Land Regularization and Technical Efficiency in Agricultural Production:

An Empirical Study in Andean Countries

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Maja Schling – Senior Economist

Magaly Saenz – Research Consultant

Juan de Dios Mattos – Senior Sector Specialist

Environment, Rural Development & Disaster Risk Management Division

Inter-American Development Bank (IDB)

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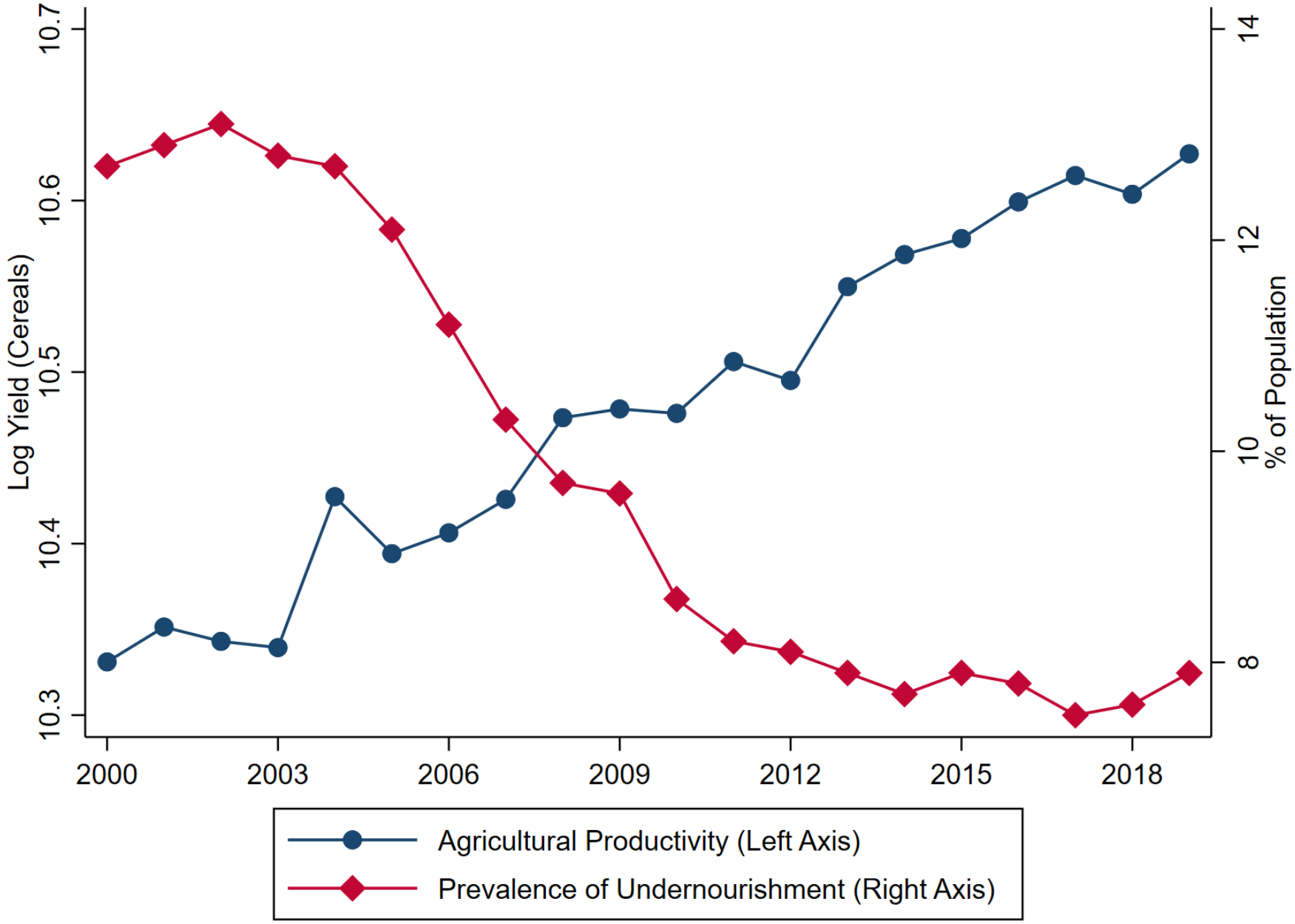
MOTIVATION

