

The Impact of Pension Systems in Labor Markets with Informality

EEA - ESEM 2022 Congress

Carla Moreno

Loyola Marymount University

August 25, 2022

1. Introduction
2. Life-cycle model with Heterogeneous Agents
3. Evaluation of Pension Systems Designs and Conclusions

Introduction

- Pensions are connected to the labor market
- Contributions depend on employment status
- Your employment status affects your pension

Introduction

- Pensions are connected to the labor market
- Contributions depend on employment status
- Your employment status affects your pension
- Additional implications for distinct labor markets
- Focus: labor markets with informality

Introduction

- Pensions are connected to the labor market
- Contributions depend on employment status
- Your employment status affects your pension
- Additional implications for distinct labor markets
- Focus: labor markets with informality

60% of the world's total labor force is **informal** (ILO, 2018)

20% of US adults participated in informal income-generating activities
(Bracha & Burke, 2016)

Latin American Pension Systems

- Enforcement of contributory systems is only possible in formal jobs
- Difficulty achieving full coverage
- Current policy debate about pension systems
- **Contributory** pension systems :
 - Pay-As-You-Go (PAYG)
 - Individual-account
 - Both
- Non-contributory pension for the uncovered and more vulnerable
- Means-tested transfer not based on working history

Latin American Pension Systems

- Enforcement of contributory systems is only possible in formal jobs
- Difficulty achieving full coverage
- Current policy debate about pension systems
- **Contributory** pension systems :
 - Pay-As-You-Go (PAYG): Social Security in the US
 - Individual-account: 401(k) plan in the US
 - Both
- Non-contributory pension for the uncovered and more vulnerable
- Means-tested transfer not based on working history

Latin American Pension Systems

- Enforcement of contributory systems is only possible in formal jobs
- Difficulty achieving full coverage
- Current policy debate about pension systems
- **Contributory** pension systems :
 - Pay-As-You-Go (PAYG)
 - Individual-account
 - Both
- **Non-contributory** pension for the uncovered and more vulnerable
- Means-tested transfer not based on working history

- 1. Does the pension system design have an impact on workers' decisions over formality?**
 - What are the channels through which the pension system impacts labor market and welfare?
 - Direct effect: Contributory and Non-contributory pension
 - Indirect effects: Government budget
- 2. What are the welfare implications of alternative pension system designs under labor informality?**

Case Study: Peru

1. High level of informality
 - About 2/3 of the working force is informal
2. Representative pension system
 - Pension schemes: **Individual-account** (Private), **PAYG** (Public) and **Non-contributory** (Pension 65)

Table 1: Coverage 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: Excludes Army Force pensions and retirees with withdrawals of 95.5% of their pension fund. 2019 estimates, SBS (2019), Midis (2019)

Case Study: Peru

1. High level of informality
 - About 2/3 of the working force is informal
2. Representative pension system
 - Pension schemes: **Individual-account** (Private), **PAYG** (Public) and **Non-contributory** (Pension 65)

Table 1: Coverage 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: Excludes Army Force pensions and retirees with withdrawals of 95.5% of their pension fund. 2019 estimates, SBS (2019), Midis (2019)

3. Panel and quarterly data of the Peruvian National Households Surveys (ENAHO) from 2011 to 2018, national representation

Approach

- Life-cycle model where labor **informality** arises endogenously
- Model household's saving decisions and optimal choice over:
 - formal and informal sector
 - pension system
- **New feature:** Workers choose between PAYG and individual-account system

▶ Informality trade-off

Findings: 1. On Contributory Pension Systems

- Structure of the pension system discourages working in formal sector
- Why? Presence of a liquidity mechanism
 - Even though formal wages are higher, mandatory contributions impose a liquidity constraint on workers
 - Liquidity constraint is binding for some workers, which makes the informal sector more attractive

Findings: 1. On Contributory Pension Systems

- Structure of the pension system discourages working in formal sector
- Why? Presence of a liquidity mechanism
 - Even though formal wages are higher, mandatory contributions impose a liquidity constraint on workers
 - Liquidity constraint is binding for some workers, which makes the informal sector more attractive
- Direct effect: when contributory pension system is removed
 - Formality \uparrow in 3.5pp
 - Elderly receiving non-contributory pensions \uparrow from 20% to 49%
- Indirect effect:
 - \uparrow Tax base, increasing government revenue
 - \uparrow Government outlays to poor elderly
 - These two effects offset leading to a small income tax adjustment
- With Government's budget balanced, I find welfare gains of 3.8%

Findings: 2. On Pension System Design

An informal economy with **both** systems is not welfare improving.

