(In)formal Growth:
Knowledge Dynamics with Learning Segmentation

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The Economics of Informality

Introduction

- Labor **informality** is a salient feature of many developing economies.
  - **30%** - **80%** in Latin America, and similar numbers for Asia, Eastern Europe.
- **Formal** and **informal** workers employed in firms within the same industries, products.
- Large differences between **formal** and **informal** workers' **wages.**

Research questions

What is the role of **human capital** in explaining **formal/informal** wage differences?

How does aggregate **human capital** determine the size of the **informal sector**?

What is the aggregate effect of this interaction on **growth** and **welfare?**

This Paper: Approach and Findings

(1) Document new facts on wage dynamics for **formal** and **informal** workers.

- A substantial portion of the **formal** wage premium is explained by worker **sorting**.
- **Formal** experience is associated with higher **wages**, while **informal** experience is not.
- **Formal** workers experience higher future wage **growth.**

(2) Propose a **growth** theory with **informal labor**, worker sorting & knowledge diffusion.

- Endogenous **growth:** workers improve their skills by meeting/**learning** from others.
- **Learning** segmentation: different meeting rates within/across labor markets.

(3) Evaluate the **general equilibrium** effects of **formalization policies.**

- Contrast: **carrot** policy (↓ cost of **formal**) vs **stick** policy (↑ cost of **informal**).
- **Crowding out:** both policies ↓ **growth** by ↓ quality of interactions most skilled workers.

Literature and Contribution

(1) Wage Dynamics and Development: Lagakos et al. (2018)

- Steeper experience-wage profiles in developed economies.

This paper: differences in wage levels and growth rates for formal/informal workers.

(2) Effects Informal Labor: Dix-Carneiro et al. (2021), Bobba et al. (2022)

- Dynamic models of labor markets with homogeneous workers or time-invariant skills.

This paper: endogenous time-varying heterogeneous skills + dynamic worker sorting.

(3) Learning and Growth: Lucas & Moll (2014), Perla & Tonetti (2014)

- Endogenous long-run growth driven by interactions/imitation.

This paper: informal labor markets segment learning $\longrightarrow$ long-run growth.

Descriptive Evidence

Data: Chile

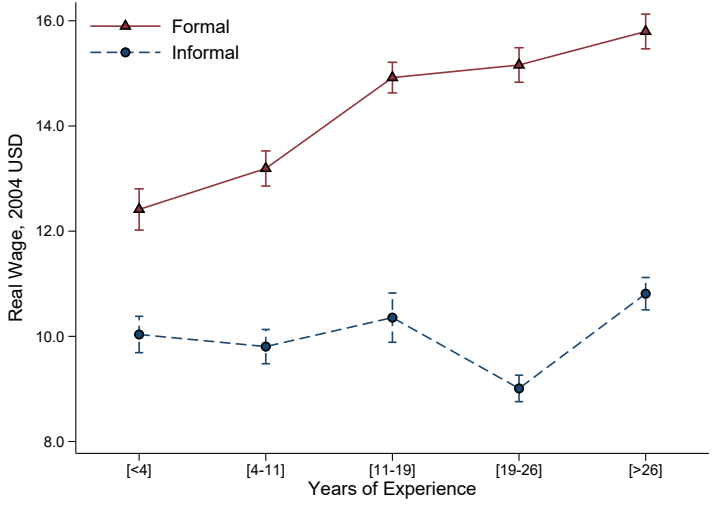
- Encuesta de Proteccion Social (EPS), 2002 - 2016:
  - **Informality rate:** **30%**.
  - **Longitudinal worker survey:** 17K workers, representative of population.
  - **Individual work history:** wage, occupation, industry, region, firm size, hours worked.
  - **Demographics:** age, education, gender.
  - **Informality:** type of contract (salaried workers) and pension contributions.

- **Informal jobs**: jobs not complying with labor regulations.

  (1) All salaried workers must have a **formal** labor contract.

  (2) All workers must **contribute** to **pension funds.**

Fact 0: Experience-Wage Profiles for Formal and Informal Workers



Growth Only | Profile Salaried | Age-Wage Profiles | Age-Wage Profiles (Growth Only) | Age-Wage Profiles Salaried

Fact 1: Large Fraction of Formal Premium Given by Worker's Sorting

$$\log w_{it} = \beta \textbf{Formal}_{it} + \Gamma X_{it} + \delta_i + \varepsilon_{it}$$

	Dep. var.: $\log w_{it}$		
	(1)	(2)	(3)
Formal$_{it}$, β	0.396***	0.161***	0.0950***
	(0.0151)	(0.0132)	(0.0167)
Corr(Formal$_{it}$, δ_i)			0.168
			(0.004)
Controls		✓	✓
Worker FE			✓
Observations	58,926	58,926	58,926
Adj R-squared	0.0746	0.460	0.839

Controls: age, education, gender, occupation, industry, region, firm size, experience, and time-fixed effects. Standard errors in parentheses clustered at the individual level. ***p<0.01, **p<0.05, *p<0.1.