AGRICULTURAL PRODUCTIVITY GROWTH ALLEVIATES POVERTY AND IMPROVES FOOD SECURITY



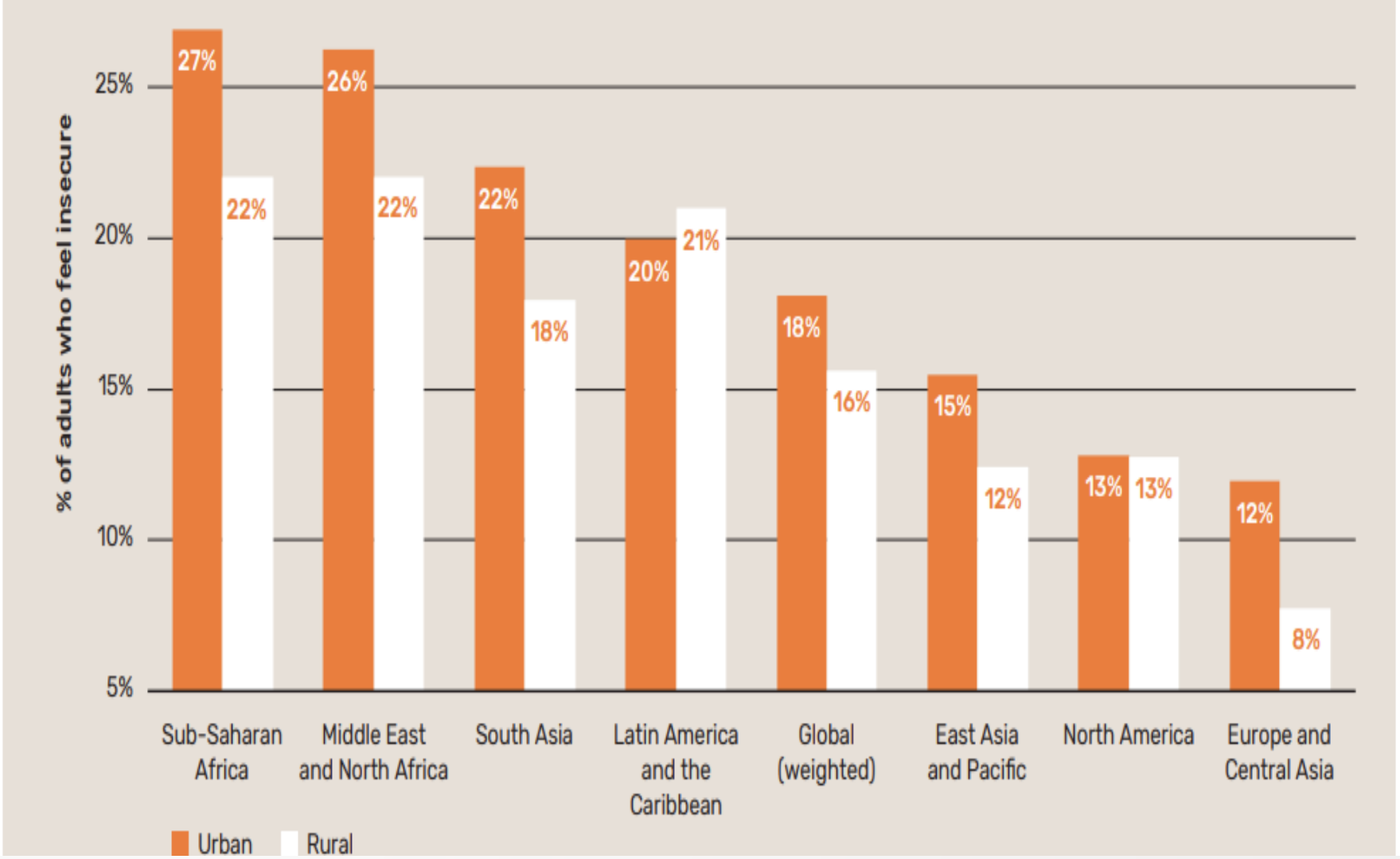
Source: Own calculations based on the World Bank Development Indicators

For Latin America, aggregate growth originating in agriculture is estimated to be 2.7 times more effective in reducing poverty than growth in other sectors (WB, 2008)

LAND TENURE PLAYS A SIGNIFICANT ROLE IN AGRICULTURAL PRODUCTIVITY

Land is a key economic resource linked to the use of and control over other economic and productive resources and livelihoods (Feder & Nishio, 1988).

Land is a key input for agricultural production; it can be used as collateral to access financial resources, extension services or producer organizations (Besley & Ghatak, 2010).



Source: Prindex Survey

In Latin America, lack of formal tenure security continues to be a widespread issue, particularly in rural areas.

Bolivia: 30% of agricultural land still needed to be regularized, titled, and registered by 2016.