- A PAYG system is preferred by low-income workers while individual-account system by high-income workers
- Having both system available impacts sustainability of PAYG

Which pension design to choose? None

Findings: 2. On Pension System Design

An informal economy with **both** systems is not welfare improving.

- A PAYG system is preferred by low-income workers while individual-account system by high-income workers
- Having both system available impacts sustainability of PAYG

Which pension design to choose?

- A **PAYG-only system** has the highest ex-ante welfare in comparison to an only individual-account system or having both available.
- Fraction of formal workers increase in 3.1pp if only PAYG is offered
- A PAYG-only generates 2.2% welfare gains compare to benchmark

1. Introduction
2. Life-cycle model with Heterogeneous Agents
3. Evaluation of Pension Systems Designs and Conclusions

- Time is discrete
- Different sectors
 - Formal worker, f
 - Informal worker, i
 - Informal self-employed, s
- Earning functions differ by type of sector
- Idiosyncratic labor income shocks by sector
- Heterogeneity in age, education, and initial wealth a_0
- Mechanisms affecting decision to be informal:
 1. Income tax, τ
 2. Job opportunity in formal and informal sector
 3. Pension system features: Contribution rate x

Working years:

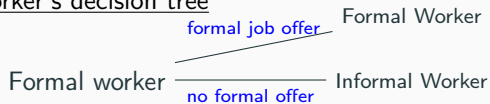
- Workers compare each sector's value function conditional on their current state and sector:

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

- Job offer probabilities vary by education and current sector
- Workers make a consumption-saving decision and an optimal sector decision each period
- Only formal sector workers contribute to a pension scheme
- Correlated earning shocks for formal and informal sectors

Household's decision

Worker's decision tree

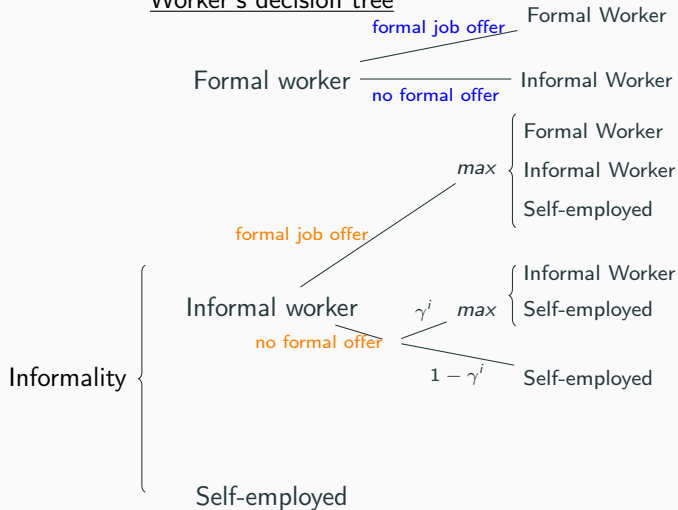


Informal worker

Self-employed

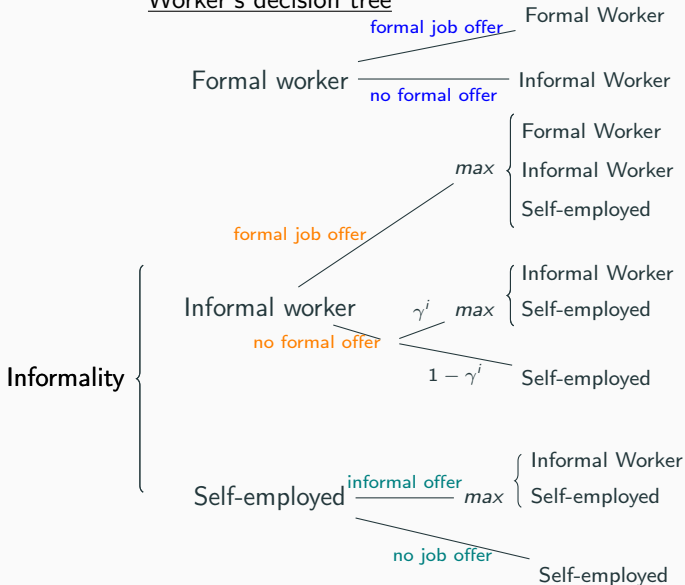
Household's decision

Worker's decision tree



Household's decision

Worker's decision tree



Retirement years:

- Individuals face a mortality risk $\Gamma(t)$
- Individuals can continue working:
 - Only available jobs are in the informal sector
 - Retirees face a disutility from working ϕ
- Once an individual stops working they are fully retired and can't go back to work (retirement is an absorbing state)
- Retirees receive a pension if available and make a consumption-saving decision each period

Formal Worker Problem

$$\tilde{V}^f(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \left(\underbrace{\gamma^f(f, e) \mathbb{E}[\tilde{V}^f(\mathbf{s}') | \varepsilon^f]}_{\text{with formal offer}} + \underbrace{(1 - \gamma^f(f, e)) (\mathbb{E}[V^i(\mathbf{s}') | \varepsilon^i] - \nu_{f,e})}_{\text{without formal offer}} \right) \right\}$$

Parameters for formal workers given education level

- $\gamma^f(f, e)$ -> Probability of formal job offer arrival given being formal
- $\nu_{f,e}$ -> Unemployment spell when separated from formal job

Formal Worker Problem

$$\tilde{V}^f(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \left(\underbrace{\gamma^f(f, e) \mathbb{E}[\tilde{V}^f(\mathbf{s}') | \varepsilon^f]}_{\text{with formal offer}} + \underbrace{(1 - \gamma^f(f, e)) (\mathbb{E}[V^i(\mathbf{s}') | \varepsilon^i] - \nu_{f,e})}_{\text{without formal offer}} \right) \right\}$$

State space (\mathbf{s})

- e , education level: Less than HS, HS completed, More than HS
- a , liquid savings
- t , age
- j , working sector: f, i, s
- p , pension scheme: 1 (Individual-account) or 2 (PAYG)
- \tilde{Y} , retirement savings in individual-account
- z , years of contribution to PAYG system

State variables affecting income process

- l , sector change in last 3 years
- θ , entrepreneurial ability: High or Low

Formal Worker Problem

$$\tilde{V}^f(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \left(\underbrace{\gamma^f(f, e) \mathbb{E}[\tilde{V}^f(\mathbf{s}') | \varepsilon^f]}_{\text{with formal offer}} + \underbrace{(1 - \gamma^f(f, e)) (\mathbb{E}[V^i(\mathbf{s}') | \varepsilon^i] - \nu_{f,e})}_{\text{without formal offer}} \right) \right\}$$

s.t.

$$c + a' = (1 - \tau - x_p)y^f - \mathbb{1}_{p=1}\{\eta y^f\} + (1 + r)a$$

$$a' \geq 0$$

Formal Worker Problem

$$\tilde{V}^f(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \left(\underbrace{\gamma^f(f, e) \mathbb{E}[\tilde{V}^f(\mathbf{s}') | \varepsilon^f]}_{\text{with formal offer}} + \underbrace{(1 - \gamma^f(f, e)) (\mathbb{E}[V^i(\mathbf{s}') | \varepsilon^i] - \nu_{f,e})}_{\text{without formal offer}} \right) \right\}$$

s.t.

$$c + a' = (1 - \tau - x_p)y^f - \mathbb{1}_{p=1}\{\eta y^f\} + (1 + r)a$$

$$a' \geq 0$$

$$\tilde{Y}' = (1 + \varrho) \tilde{Y} + \mathbb{1}_{p=1}\{x_1 y^f\}$$

$$z' = z + \mathbb{1}_{p=2}\{1\}$$

▸ Wage function

▸ Informal Worker Problem

▸ Self-employed Problem

Retiree's Problem

At $age \geq R$, the worker is a retiree and might be eligible to:

- **Individual-account**: retirement savings \tilde{Y}_R , as an annuity
- **PAYG**: pension benefits calculated with a replacement rate
- **Non-contributory**: a monetary transfer \bar{c}

The retiree has 2 choices to continue working in the informal sector or completely retire, represented as:

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

▸ Pensions set-up

▸ Retiree value functions

▸ Government problem

- Pension system requirements, contributions, fees and taxes replicate current Peruvian system
- Male and Non-agricultural sector
- Earning process:
 - Deterministic component for formal, informal workers and self-employed estimated from Peruvian panel data
 - Stochastic component for correlated shocks follows Chilean estimates (Lopez, 2015)
- Workers' transition matrix by education estimated from the data
 - ▶ Shocks
 - ▶ Job offer probabilities
 - ▶ Estimation results

1. Introduction
2. Life-cycle model with Heterogeneous Agents
3. Evaluation of Pension Systems Designs and Conclusions

Evaluating counterfactual

I compare the outcomes against the calibrated benchmark economy.
The results are divided in two sections:

1. An economy without a contributory pension system
2. Two economies with two different pension systems: PAYG-only system or only individual-account system

I study the effects over:

- Labor composition
- Government budget
- Welfare

1. Removing Contributory System: Government Budget

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

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

1. Removing Contributory System: Government Budget

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

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

1. Removing Contributory System: Summary

- ↑ Formality for all workers
- ↑ Tax base → increase in income tax collection
- ↑ Non-contributory pension → increase government transfers
- Only small adjustment in income taxes is needed
- Welfare gains in partial and general equilibrium

2. Pension Design: Government Budget

In comparison with the benchmark, a PAYG-only system has:

1. Higher amount of contributions to the PAYG system:
 - The integration of high-income workers to the system
2. Pensions requirements
 - Requirement of years of contributions to obtain a pension
 - Capped maximum pension benefit

Payment of pension benefits < Increased collection from contributions

▶ results labor force

In an economy with large informal labor:

- Removing the contributory pension system:
 - Increases formality rates
 - There are unintended positive effect on the government budget because it provides a higher tax base
 - Generates welfare gains to workers

Conclusions

In an economy with large informal labor:

- Removing the contributory pension system:
 - Increases formality rates
 - There are unintended positive effect on the government budget because it provides a higher tax base
 - Generates welfare gains to workers

But, if you have to choose a contributory pension system:

- A PAYG-only system, with capped benefits and an eligibility requirement based on years of contributions, is welfare improving
- From ex-ante perspective, having an individual-account and a PAYG available as a worker's choice is not better.

Thank you

The liquidity mechanism

- Formal workers contribute a percentage of their income to the pension system
- Contributions for retirement are an illiquid asset, that imposes a liquidity constraint to the worker
- People who value liquidity more, such as low-income workers, are less likely to be formal to avoid contributions
- Using an empirical approach I tested for evidence of this mechanism in Peru

Income and Formality

- If liquidity mechanism is operative in Peru, workers with higher labor productivity should be more likely to choose formality
- Can use income as measure of labor productivity
- But must control for the fact that formal jobs may just pay higher salaries
- A two-stage approach (Escanciano et al., 2016) is used here to identify the effect of productivity on formality status
- It uses an exogenous instrument created from the residuals from the estimation of real income on other explanatory variables exploiting the non-linearity between them

$$\text{Formality} = \mathbb{I}(\alpha_0 + \alpha_1 \text{Education} + \alpha_2 \text{Hours} + \alpha_3 \text{Gender} + \alpha_4 \text{Age} + \alpha_5 \text{SelfEmployed} + \alpha_6 \text{Agriculture} + \delta_0 \text{LogIncome} - e \geq 0)$$

Formality Probability

Determinants	Logit
Log of Real Income	2.297*** (0.059)
Log of Weekly Hours Worked	-0.467*** (0.042)
Female	0.589*** (0.032)
Age	0.007*** (0.001)
Self-employed	-1.964*** (0.029)
High School Education	0.521*** (0.039)
More than High School	0.755*** (0.060)
Correction Term	-1.007*** (0.059)
Constant	-15.101*** (0.233)

Notes: Survey-weighted Logit estimation of formality probability for employed workers in the non-agricultural sector from the ENAHO survey. Bootstrap Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

3-period OLG model

- 3-period economy with J number of households
- Households are heterogeneous in initial endowment profiles
- They work in period 1 and 2 and retire in period 3
- Formal workers pay taxes and have mandatory savings for retirement
- Informal workers might qualify for a means-tested Social Pension
- No lifetime uncertainty, complete information
- Households maximize life time utility based on:
 1. Discrete Decision of Formality
 2. Decision over liquid and illiquid (retirement) savings each period

First findings

- Mandatory savings policies have an impact on the sector decision and composition of the labor force
- Above a certain income level mandatory savings is optimal
- Workers with a lower income will be better off in informality
- Worker's income distribution is crucial for determining the impact of a change of the policy on the size of informality