Salaried Workers

Fact 2: ↑ Formal Experience, ↑ Wages - ↑ Informal Experience, ↓ Wages

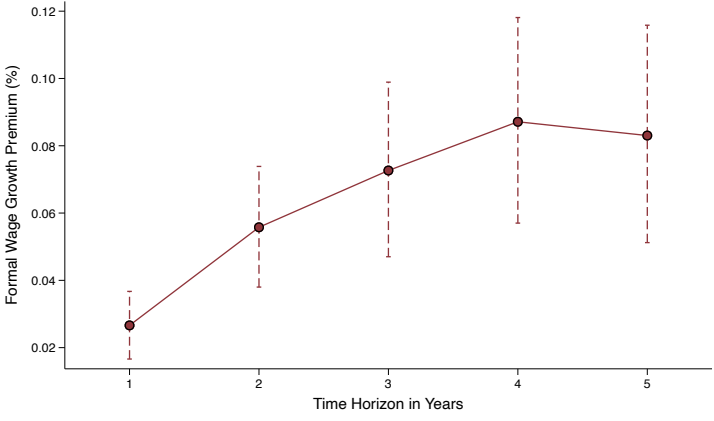
	Dep. Var.: $\log w_{it}$			
	(1)	(2)	(3)	(4)
Formal$_{it}$, β	0.160***	0.0948***	0.0959***	0.0805***
	(0.0132)	(0.0167)	(0.0145)	(0.0176)
asinh exp	0.0373***	0.0151		
	(0.00904)	(0.0177)		
asinh exp^F			0.0396***	0.0322**
			(0.00583)	(0.0149)
asinh exp^I			-0.0156***	-0.0292**
			(0.00502)	(0.0138)
Corr(β Formal$_{it}$, δ_i)		0.1679		0.1044
		(0.004)		(0.004)
Controls	✓	✓	✓	✓
Worker FE		✓		✓
Observations	58,926	58,926	58,926	58,926
Adj R-squared	0.460	0.839	0.463	0.839

Controls: age, education, gender, occupation, industry, region, firm size, and time-fixed effects. Standard errors in parentheses clustered at the individual level. ***p<0.01, **p<0.05, *p<0.1.

Salaried

Fact 3: Formal Workers Experience Higher Wage Growth

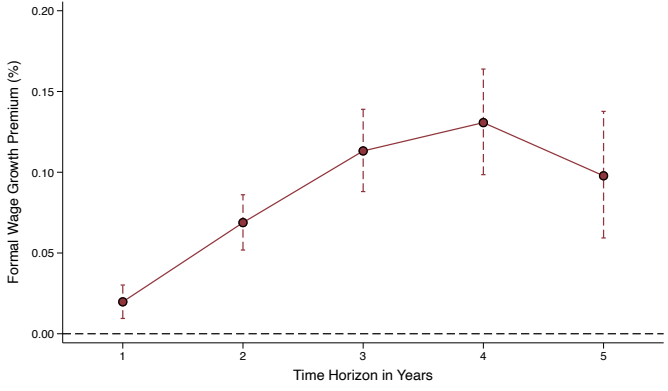
$$\Delta \log w_{i,t+h} = \alpha + \beta_h \textbf{Formal}_{it} + \Gamma X_{i,t} + \varepsilon_{i,t}$$



Controls: age, education, gender, occupation, industry, region, firm size, and time-fixed effects and wage decile.

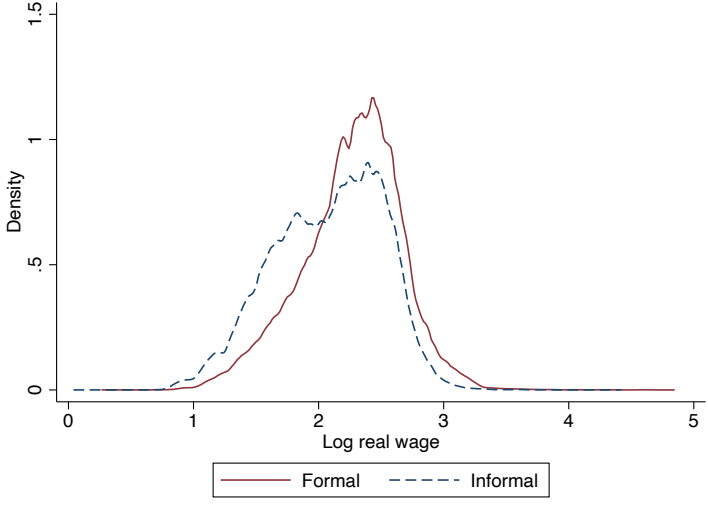
Mechanism: Peer effects

$$\Delta \log w_{i,t+h} = \alpha + \beta_h \bar{w}^{-}_{i,t} + \Gamma X_{i,t} + \varepsilon_{i,t} \qquad \text{with} \qquad \bar{w}^{-}_{i,t} = \frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} w_{j,t}$$



Controls: age, education, gender, occupation, industry, region, firm size, and time-fixed effects and wage decile.
Peers: Region x Year x Industry x Firm Size Bracket.

Learning Segmentation: Formal Workers have better peers



Notes: Figure depicts the distribution of the average wage of peers.

Salaried

Model

Workers

- Time is continuous.
- A unit mass of workers discount future, and exit the labor market at rates ρ, and δ.
  - Spend their income every period on a final consumption good (no savings).
- Workers differ in their skill level z, with $G(z,t)$ CDF of skill distribution at time t.
  - Initial productivity distribution, $G(z,0)$: Pareto with tail θ, location κ.
  - Newborn productivity distribution, $B(z,t)$: Pareto with tail θ, location κ_0.
- Workers improve their skills by **learning** from others.
- Given their skill level, z, workers decide to work **formally** or **informally**.
  - **Static implication:** different wages.
  - **Dynamic implication:** different learning opportunities.

Firms

- A **representative**, **perfectly competitive** firm produces the final consumption good:

$$Y(t) = \int_0^\infty z\left(n_f(z) + n_i(z)\right) dz,$$

  - $n_f(z)$, $n_i(z)$: mass of **formal** and **informal** workers with skill level z.