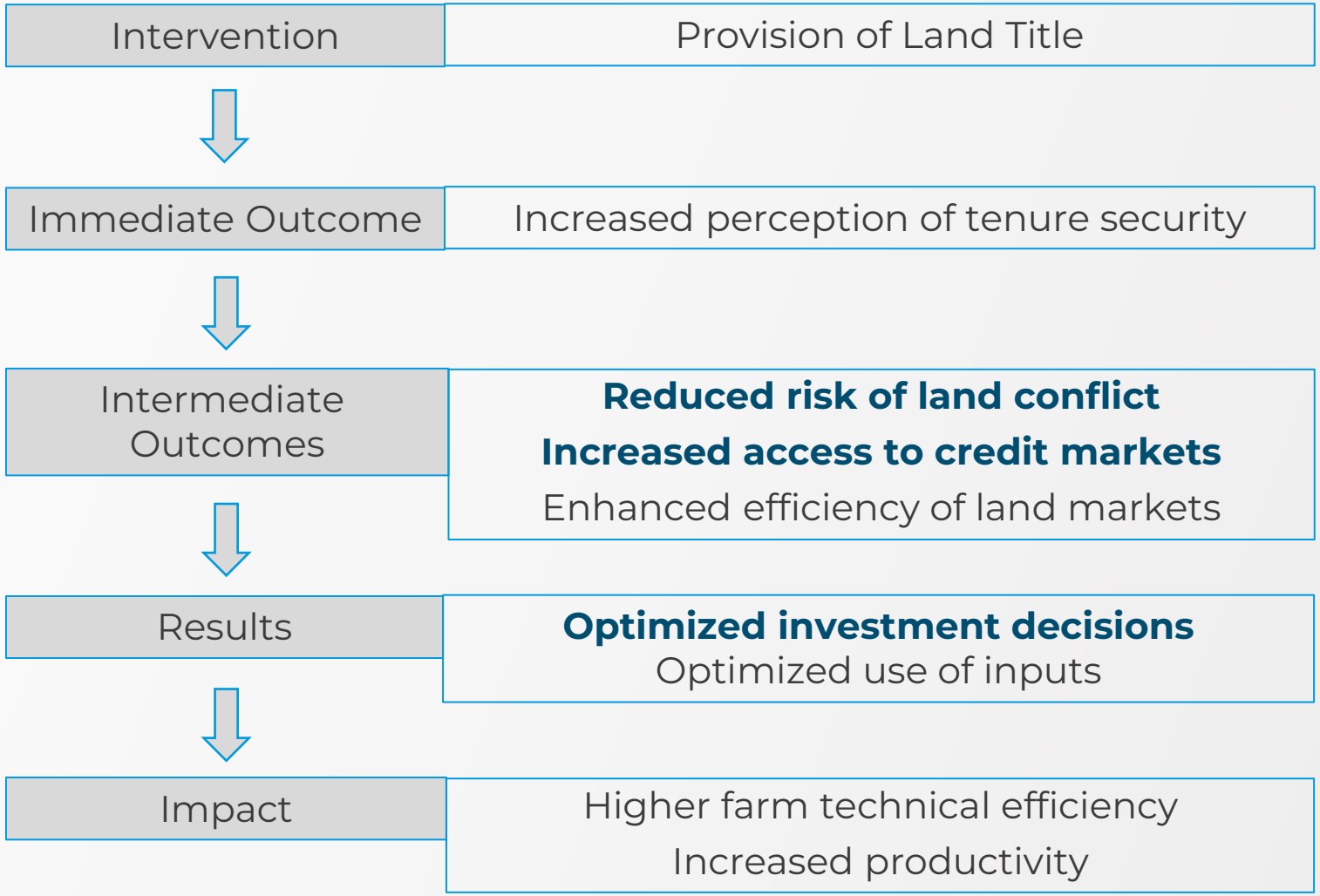
Ecuador: 60% of farmers did not have property titles by 2008.

Peru: 65% of farmers did not have a property title by 2022; only 20% had a title registered in Public Registries.

LATIN AMERICA IS THE ONLY REGION WHERE TENURE INSECURITY IS HIGHER IN RURAL AREAS THAN IN URBAN AREAS

CONCEPTUAL FRAMEWORK

THEORY OF CHANGE



EMPIRICAL EVIDENCE

- **No clear consensus in the literature:**
  - **Positive impacts** on productive outcomes (Deininger & Chamorro, 2004; Goldstein & Udry, 2008; Higgins et al., 2018)
  - **No causal impacts** found or context dependent (Fort, 2008; Hong et al., 2020; Suchá et al., 2020; Zegarra et al., 2008)
  - Important **moderating role** of pre-existing customary land rights systems (Brasselle et al., 2002; Corral & Montiel, 2021; Deininger, 1999; Goldstein & Udry, 2008)