Mandatory Pension schemes

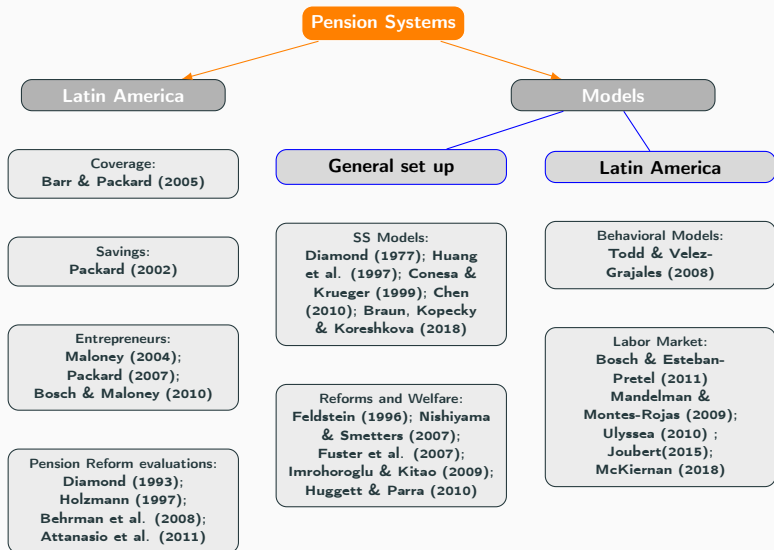
Mandatory pension systems can be classify by:

- how benefits are calculated: Defined benefit or Defined contributions
- how benefits are financed: PAYG or Fully funded
- who manages the system: Public or Private

World Bank develop a multi-pillar typology for Pension systems

- Non-contributory pillar
- Mandatory earnings based
- Mandatory savings based
- Complementary voluntary
- Non-financial

Literature Review: Pension Systems



Formal vs Informal Workers

Characteristics	All Formal Workers	All Informal Workers	Non-agric. Informal
Proportion Female	0.37 (0.002)	0.42 (0.002)	0.46 (0.001)
Average age	38.90 (0.058)	39.31 (0.038)	38.22 (0.044)
Average Weekly Hours Worked	48.88 (0.071)	45.43 (0.054)	46.22 (0.064)
Proportion Self-employed	0.11 (0.001)	0.45 (0.001)	0.53 (0.001)
Average Log Real Income*	7.28 (0.003)	6.01 (0.003)	6.19 (0.003)
Average Education level	2.58 (0.003)	1.80 (0.002)	1.93 (0.002)
Education Distribution			
1=Less than Highschool	0.09	0.49	0.38
2=Highschool	0.25	0.28	0.32
3=More than Highschool	0.67	0.23	0.30

* Income is based on information of Monthly Total Income (2011 USD) including main and secondary job, before taxes and deductions. Bootstrap standard errors in parentheses.

Informality trade-off in households' decisions

Pros of informal labor

- No income tax payments (Ulyssea, 2010)
- Higher Income
 - Higher liquid income (Barr & Packard, 2005)
 - Higher earnings (Perry et al., 2007)
- Access/eligibility to social protection programs (Frölich et al., 2014; Levy & Shady, 2013)
- Independent work and flexibility (Maloney, 2004)

Informality Trade-off in Households decisions

Cons of informal labor

- Lower wages and no minimum wage
- Lack of social protection
- Labor instability
- Reduced access to financial markets
- No transfer from contributory pension system

▶ Back

Income process

Income level y_t^s for their work in the sector $s \in [f, i]$ is given as:

$$y_t^s = \omega^s(\text{age}, \text{edu}, L, \varepsilon_t^s)$$

Where wage function ω reflects the worker's productivity level that depends on:

- Age
- Max education level attained, edu
- Labor experience in previous sector, L
- Sector specific shock, ε_t^s

The wage function is calculated for each sector

Sector specific shocks

- Shocks in the informal sector affect wage for formal workers while and shocks in the informal sector affect earning process for informal workers and self-employed workers.
- We follow Lopez(2015) wage offer model and calculation for Chile.
- Persistent productivity shocks with sector specific innovations that are allowed to be correlated.

$$\varepsilon_t^s = \rho^s \varepsilon_{t-1}^s + \xi_t^s$$
$$\xi_t^s \sim \mathcal{N}(0, \Sigma)$$

- Earning shocks are drawn from a multivariate normal distribution between sectors with:

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

Self-employed Production Function

Self-employed earnings are defined by the production function:

$$y_t^s = \theta k_t^\alpha \omega^s(\text{age}, \text{edu}, \varepsilon_t^s)$$

Where:

- Capital utilization parameter $\alpha \in [0, 1]$,
- Entrepreneurial ability parameter $\theta \in [\theta_{low}, \theta_{high}]$,
- and ε_t is a productivity shock in period t .
- Capital depreciates each period at a constant rate δ
- No borrowing