- Differential **hiring costs** for formal and informal workers with $\varphi_z > 0$, $\varphi_{zz} > 0$:

$$c_f(z,t) = \underbrace{(1+\tau)}_{\text{payroll tax}} w_f(z,t) + \underbrace{F(t)}_{\text{registering}}, \qquad c_i(z,t) = w_i(z,t) + \underbrace{\varphi(z,t)}_{\text{gov. fines}}$$

- Equilibrium **wages**:

$$w_f(z,t) = \frac{1}{1+\tau} z - \frac{F(t)}{1+\tau}, \qquad w_i(z,t) = z - \varphi(z,t).$$

Learning: Meetings and Technology

- Workers meet other workers at a Poisson rate α.
- Conditional on a meeting, workers in sector ℓ meet workers in ℓ' with probability:

$$\mathbb{P}_{\ell}^{\ell}(t) = \frac{\pi_{\ell}\mu_{\ell}(t)}{(1-\pi_{\ell})\mu_{-\ell}(t) + \pi_{\ell}\mu_{\ell}(t)}, \qquad \mathbb{P}_{\ell}^{\ell'}(t) = 1 - \mathbb{P}_{\ell}^{\ell}(t), \qquad \ell, \ell' \in \{f, i\},$$

  - μ_{ℓ}: mass of workers in sector ℓ.
  - $\pi_{\ell} \in [\frac{1}{2}, 1]$: degree of **learning segmentation** ($\pi_f = \pi_i = 1/2$, random meetings).
- When worker $z(t)$ meets a worker $z'(t)$, $z(t+\Delta) = \max\{z(t), z'(t)\}$ with probability:

$$\psi\left(\frac{z'(t)}{z(t)}\right) = \begin{cases} 1 & \text{if } z'(t) \leq z(t) \\ \sigma + (1-\sigma)\left(\frac{z'(t)}{z(t)}\right)^{-\xi} & \text{if } z'(t) > z(t) \end{cases}$$

  - $\sigma \in (0, 1]$: **knowledge diffusion**, $\xi > 0$: **limits to learning**.

Value Functions and Worker Sorting

- The value function for a worker in sector $\ell \in \{i, f\}$ satisfies the Bellman equation:

$$
\begin{aligned}
(\rho+\delta)V_\ell(z,t) = w_\ell(z,t) + \dot{V}_\ell(z,t) \\
+ \alpha \mathbb{P}_\ell^f(t) \int_{\Omega_f(t)} \max\left\{V(\tilde{z},t) - V_\ell(z,t), 0\right\} \psi\left(\frac{\tilde{z}}{z}\right) \frac{g(\tilde{z},t)}{\mu_f(t)} d\tilde{z} \\
+ \alpha \mathbb{P}_\ell^i(t) \int_{\Omega_i(t)} \max\left\{V(\tilde{z},t) - V_\ell(z,t), 0\right\} \psi\left(\frac{\tilde{z}}{z}\right) \frac{g(\tilde{z},t)}{\mu_i(t)} d\tilde{z},
\end{aligned}
$$

  - $V(z,t) = \max\{V_f(z,t),\, V_i(z,t)\}$.
  - $\Omega_\ell(t)$: support of **formal/informal** skill distribution.

- **Sorting:** there exists **formality** cutoff $\bar{z}(t)$ such that:

$$
V_f(z,t) > V_i(z,t) \text{ for } z > \bar{z}(t), \qquad V_f(z,t) < V_i(z,t) \text{ for } z < \bar{z}(t).
$$

Balanced Growth Path Equilibrium with Informality

- An equilibrium: HJB (V_f, V_i) + KFE $g(z,t)$ + **formality** cutoff $\bar{z}(t)$.
- Focus on **Balanced Growth Path** equilibrium: productivity quantiles grow at rate γ.
  - Relative skill: $x \equiv z(t)e^{-\gamma t}$, with $\bar{x} = \bar{z}(t)e^{-\gamma t}$.
  - Invariant distribution: $\Phi(x) = G(z,t)$, with $\Phi(\bar{x})$ share of **informal** workers.
- The share of **informal** workers affects the economy's **growth** rate, γ:

$$\gamma = \alpha\theta\sigma\Big[\underbrace{\frac{\Phi(\bar{x})}{1-\Phi(\bar{x})}}_{\text{informal/formal}}\underbrace{\mathbb{P}_i^f\left(\Phi(\bar{x})\right)}_{\substack{\text{prob. informal}\\ \text{meets formal}}} + \underbrace{\mathbb{P}_f^f\left(\Phi(\bar{x})\right)}_{\substack{\text{prob. formal}\\ \text{meets formal}}}\Big] - \underbrace{\delta\theta\left[1-\frac{\kappa_0}{\kappa}\right]}_{\text{newborn skill diff.}}$$

  - Without **learning segmentation** ($\pi_f = \pi_i = 1/2$): $\gamma = \alpha\theta\sigma - \delta\theta\left[1-\frac{\kappa_0}{\kappa}\right]$.
  - Government **policies** can only generate movements along the **growth** curve.

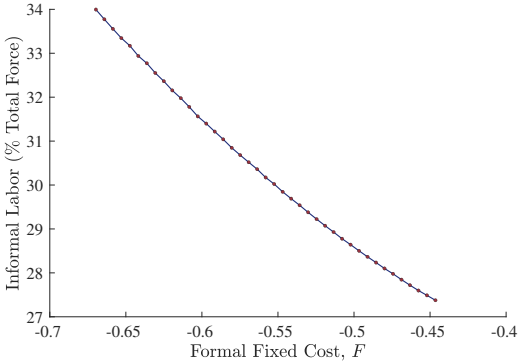
Quantitative Analysis

Model to the Data and Formalization Policies

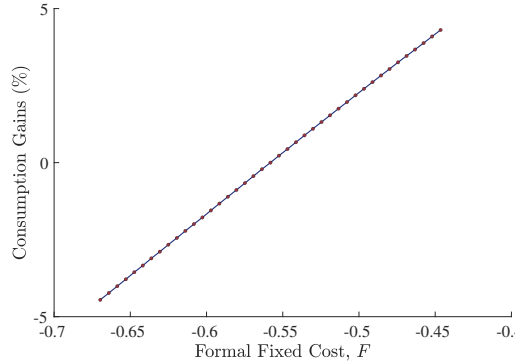
- Adopt a functional form for informality cost, $\varphi(z,t) = z + (\exp(-\eta z) - 1)/\eta$.
- 12 parameters: $\underbrace{\tau, F, \eta}_{\text{Regulatory}}, \underbrace{\alpha, \pi_i, \pi_f, \sigma, \xi}_{\text{Learning}}, \underbrace{\theta, \kappa/\kappa_0}_{\text{Distributional}}, \underbrace{\rho, \delta}_{\text{Population}}$
  - τ, ρ: external calibration, and δ: age's empirical CDF.
  - Simulated Method of Moments **(SMM)** for remaining 9 parameters.
  - **Moments:** growth, informality share (agg. and by age), formal premium, transition probs.
- Use the estimated model to evaluate two types of formalization policies:
  - **(1)** **Carrots:** decrease the cost of being formal through $\downarrow F$.
  - **(2)** **Sticks:** increase the cost of being informal through $\uparrow \eta$ (not today).