- **Limitations of empirical evidence:**
  - Most studies rely on **cross-sectional data** and are unable to **isolate causal impacts** due to **underlying endogeneity** between tenure security and production decisions

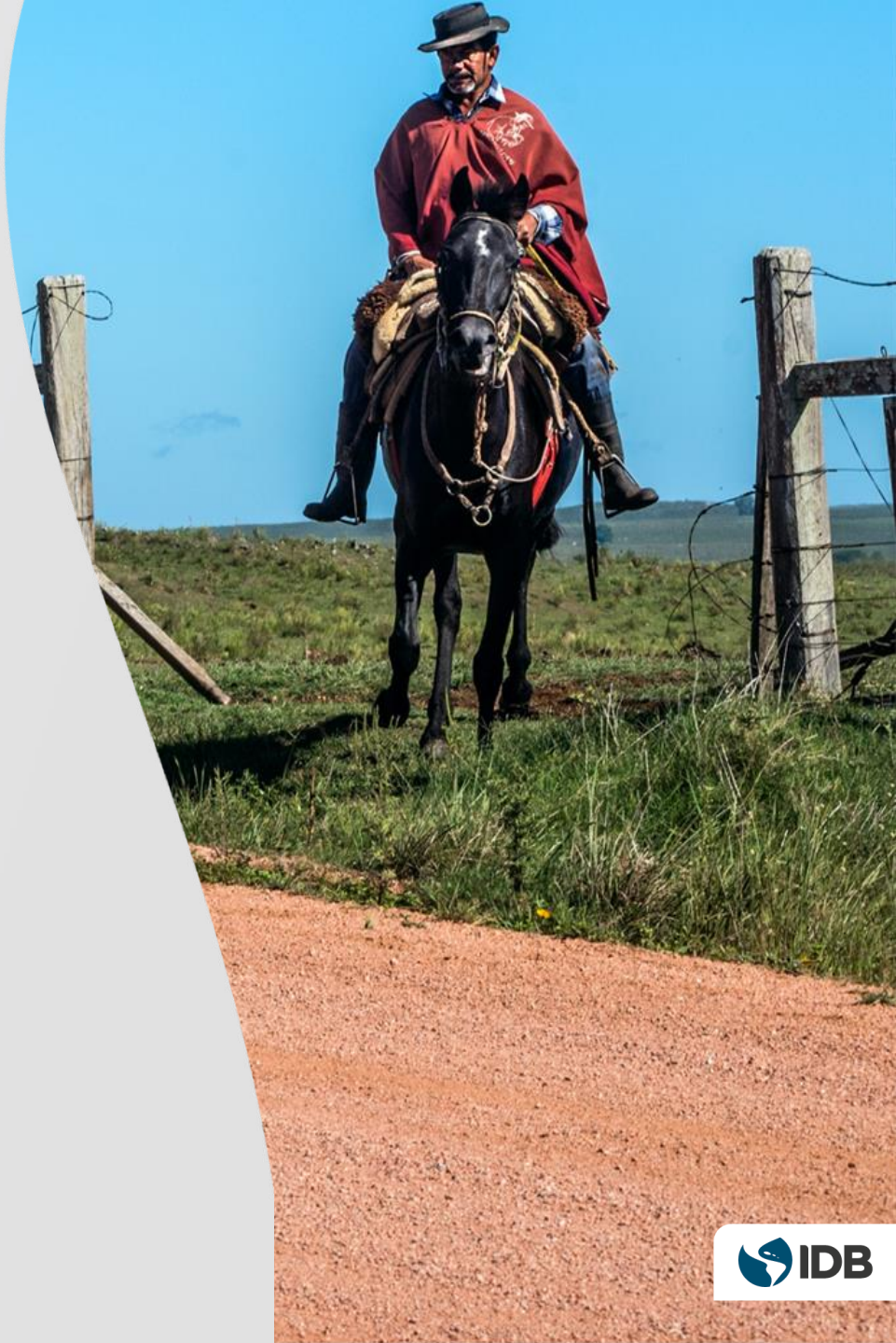
RESEARCH QUESTIONS

- What is the effect of formal legal title on technical efficiency?
- Does the impact of tenure security on technical efficiency vary by country?