Thus, the most they can invest in k_t is a_t

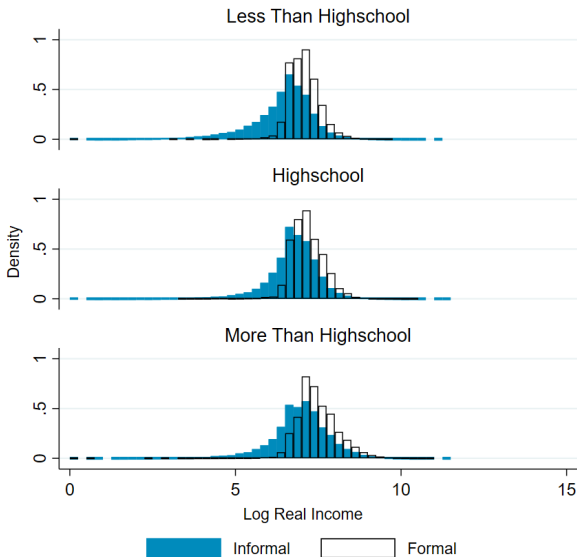
1. Formality by income and education

Table 2: Distribution of workers by income level and education

Distribution of workers	Formal Workers	Informal Workers
By Income level		
First Quintile	0.02	0.37
Second Quintile	0.19	0.31
Third Quintile	0.29	0.16
Fourth Quintile	0.29	0.11
Fifth Quintile	0.23	0.06
By Education		
Less than Highschool	0.09	0.38
Highschool	0.25	0.32
More than Highschool	0.67	0.30

Note: Source ENAHO survey, average values for 2011-2017

1. Distribution by income and education



Note: ENAHO survey for 2011-2017. Sample of male workers in non-agricultural sector, prime

2. Pension system by income level

At the beginning of first formal job, a worker chooses to enroll in one pension system

- 22 % of workers contribute to private system
- 12 % of workers contribute to public system

Table 3: Income distribution by pension system

Income level	Public system	Private system
First quintile	0.10	0.09
Second quintile	0.31	0.27
Third quintile	0.31	0.27
Fourth quintile	0.19	0.20
Fifth quintile	0.09	0.17

Note: ENAHO survey, average values for workers between 18 and 65 years for period 2011-2017

3. Types of workers

- About half of informal workers are self-employed across all education levels
- Self-employed have a higher level of income compared to informal workers
- 58% of workers change sectors at least once in a 5 year period
- In a 5 year period, a worker changes sectors 1.15 times in average

▶ back

3. Worker's Transition Matrix

Table 4: Transition matrix overall ages by education

Currently \ Previously	Formal worker		Informal worker		Self-employed	
	Low	High	Low	High	Low	High
Formal Worker	0.79	0.85	0.16	0.23	0.03	0.05
Informal Worker	0.15	0.11	0.63	0.58	0.16	0.16
Informal Self-employed	0.05	0.04	0.21	0.19	0.80	0.79

Note: Transitions based on weighted average from ENAHO panel data 2011-2015 and 2014-2018. Sample of male workers in non-agricultural sector, prime age.

4. Individuals behavior after retirement age

Table 5: Distribution of people over 65 years by working status

Age group	Not working	Formal	Informal	Self-employed
65-69	0.42	0.07	0.31	0.21
70-74	0.51	0.03	0.36	0.10
75-80	0.65	-	0.31	0.04
80 or more	0.81	0.01	0.14	0.05

Note: Proportions estimated based on 5-years age groups using weighted ENAHO survey data for year 2015

State space variables

$$\mathbf{s} = (\theta, e, p, t, j, a, \tilde{Y}, z, l, \varepsilon^f, \varepsilon^i)$$

Where,

- θ , entrepreneurial ability
- e , education level
- p , pension scheme
- t , age
- j , working sector
- a , liquid savings
- \tilde{Y} , retirement savings in individual account
- z , years of contribution to public system
- l , sector change in last 3 years

Private pension calculation

- Transfers for retirees enrolled in the private pension system are calculated based on their accumulated individual account level at the moment of retirement, \tilde{Y}_R .
- The retiree receive a fixed amount $\zeta(\tilde{Y}_R)$ each year until the end of their life
- The calculations follows the ordinary annuity formula:

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

Informal Problem

A retiree that works receives an income y^i but suffers disutility of working as a fix cost ϕ_t increasing with age.

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

s.t.

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

Retiree's Problem

The value function for the retiree is given by:

$$W^r(\mathbf{s}) = \max_{a'} \{u(c) + \beta \Gamma_t W^r(\mathbf{s}')\}$$

s.t.