Changes in Registering Costs F: Informality and Consumption

(a) Informality Rate



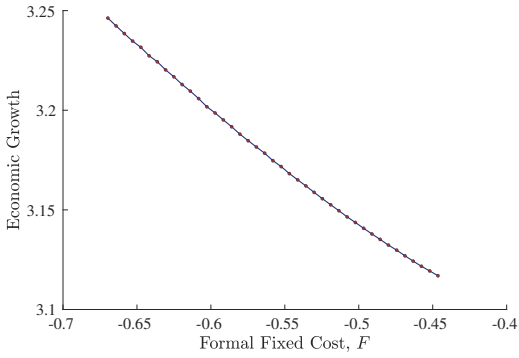
(b) Aggregate Consumption



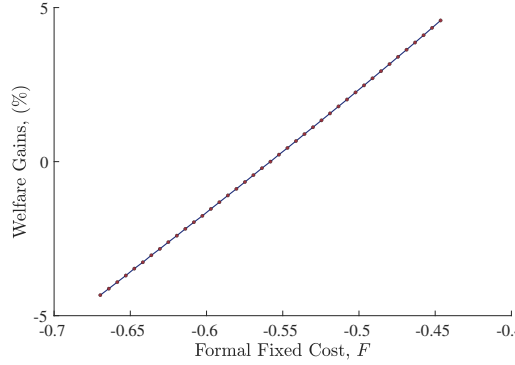
Note: the x-axis displays 1% increments around the estimated value of F, from -20% to 20%.

Changes in Registering Costs F: Growth and Welfare

(a) Growth Rate



(b) Welfare



Note: the x-axis displays 1% increments around the estimated value of F, from -20% to 20%.

Decomposing Changes in Growth Rate: Crowding Out Effect

- $\downarrow F \longrightarrow \downarrow \Phi(\bar{x})$ (**informality share**). How does this affect the **growth rate**?
  - Without learning segmentation, $\pi_i = \pi_f = 1/2$, no effect: $\frac{\partial \gamma}{\partial(1-\Phi(\bar{x}))} = 0$.
  - But in estimated model has learning segmentation $\pi_i \approx 0.6$ and $\pi_f \approx 0.8$.

- When decreasing F by 20% :

$$\underbrace{\frac{\partial \gamma}{\partial\left(1-\Phi\left(\bar{x}\right)\right)}}_{\substack{\Delta \text{ growth when} \\ \text{formalizing workers} \\ -1.82\%}} = \alpha\theta\sigma\left[\underbrace{\frac{\mathbb{P}_f^f(\bar{x}) - \mathbb{P}_i^f(\bar{x})}{1-\Phi\left(\bar{x}\right)}}_{\substack{\text{Switchers} \\ >0 \\ +1.46\%}} + \underbrace{\Phi\left(\bar{x}\right)\frac{\partial \mathbb{P}_i^f(\bar{x})}{\partial\left(1-\Phi\left(\bar{x}\right)\right)}}_{\substack{\text{Always Informal} \\ >0 \\ +0.3\%}} + \underbrace{\left(1-\Phi\left(\bar{x}\right)\right)\frac{\partial \mathbb{P}_f^f(\bar{x})}{\partial\left(1-\Phi\left(\bar{x}\right)\right)}}_{\substack{\text{Always Formal} \\ <0 \\ -3.57\%}}\right]$$

Conclusion

(1) Documented different wage dynamics for formal and informal workers.

- More skilled workers **sort** into the **formal** sector $\longrightarrow \uparrow$ **formal** wage premium.
- **Formal** experience: $\uparrow$ wages, **informal** experience $\downarrow$ wages.
- **Formal** workers: $\uparrow$ wage **growth**.

(2) Proposed a framework emphasizing worker sorting and learning segmentation.

- Labor **informality** affects long-run **growth** by segmenting learning environments.
- **Formalization** policies can lower long-run **growth** by lowering the quality of interactions.

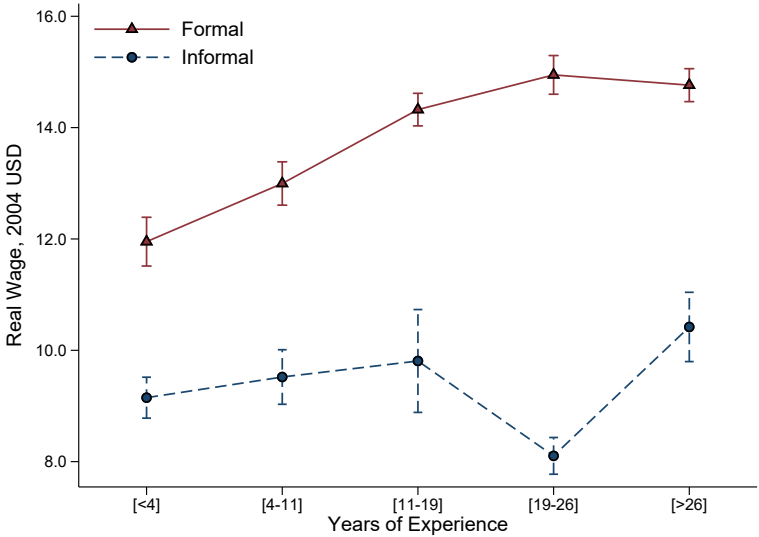
(3) Implications for **policy design** (next steps).