CONTRIBUTION OF OUR RESEARCH

- First **causal analysis** of the effects of land tenure security on agricultural productivity for Latin America
- Using **rich agricultural household** data from three Andean countries
- Applying **multiple empirical** strategies to address concerns of endogeneity

DATA



DATA

Agricultural household data collected from **7,380 farmer households** in Andean countries (Bolivia, Ecuador, and Peru) in the course of land regularization & administration programs supported by IDB

Bolivia

- Survey collected in 2023 (baseline)
- Sample size: **2,283** smallholder farmers
- "Rural Land Regularization and Titling Program" (approved in 2024)

Ecuador

- Surveys collected in 2014 (baseline) and 2018 (endline)
- Sample size: **2,712** smallholder farmers
- "National System for Rural Land Information & Management and Technology Infrastructure (SigTierras)" Program (2012-2019)

Peru

- Survey collected in 2019 (baseline)
- Sample size: **2,385** smallholder farmers
- "Rural Land Cadaster, Titling and Registration Program - Phase 3 (PTRT-3)" (approved 2016, cancelled)

Questionnaires collected data on:

- Perceived and actual tenure status
- Sociodemographic characteristics
- Productive characteristics:
  - Crop choices
  - Production volume
  - Use of inputs
  - Productive practices

DATA STATISTICS

Sample Selection:

- Include only farmers who own at least one plot and are actively engaged in agric. and/or livestock activities.
- Exclude farmers with USD/ha productivity above the 95th percentile of the distribution.

Sample Size by country:

Bolivia	Ecuador	Peru	Total
1,344	2,353	1,591	5,288

BY COUNTRY

Variable	Bolivia	Ecuador	Peru
Panel A: Sociodemographic Characteristics			
Household head is a woman	0.20	0.22	0.20
Age of household head	53.67	52.38	53.53
Education of household head (in years)	5.82	5.11	6.17
% of households with non-farm income	0.20	0.50	0.81
Panel B: Land Characteristics			
Plot size (in hectares)	6.70	4.61	5.15
Number of plots owned by household	2.94	2.74	2.18
% of irrigated plots	0.26	0.19	0.14
% households with legal land title	0.58	0.52	0.10
Panel C: Productive Characteristics			
Surface area harvested in last year (in ha)	3.25	1.44	0.83
% of organic fertilizer use	0.68	0.39	0.38
% of chemical fertilizer use	0.24	0.27	0.07
% of tractor use	0.52	0.24	0.22
% of paid labor use	0.37	0.35	0.7
% of plots that received investment	0.23	0.07	0.05
% of access to credit	0.29	0.29	0.07
Volume of annual agricultural production (in kg)	2,428.11	2,259.37	2,512.40
Value of annual agricultural production (in US$)	1,793.09	1,169.71	1,320.96
Annual agricultural productivity (in kg/Ha)	2,779.95	3,858.31	6,071.65
Annual agricultural productivity (in US$/Ha)	1,212.75	891.91	1,219.47

Notes: Standard deviation in parentheses. All monetary values expressed in 2022 PPP USD.

PRODUCTIVE CHARACTERISTICS BY LAND TENURE STATUS

	I. Bolivia			II. Ecuador			III. Peru		
Variable	**No Land Title**	**Land Title**	**Diff.**	**No Land Title**	**Land Title**	**Diff.**	**No Land Title**	**Land Title**	**Diff.**
Share of Household	0.42	0.58		0.48	0.52		0.9	0.1	
Plot size (in ha)	3.27	9.21	5.94***	4.59	4.63	0.04	5.07	5.87	0.8
Surface area harvested (in ha)	1.92	4.18	2.26	1.25	1.61	0.37	0.82	0.9	0.08
% of land irrigated	0.2	0.31	0.11***	0.12	0.26	0.15***	0.14	0.19	0.05*
Annual production volume (Kg)	1,066.61	3,378.96	2,312.35***	2,274.32	2,246.38	-27.94	2,382.82	3,536.62	1,153.80***
Annual production value (USD)	1,400.02	2,081.69	681.67***	975.93	1,346.63	370.70***	1,307.76	1,444.09	136.33
Agricultural productivity (Kg/Ha)	2,422.36	3,029.69	607.32	3,572.19	4,113.30	541.11	6,117.15	5,757.14	-360.01
Agricultural productivity (USD/Ha)	1,388.26	1,083.88	-304.38***	957.85	831.71	-126.14**	1,261.52	827.09	-434.43*

EMPIRICAL APPROACH

EMPIRICAL STRATEGY

We propose to apply a **bias-corrected stochastic production frontier (SPF) model approach**:

The SPF models farm output as a function of input, technical inefficiency, and random error.

