8	*0.0*
Informal worker	38.7	38.2	*-0.5*	38.6	*0.0*
Informal self-employed	37.5	36.9	*-0.6*	37.6	*0.1*
		High school completed			
Formal worker	30.2	30.8	*0.6*	30.2	*0.0*
Informal worker	35.1	35.0	*-0.1*	34.8	*-0.3*
Informal self-employed	34.7	34.2	*-0.5*	35.0	*0.3*
		More than high school			
Formal worker	44.8	44.3	*-0.4*	46.4	*1.7*
Informal worker	30.7	31.0	*0.4*	30.4	*-0.3*
Informal self-employed	24.6	24.6	*0.0*	23.2	*-1.4*

Note: 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 (4), and economy with only a PAYG pension system (5). The first three rows correspond to the overall economy, and the following rows provide results by education level. Δ is the percentage point change with respect to (1).