- Trade-off: $\uparrow$ **growth rate** vs $\downarrow$ **inequality.**
- Learning externalities: **efficient benchmark** and **optimal level of informality.**

Thank You!

Appendix

Wage-Experience Profiles for Salaried Formal and Informal Workers



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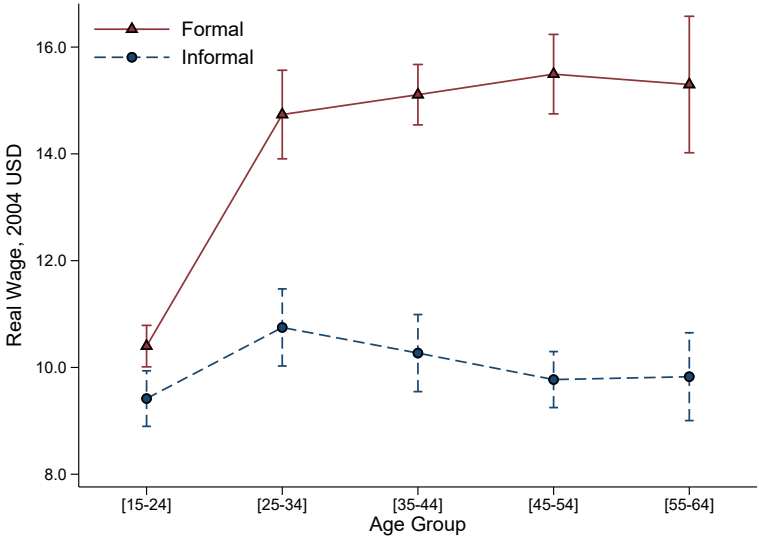
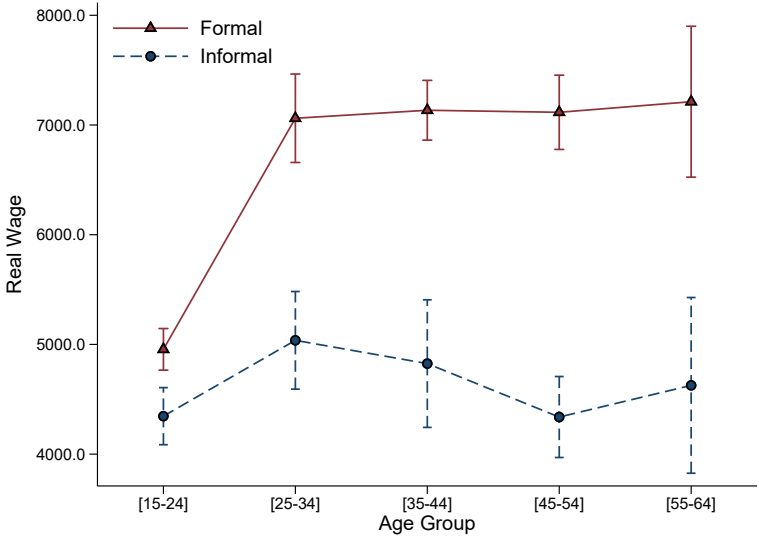
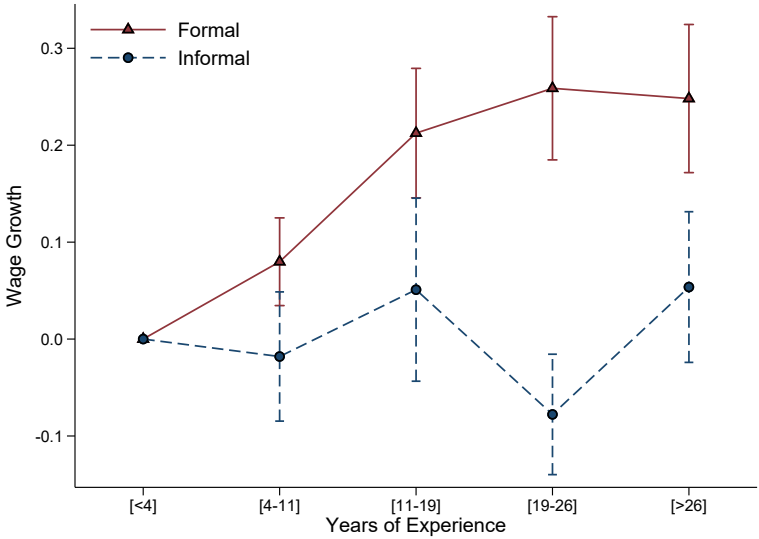
Wage-Age Profiles for Formal and Informal Workers



Wage-Age Profiles for Salaried Formal and Informal Workers



Wage-Experience Profiles Formal and Informal Workers (Growth)



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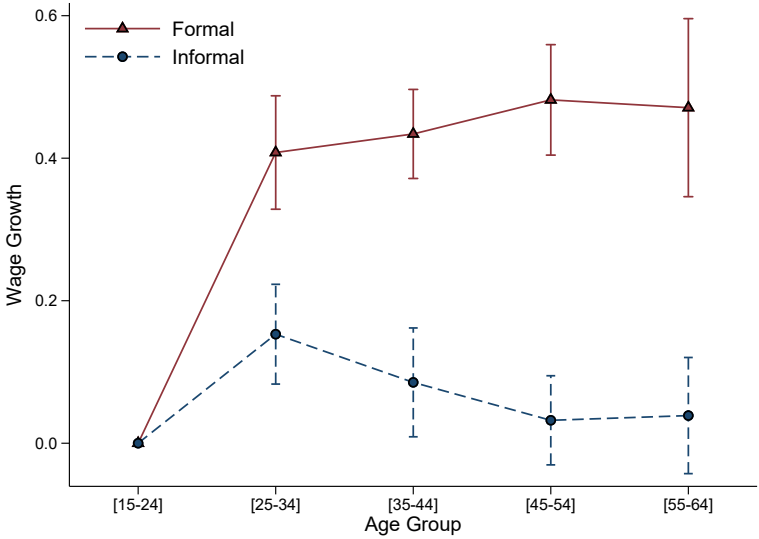
Wage-Age Profiles Formal and Informal Workers (Growth)