The SPF model will be estimated using a log-linear Cobb-Douglas specification:

$$log(Y_i) = \beta_0 + \sum_{j=1}^{n} \beta_j \cdot \log(X_{ji}) + v_i - \mu_i \quad (1)$$

where:

Y_i denotes production output of farmer i

X_i represents a vector of farm level inputs (land, labor and variable inputs)

v_i accounts for purely random factors

μ_i represents technical efficiency factors

Technical Efficiency TE_i is then defined as: $TE_i = \exp(-\mu_i)$ (2)

ADDRESSING POTENTIAL ENDOGENEITY CONCERNS:

1. **Propensity Score Matching** to correct for selection bias from observable characteristics by matching treatment observations and closest possible observation(s) from the control group

2. **SPF with a bias-correcting selection model** (Greene, 2010), comprising two simultaneous equations:

   i. The SPF function, and

   ii. A selection equation that estimates the likelihood that a farmer will exhibit full property rights as follows:

$$D_i = \alpha_0 + \sum_{k=1}^{n} \alpha_k \cdot Z_{ki} + \epsilon_i \qquad (3)$$

where:

D_i is a binary variable representing the likelihood the farmer has a formal land title

Z_i is a vector of exogenous variables including socio-demographic characteristics of the farmer and his HH, as well as land-specific characteristics, such as land size

META FRONTIER APPROACH:

- Creates common benchmark technology to be able to directly compare farmers with and without title
- Differentiates between the effect of tenure security on factor use and technological change

- This meta frontier production function can be expressed as:

$$y^* = f(x_i, \beta^*) = e^{x_i \beta^*} \qquad (4)$$

where:

y^* is the meta frontier output

β^* denotes the vector of parameters such that $x_i \beta^* \geq x_i \beta_j$

β_j are parameters obtained from each of the group specific frontiers

ESTIMATING THE IMPACT OF TENURE SECURITY ON TECHNICAL EFFICIENCY

Once technical efficiency has been estimated, we estimate the following Tobit model:

$$TE_i = \gamma_0 + \gamma_1 Tenure_i + \sum_{i=1}^{n} \gamma_2 W_i + \sigma_i \qquad (9)$$

where:

TE_i = technical efficiency of farmer household i.

$Tenure_i$ = binary variable indicating whether farmer HH i holds formal legal title for at least one parcel

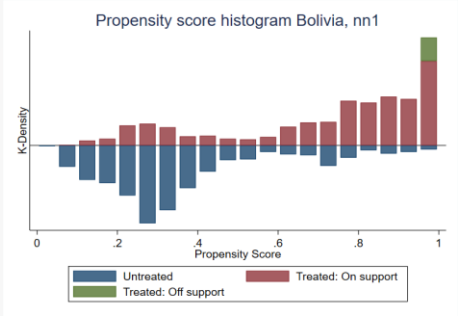
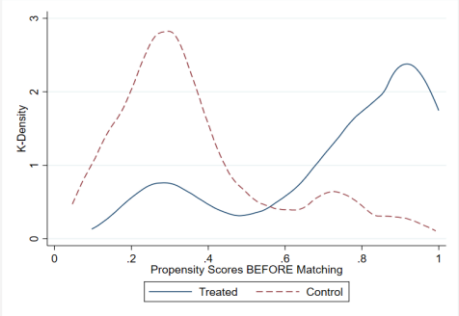
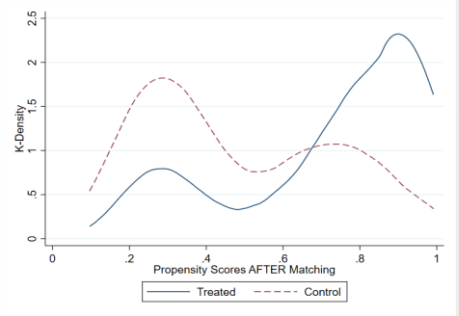
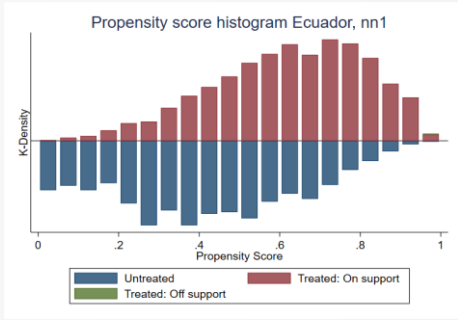
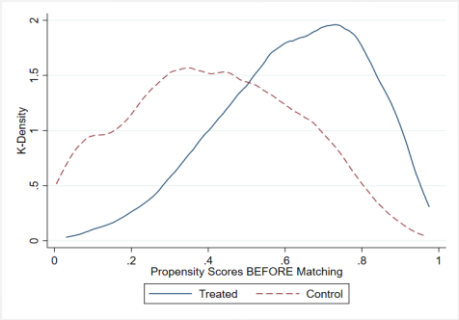
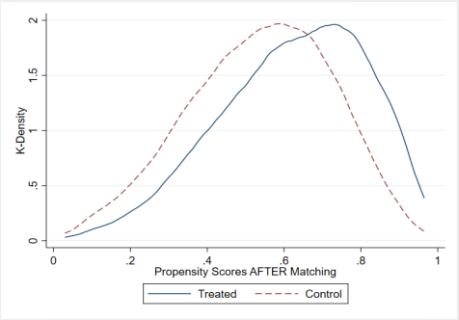
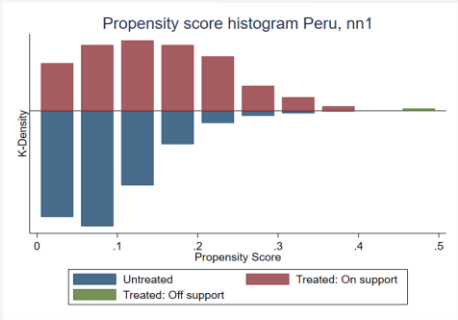
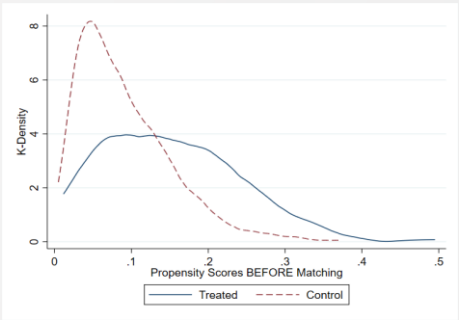
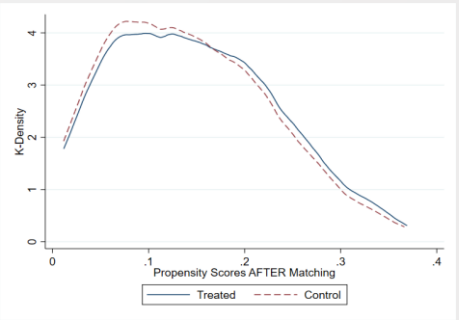
W_i = vector of socio-demographic and productive covariates at the farm HH level