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

$$a' \geq 0$$

- Once the retiree chooses to exit the labor force she becomes a retiree all future periods
- Retirees are subject to a mortality risk Γ_t

Other parameters

Assigned parameters

Risk aversion	$\Gamma = 2$
Capital utilization factor	$\alpha = 0.2$
Depreciation of capital	$\delta = 0.1$

Shocks	Formal	Informal
Autocorrelation	$\rho_f = 0.91$	$\rho_i = 0.87$
Std. innovation	$\sigma_f = 0.25$	$\sigma_i = 0.27$
Correlation	$\rho_{fi} = 0.32$	

Labor market calibrated parameters

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

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

Moments targeted in the calibration

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

Less than high school education, $e = 1$

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

High school education, $e = 2$

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

More than high school education, $e = 3$

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

Estimation results

▶ Back

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

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

1. Removing Contributory System: On labor force

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

Note: Distribution of worker's job status for (1) benchmark economy, (2) PE economy without contributory pension system in partial equilibrium and (3) GE economy without contributory system in general equilibrium. % Δ is the percentage change calculated with respect to (1).

2. Pension Design: On labor force

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

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

3-Period OLG Model

The Formal Household Problem:

$$V^f = \max_{m_1, x_1, m_2, x_2} u(c_1) + \beta u(c_2) + \beta^2 u(c_3)$$

s.t.

$$c_1 + m_1 = (1 - x_1 - \tau)y_1$$

$$c_2 + m_2 = (1 - x_2 - \tau)y_2 + r^f m_1$$

$$c_3 = r^f m_2 + \zeta(x_1 y_1, x_2 y_2)$$

$$x_1 \geq x_{min}, x_2 \geq x_{min}$$

$$m_1 \geq 0, m_2 \geq 0$$

s.t.

$$c_1 + m_1 = y_1$$

$$c_2 + m_2 = y_2 + r^i m_1$$

$$c_3 = \max [r^i m_2, \underline{c}]$$

$$m_1 \geq 0, m_2 \geq 0$$

3-Period OLG Model

The Informal Household Problem:

$$V^i = \max_{m_1, m_2} u(c_1) + \beta u(c_2) + \beta^2 u(c_3)$$

s.t.

$$c_1 + m_1 = (1 - x_1 - \tau)y_1$$

$$c_2 + m_2 = (1 - x_2 - \tau)y_2 + r^f m_1$$

$$c_3 = r^f m_2 + \zeta(x_1 y_1, x_2 y_2)$$

$$x_1 \geq x_{min}, x_2 \geq x_{min}$$

$$m_1 \geq 0, m_2 \geq 0$$

s.t.

$$c_1 + m_1 = y_1$$

$$c_2 + m_2 = y_2 + r^i m_1$$

$$c_3 = \max [r^i m_2, \underline{c}]$$

$$m_1 \geq 0, m_2 \geq 0$$

▶ Back

2. Pension Design: On labor force

Comparison between pension systems in general equilibrium

Model	<i>both</i>	<i>only</i>		<i>only</i>	
	Benchmark (1)	Individual account (7)	<i>pp.</i> Δ	PAYG (8)	<i>pp.</i> Δ
Formal worker	33.2	32.4	-0.8	36.3	3.1
Informal worker	35.0	35.5	0.5	33.4	-1.6
Informal self-employed	31.7	32.1	0.4	30.3	-1.4

Distribution of worker's job status for benchmark economy where workers choose a PAYG or individual accounts system (1), economy with only an individual-account pension system in GE (7), and economy with only a PAYG pension system in GE (8).

- When both systems are available, high-income workers self-select to individual-account system \rightarrow deterioration of PAYG

Pensions: \tilde{P}

- From **individual-account** system: pension in the form of an annuity.

$$\tilde{P} = \zeta(\tilde{Y}_R, \Gamma, r)$$

▸ formula

Pensions

Pensions: \tilde{P}

- From **individual-account** system: pension in the form of an annuity.

$$\tilde{P} = \zeta(\tilde{Y}_R, \Gamma, r)$$

▸ formula

- From **PAYG system**: pension benefit, b , is calculated based on a replacement rate μ and required years of contributions Z_{req} .