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Fact 1: Formal Premium Given and Worker's Sorting (Salaried)

	Dep. var.: $\log w_{it}$		
	(1)	(2)	(3)
Formal$_{it}$, β	0.412***	0.154***	0.0733***
	(0.0188)	(0.0148)	(0.0201)
Corr(β*Formal$_{it}$, δ_i)			0.179
			(0.005)
Controls		✓	✓
Worker FE			✓
Observations	44,329	44,329	44,329
Adj R-squared	0.068	0.512	0.863

Controls: age, education, gender, occupation, industry, region, firm size, experience, and time-fixed effects. Standard errors in parentheses clustered at the individual level. ***p<0.01, **p<0.05, *p<0.1.

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Fact 2: ↑ Formal Experience, ↑ Wages - ↑ Informal Experience, ↓ Wages

	Dep. Var.: $\log w_{it}$			
	(1)	(2)	(3)	(4)
Formal$_{it}$, β	0.135***	0.0720***	0.0828***	0.0605***
	(0.0148)	(0.0201)	(0.0161)	(0.0205)
asinh exp	0.0541***	0.0263		
	(0.00955)	(0.0181)		
asinh exp^F			0.0442***	0.0379**
			(0.00667)	(0.0154)
asinh exp^I			-0.0125**	-0.0187
			(0.00510)	(0.0152)
Corr(β Formal$_{it}$, δ_i)		0.177		0.134
		(0.005)		(0.005)
Controls	✓	✓	✓	✓
Worker FE		✓		✓
Observations	44,329	44,329	44,329	44,329
Adj R-squared	0.515	0.863	0.517	0.863

Controls: age, education, gender, occupation, industry, region, firm size, and time-fixed effects. Standard errors in parentheses

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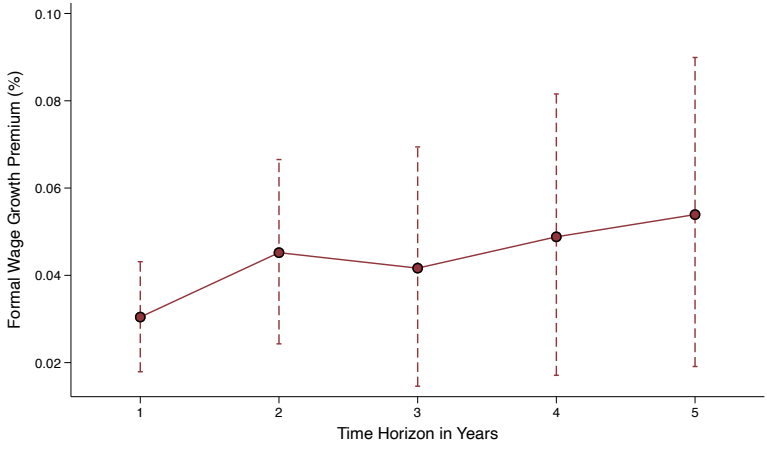
Fact 3: Formal Workers Experience Higher Future Wage Growth



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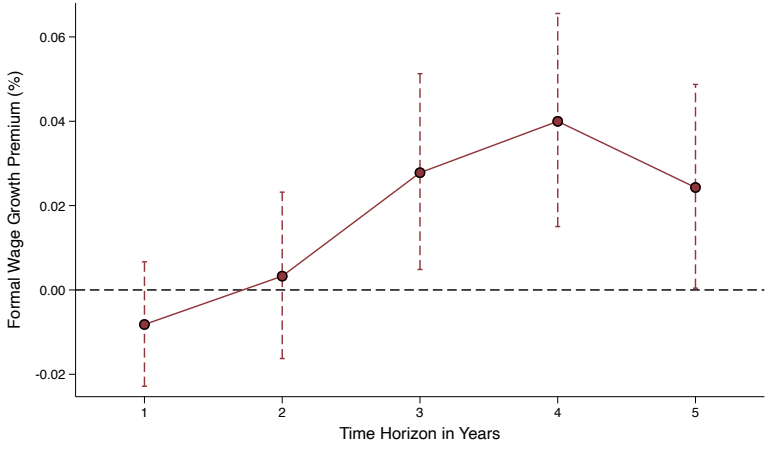