γ_1 = parameter of interest

RESULTS

PROPENSITY SCORE MATCHING

- **Matching mechanism:** 1-to-1 nearest neighbor with replacement
- **Covariate selection:** incremental inclusion that improve model fit (Imbens & Rubin, 2015)
- **Base covariates:** total land extension, sociodemographic characteristics of HH head, total HH members of working age, and regional controls.
- **Covariates to select from:** livestock activity, wealth quintiles, off-farm income, among others
- **Matched sample:** 2,986 farmer HH – 2,118 titled and 868 untitled HH

	I. PS Support	II. Pre - PSM	III. Post - PSM
Panel A: Bolivia			
Panel B: Ecuador			
Panel C: Peru			

SPF - POOLED

	Unmatched Sample				Matched Sample			
	Conventional SPF	Sample Selection			Conventional SPF	Sample Selection		
	Pooled	Land title	No land title	Meta frontier	Pooled	Land title	No land title	Meta frontier
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Land (in Ha)	0.747***	0.602***	0.667***	0.677***	0.730***	0.619***	0.741***	0.619***
	(0.026)	(0.026)	(0.034)	(0.005)	(0.033)	(0.028)	(0.074)	(0.000)
Log Input Expenses	0.154***	0.182***	0.126***	0.162***	0.171***	0.176***	0.149***	0.177***
	(0.011)	(0.014)	(0.016)	(0.003)	(0.014)	(0.014)	(0.027)	(0.000)
Log Livestock Expenses	0.078***	0.142***	0.054***	0.084***	0.116***	0.133***	0.093***	0.134***
	(0.009)	(0.015)	(0.014)	(0.002)	(0.013)	(0.015)	(0.028)	(0.000)
Log Other Expenses	0.050***	0.019	0.066***	0.072***	0.029	0.022	0.06309	0.023***
	(0.015)	(0.024)	(0.025)	(0.004)	(0.018)	(0.025)	(0.051)	(0.000)
Log Labor Expenses	0.119***	0.097***	0.139***	0.129***	0.089***	0.093***	0.116***	0.093***
	(0.011)	(0.018)	(0.019)	(0.003)	(0.014)	(0.019)	(0.036)	(0.000)
Total HH Members	0.013	0.035**	0.042**	0.133***	0.029	0.027*	0.075**	-0.039***
	(0.059)	(0.016)	(0.019)	(0.014)	(0.071)	(0.016)	(0.036)	(0.000)
Land Irrigation	0.026**	-0.011	0.046	0.033***	0.035**	-0.0386	0.198	0.028***
	(0.012)	(0.090)	(0.091)	(0.003)	(0.014)	(0.087)	(0.165)	(0.000)
σ_u		3.416***	3.997***			3.388***	3.494***	
		(0.058)	(0.066)			(0.056)	(0.107)	
σ_v		0.824***	0.903***			0.768***	1.365***	
		(0.075)	(0.051)			(0.085)	(0.167)	
$\rho(w, v)$		-0.678***	0.905***			-0.619***	0.974***	
		(0.121)	(0.045)			(0.235)	(0.032)	
Log Likelihood	-11,400.00	-6,269.81	-8,454.59	-2,639.21	-6,211.35	-5,085.60	-2,908.35	-1,941.51
Observations	5,288	2,159	3,129	5,288	2,986	2,118	868	2,986