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

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

where \tilde{W}_R is the last 5-years average wage in the formal sector

Non-contributory or Social Pension

Transfers: \bar{c}

The non-contributory pension works as a means-tested program where, \bar{c} is transfer to an elderly individual that:

- Does not receive a pension from the formal pension system and
- Has wealth (income plus assets) Ξ below a threshold level M

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

Informal Worker Problem

$$V^i(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \left(\underbrace{\gamma^f(i, e) \max \{ \mathbb{E}[V^f(\mathbf{s}')|\varepsilon^f], \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \}}_{\text{with formal job offer}} \right. \right. \\ \left. \left. + (1 - \gamma^f(i, e)) \left[\underbrace{\gamma^i(i, e) \max \{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \}}_{\text{with informal job offer}} \right. \right. \right. \\ \left. \left. \left. + \underbrace{(1 - \gamma^i(i, e))(\mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] - \nu_{i,e})}_{\text{without any job offer}} \right] \right) \right\}$$

Parameters for informal workers given education level:

- $\gamma^f(i, e)$ \rightarrow Probability of formal job offer arrival given being informal
- $\gamma^i(i, e)$ \rightarrow Probability of informal job offer arrival given being informal
- $\nu_{i,e}$ \rightarrow Unemployment spell when separated from informal job

Informal Worker Problem

$$V^i(\mathbf{s}) = \max_{a'} \left\{ u(c) + \beta \underbrace{\left(\gamma^f(i, e) \max \{ \mathbb{E}[V^f(\mathbf{s}')|\varepsilon^f], \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \} \right)}_{\text{with formal job offer}} \right. \\ \left. + (1 - \gamma^f(i, e)) \left[\underbrace{\gamma^i(i, e) \max \{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \}}_{\text{with informal job offer}} \right. \right. \\ \left. \left. + \underbrace{(1 - \gamma^i(i, e))(\mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] - \nu_{i,e})}_{\text{without any job offer}} \right] \right\}$$

s.t.

$$c + a' = y^i + (1 + r)a$$

$$\tilde{Y}' = (1 + \varrho) \tilde{Y}$$

$$z' = z$$

$$a' \geq 0$$

Self-employed Worker Problem

$$V^s(\mathbf{s}) = \max_{a', k} \left\{ u(c) + \beta \left(\gamma^i(s, e) \underbrace{\max \{ \mathbb{E}[V^i(\mathbf{s}')|\varepsilon^i], \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i] \}}_{\text{with informal job offer}} \right) \right. \\ \left. + \underbrace{(1 - \gamma^i(s, e)) \mathbb{E}[V^s(\mathbf{s}')|\varepsilon^i]}_{\text{without any job offer}} \right\}$$

Parameters for self-employed workers given education level:

- $\gamma^i(s, e)$ \rightarrow Probability of informal job offer arrival given being self-employed
- Income comes from the self-employed's return on k and her age-education profile

Self-employed Worker Problem

$$V^s(\mathbf{s}) = \max_{a', k} \left\{ u(c) + \beta \left(\underbrace{\gamma^i(s, e) \max \{ \mathbb{E}[V^i(\mathbf{s}') | \varepsilon^i], \mathbb{E}[V^s(\mathbf{s}') | \varepsilon^i] \}}_{\text{with informal job offer}} \right) \right. \\ \left. + \underbrace{(1 - \gamma^i(s, e)) \mathbb{E}[V^s(\mathbf{s}') | \varepsilon^i]}_{\text{without any job offer}} \right\}$$

s.t.

$$c + a' = y^s + (1 + r)(a - k) + (1 - \delta)k$$

$$\tilde{Y}' = (1 + \varrho) \tilde{Y}$$

$$z' = z$$

$$a' \geq 0$$

$$0 \leq k \leq a$$

1. Formality is increasing in income and education [▶ data](#)
2. Private pension system (Individual accounts) is chosen by higher income workers [▶ data](#)
3. Half of informal workers are self-employed [▶ data](#)
4. Retirees that work, work in the informal sector [▶ data](#)

[▶ back](#)

Government Budget

$$G + \bar{c} n^{\bar{c}} + \underbrace{\sum_{t=R}^T \sum_i^{n_t} \mathbb{1}_{p=2} b_{i,t}}_{\text{PAYG expenses}} = \underbrace{\sum_{t=1}^{R-1} \sum_i^{n_t} \mathbb{1}_{j=f} \tau y_{i,t}^f}_{\text{Income tax collection}} + \underbrace{\sum_{t=1}^{R-1} \sum_i^{n_t} \mathbb{1}_{j=f} \mathbb{1}_{p=2} (x_p y_{i,t}^f)}_{\text{PAYG collection}}$$

- $n^{\bar{c}}$ is the number of beneficiaries that qualify for the non-contributory
- n_t is the number of households age t
- $\mathbb{1}_{p=2}$ is 1 when the worker i is enrolled in the PAYG
- $\mathbb{1}_{j=f}$ is 1 when current individual i is a formal worker $j = f$