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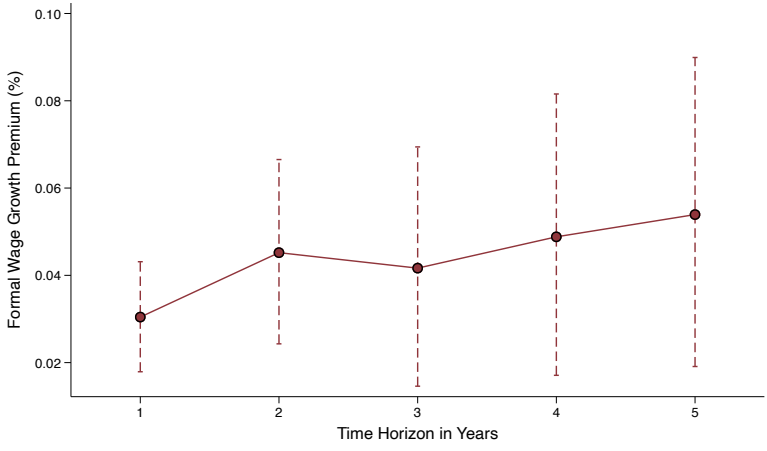
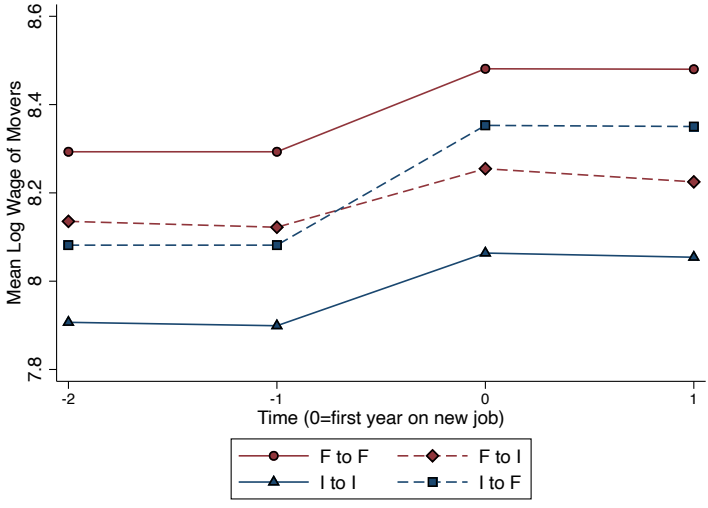


Fact 3: Transitioning to the formal sector has higher returns



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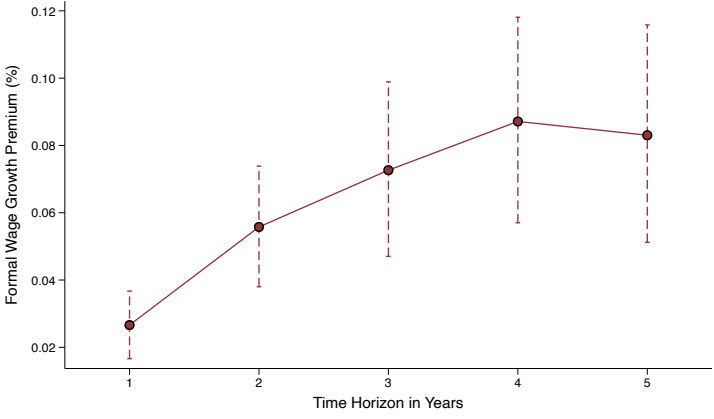
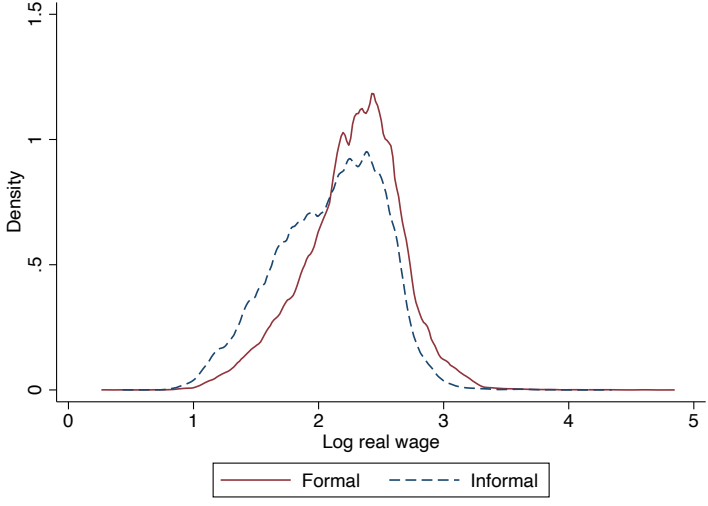
Mechanism: Peer effects

$$\Delta \log w_{i,t+h} = \alpha + \beta_h \bar{w}^{-}_{i,t} + \Gamma X_{i,t} + \varepsilon_{i,t} \qquad \text{with} \qquad \bar{w}^{-}_{i,t} = \frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} w_{j,t}$$



Controls: age, education, gender, occupation, industry, region, firm size, and time-fixed effects and wage decile.

Learning Segmentation: Formal Workers have better peers



Notes: Figure depicts the distribution of the average wage of peers.

Equilibrium Definition

Given $g(z,0)$, an equilibrium is a trajectory $\bar{z}(t)$ and a tuple of funct. (g, V_f, V_i, V):

(1) Given $\bar{z}(t)$: $g(z,t)$ satisfies the Kolmogorov Forward Equation ▸ KFE

(2) Given g and $\bar{z}(t)$: $V_f(z,t)$ and $V_i(z,t)$ satisfy the Bellman equations

(3) Given V_f and V_i: $\bar{z}(t)$ satisfies the indifference condition and V is given by $\max\{V_i, V_f\}$

(4) The government has a balanced budget

Kolmogorov Forward Equations

- The Kolmogorov Forward equation for the distribution of skills for $z \geq \bar{z}(t)$:

$$\frac{\partial g(z,t)}{\partial t} = -\alpha\lambda_f^f g(z,t)\int_z^\infty k\left(\frac{y}{z}\right)g(y,t)\mathrm{d}y \qquad \textbf{outflow}$$

$$-\alpha\lambda_i^f g(z,t)\int_0^{\bar{z}} k\left(\frac{z}{y}\right)g(y,t)\mathrm{d}y \qquad \textbf{inflow from informals}$$

$$+\alpha\lambda_f^f g(z,t)\int_{\bar{z}}^z k\left(\frac{z}{y}\right)g(y,t)\mathrm{d}y \qquad \textbf{inflow from formals}$$

with $\lambda_\ell^k(t) \equiv \mathbb{P}_\ell^k(t)/\mu_k(t)$, and for $z < \bar{z}(t)$:

$$\frac{\partial g(z,t)}{\partial t} = -\alpha\lambda_i^f g(z,t)\int_{\bar{z}}^\infty k\left(\frac{y}{z}\right)g(y,t)\mathrm{d}y \qquad \textbf{outflow}$$

$$-\alpha\lambda_i^i g(z,t)\int_z^{\bar{z}} k\left(\frac{y}{z}\right)g(y,t)\mathrm{d}y \qquad \textbf{outflow}$$

$$+\alpha\lambda_i^i g(z,t)\int_0^z k\left(\frac{z}{y}\right)g(y,t)\mathrm{d}y \qquad \textbf{inflow from informals}$$