Notes: Robust standard errors in parentheses. Difference unequal to zero if p-value significant at the 99 (***), 95 (**), or 90 (*) confidence level. All specifications included country fixed effects.

TECHNICAL EFFICIENCY ESTIMATES

	Panel A: Unmatched Sample				Panel B: Matched Sample			
	All Countries	Bolivia	Ecuador	Peru	All Countries	Bolivia	Ecuador	Peru
Land Title								
TE Pool	22.78	21.25	23.74	22.80	24.16	23.33	24.63	24.46
TE Sample Selection	21.10	21.09	20.94	22.40	21.27	21.05	21.27	22.38
TE Meta Frontier	21.09	21.08	20.93	22.40	21.27	21.05	21.27	22.38
No Land Title								
TE Pool	22.33	20.39	22.03	23.34	24.05	22.91	23.67	27.13
TE Sample Selection	18.43	16.07	18.48	19.33	19.66	17.90	19.94	21.31
TE Meta Frontier	17.77	15.37	17.28	19.11	15.48	14.30	15.47	17.30

EFFECT OF TENURE SECURITY ON TECHNICAL EFFICIENCY

POOLED ANALYSIS

Outcome: Technical Efficiency					
	All Countries		**Bolivia**	**Ecuador**	**Peru**
	(1)	(2)	(3)	(4)	(5)
Panel A: Unmatched Sample					
Farmer holds title	**3.316***** (0.516)	**4.244***** (0.567)	**5.712***** (1.059)	**3.649***** (0.714)	**3.292**** (1.637)
Panel B: Matched Sample					
Farmer holds title	**5.797***** (0.707)	**5.976***** (0.716)	**6.754***** (1.421)	**5.800***** (0.897)	**5.083***** (2.090)
Country FE	*No*	*Yes*	-	-	-

Standard errors in parenthesis.
*, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

PATHWAYS OF INCREASED PRODUCTIVITY

Dependent Variable:	Access to Credit		Productive Investment		Land Conflicts	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coef.	Margin	Coef.	Margin	Coef.	Margin
A. All countries						
Farmer holds land title	**0.120**** (0.060)	**0.033**** (0.017)	0.105 (0.069)	0.021 (0.014)	**0.170**** (0.081)	**0.034**** (0.016)
B. Bolivia						
Farmer holds land title	**0.456***** (0.103)	**0.077***** (0.018)	**0.241***** (0.078)	**0.073***** (0.023)		
C. Ecuador						
Farmer holds land title	0.098 (0.167)	0.031 (0.052)	**0.525**** (0.256)	**0.060**** (0.030)	**-0.366**** (0.220)	**-0.057**** (0.034)
D. Peru						
Farmer holds land title	-0.134 (0.212)	-0.02 (0.032)	0.267 (0.214)	0.041 (0.033)	0.241 (0.257)	0.024 (0.026)

Notes: Robust standard errors in parentheses. Difference unequal to zero if p-value significant at the 99 (***), 95 (**), or 90 (*) confidence level.

CONCLUSIONS

CONCLUSIONS

1. Observed **selectivity bias** of groups confirms chosen empirical approach to estimate causal effects
2. SPF estimation highlights **statistical relevance of land** as a determinant of production output
3. Titled farmers generally exhibit **higher technical efficiency** scores compared to untitled farmers
4. Holding legal land title is estimated to increase technical efficiency **by 6.0 p.p., or 38.6%**, relative to untitled farmers
5. This positive impact **holds at the regional level**, though magnitude varies by country
6. Holding legal title is associated with **higher access to credit and increased productive investment**, with heterogeneity across countries
7. **Comprehensive land regularization efforts are essential** for enhancing agricultural productivity and food security among smallholder farmers in Latin America

THANK YOU!

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