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Summary Statistics

	(1) Informal	(2) Formal
Fraction of workers	0.29	0.71
Mean real hourly wage	4,655	6,367
Mean weekly working hours	42.4	46
Fraction of male workers	0.58	0.62
Mean experience (years)	15.9	16
Number of observations	35,324	86,857
Number of workers	8,022	13,762

Note: Baseline sample: EPS 2002 - 2016.

Balanced Growth Path Equilibrium

- **Balanced Growth Path:** two scalars γ, $\bar{x}$ and five functions v_f, v_i, v, ϕ, Φ s.t.:

$$V_f(z,t) = e^{\gamma t} v_f(x) \qquad V_i(z,t) = e^{\gamma t} v_i(x)$$
$$g(z,t) = e^{-\gamma t} \phi(x) \qquad G(z,t) = \Phi(x)$$

- $x \equiv z e^{-\gamma t}$ is the time-invariant skill, and $\bar{x} \equiv \bar{z}_t e^{-\gamma t}$ the time-invariant **formality** cut-off

- (g, V_f, V_i, V) is an equilibrium with initial condition $g(z,0) = \phi(z)$

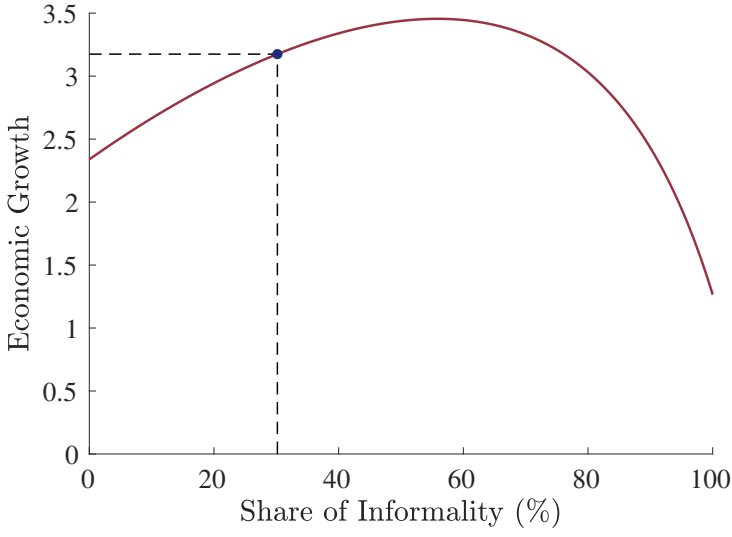
Estimated Parameters

Parameter	Description	Value
ρ	Discount Rate	0.05
k	Pareto Location	2
δ	Death Hazard Rate	0.064
σ	Learning Prob.	0.367
α	Meeting Rate	0.323
π_i	Probability of Meeting within Sector (Informals)	0.566
π_f	Probability of Meeting within Sector (Formals)	0.804
κ	Intelectual Range	3.56
θ	Pareto Tail	0.389
k_0/k	Birth Distribution Location	0.09
F	Hiring Costs	0.558
η	Informality Costs	1.168

Goodnes of Fit

	Model	Data
Growth Rate (%)	3.175	4.104
Informality Rate (%)	30.172	18.584
Avg. Formal Premium	0.070	0.060
Informality Rate (%), 15-24	0.212	0.255
Informality Rate (%), 25-34	0.182	0.137
Informality Rate (%), 35-44	0.171	0.159
Informality Rate (%), 45-54	0.187	0.191
Informality Rate (%), 55-64	0.236	0.259
Transition Probability - I-F	0.082	0.128
Transition Probability - F-I	0.017	0.018

Growth and Informality



Result 1: Formal wage premium is driven by sorting

$$\log w_{it} = \beta_1 \textbf{Formal}_{it} + \Gamma X_{it} + \delta_i + \varepsilon_{it}$$

	Log Wage ($\log w_{it}$)		
Formal Premium	0.688***	0.367***	0.143***
	(0.026)	(0.023)	(0.037)
Observations	5,347	5347	5,347
Controls	No	Yes	Yes
Worker FE	No	No	Yes

Standard errors in parentheses clustered at the individual level. Controls include occupation, age, region, gender, education, industry, and time fix effects.

*** p<0.01, ** p<0.05, * p<0.1

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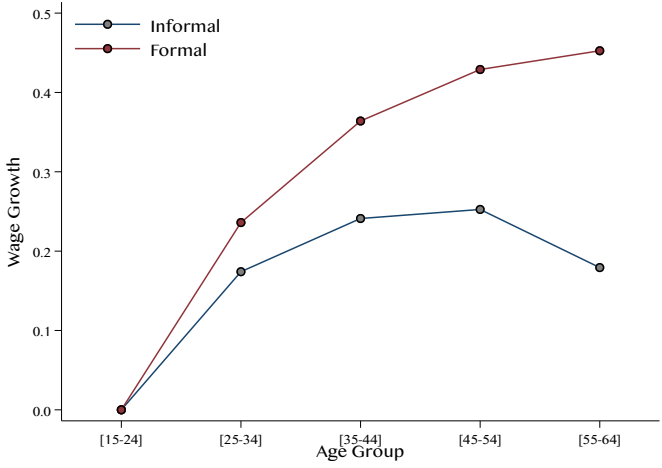
Result 3: Formal Workers experience higher Wage Growth



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