The Relationship between Land Size and Agricultural Productivity in Kyrgyzstan

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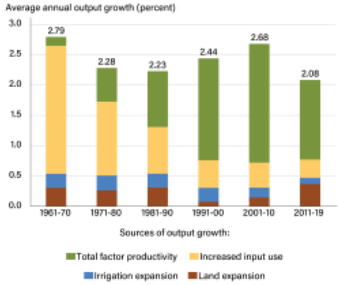
Motivation

- Agricultural productivity growth is necessary to meet rising food demand, lower food prices, facilitate structural transformation and combat climate change.
- Various entities contribute to productivity growth (e.g. farmers, public research & extension, private firms)
- In this paper we seek to understand the relationship between land size and productivity
  - *Specifically does the inverse relationship hold for the case of Kyrgyzstan?*



Source: Fuglie, Jelliffe, and Morgan (2021)

Motivation

- The inverse relationship between land size and productivity has been widely studied but remains controversial and inconclusive
  - Has implications for land reforms and small-holder led agricultural development
- Although the IR relationship has been observed in many developing countries in Africa, South Asia and Latin America, very little research in the Central Asian context
- Post-Soviet countries have seen a number of land reforms and a transition from collective to small-holder farms

Land reform in Kyrgyzstan: Three Phases

- Phase 1 (1991-1993): 10,000 private farms established by individuals within the collective agricultural system.
- Phase 2 (1994-2003): Saw increased clarity of organizational duties and an accelerated and broadened restructuring process due to agricultural production decline and farm reorganization delays.
- Phase 3: Transitioning to an individual land ownership system, focusing on improving services and infrastructure to support post-reform farms

Literature is Inconclusive

- Inverse relationship between land size and productivity
  - Chayanov (1926) first discovered farm-size productivity inverse relationships in Russian farms. Sen (1962) found smaller farms in India were more productive per hectare due to higher labor use. Inverse relationship has been found in many developing countries, including in Africa (Barrett, 1996; Kimhi, 2006; Carletto et al., 2013).
- Studies showing positive relationship
  - Obasi (2007) found a positive relationship in Nigeria due to low-quality inputs on small farms. Kimhi (2006) found a positive relationship between plot size and maize yield in Zambia when treating plot size as exogenous. Rada and Fuglie (2019) found small farms have productivity advantage in low-income countries while large farms are more productive in developed countries.
- Studies showing U-shaped relationship
  - Muyanga and Jayne (2019) found a U-shaped relationship between farm size and productivity in high-potential zones of Kenya. Relationship is negative from 0-3 hectares, flat from 3-5 hectares, and positive from 5-70 hectares.

Explanations for IR

- Market imperfections like missing labor, land, credit or insurance markets (Sen, 1966; Feder, 1985; Barrett, 1996).
- Unobserved land quality differences (Lamb, 2003; Benjamin and Brandt, 2002).
- Measurement errors in land size (Lamb, 2003) or farmer-reported yields (Desiere & Jolliffe, 2018).
- Introduction of new technologies can diminish or reverse the inverse relationship (Deolalikar, 1981; Otsuka et al., 2016).
- Heterogeneity in farmer skills can also generate an inverse relationship (Assunção & Ghatak, 2003). Evidence mixed on whether education and skills explain inverse relationship

Research Questions

- Does the IR hold for farm households in Kyrgyzstan?
- What factors contribute to the differences in agricultural productivity across farms?

Hypothesis: *There is an inverse relationship between land size and productivity in Kyrgyzstan.*

Data

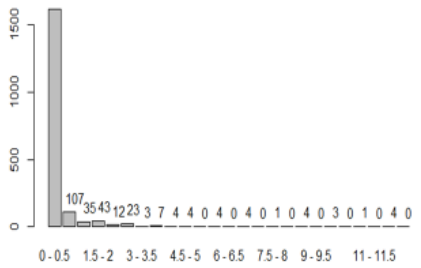
- Study uses data from the agricultural and household modules of LiK (2016 and 2019)
- Have data on number and size of plots, crops, inputs and household demographics
- Extract the following
  - Land size (hectares) - key independent variable
  - Crop value - dependent variables measuring productivity
  - Input costs for seeds, fertilizers, labor, machinery etc.
  - Demographic data on household heads like age, gender, marital status etc.
  - Regional variables
  - Crop types - fruits, cash crops, vegetables.
- Data filtered to remove missing values, outliers, and non-common households; final dataset has 1502 observations over 2016 and 2019

Descriptive Statistics

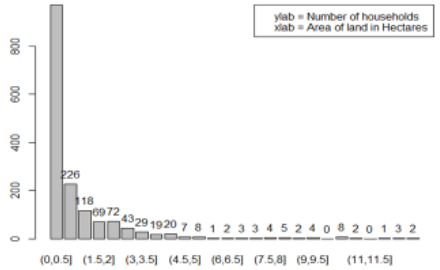
Variable	2016	2019	Pooled
Total # of Households	2529	2613	5142
Households w/plots	1813	1631	4426
Mean # of plots	1.6	1.64	
Mean crop value (soms)			
Fruits	495,685	741,650	1,237,335
Vegetables	622,775	673,760	1,296,535
Cash crops	946233	66800	1,013,033
Mean input costs (soms)			
Herbicides	1,662	1,921	3583
Insecticides	898	1,268	2166
Fertilizers	3,535	2552	6087
Seeds	1,378	2016	3394
Labor	6,181	6740	12,921

Land Size Distribution

2016



2019



Methodology

- Employs panel quantile regression and panel pooled regression
- Uses crop value as productivity measures
- Controls for crop type, regions, input costs, demographics, field characteristics
- Log transforms dependent and independent variables
- Compares results from panel pooled regression and panel quantile regression
- Quantile regression examines relationship at different productivity levels

Panel Pooled Regression

Baseline Model:

$$lnY_{ijt} = \alpha_i + \theta_i \, ln(land\ size_{1t}) + \beta_i X_{jt} + \gamma_i Z_j + \varepsilon_{it}$$

Where:

- Y represents the measure of productivity that is crop value.
- $ln(land\ size_{1t})$ is the natural logarithm of the land area in hectares at time t.
- X_{jt} denotes time variant independent variables.
- Z_j represents time invariant variables.
- ε symbolizes the error term.

Panel Quantile Regression

Panel Quantile Regression:

$$Y_{ijt} = \beta_\theta X_{jt} + \gamma_\theta Z_j + \varepsilon_{\theta jt}, \text{ with } q_\theta\left(\frac{y_{\theta jt}}{x_{it}+z_j}\right)$$

Where:

- X_{jt} represents land size and other time variant independent variables.
- Z_j predicts time invariant independent variables.
- $q_\theta\left(\frac{y_{\theta jt}}{x_{it}+z_j}\right)$ denotes the θ^{th} quantile of the dependent variables.

Results

Variables	(1) Panel pooled	(2) Q25	(3) Q50	(4) Q75
Log of area planted (ha)	7.80***	6.61***	4.79***	6.25***
Female household head	11.12***	10.18***	10.31***	11.94***
Number of adults in the household	-0.1	0.19	0.33	-0.34**
Age of household head	-0.10*	-0.105**	-0.05	-0.03
Married household head	10.24***	8.79***	10.03***	11.87***
Log of distance (meter)	-0.02	-0.49	-0.036	-0.04
Number of times herbicides were used	1.35*	1.32	1.14	1.01*
Fertilizers cost (som)	-0.00007	-0.00001	-0.00002	-0.00008
Number of times Insecticides were used	0.58	0.71**	0.32	0.50**
Manure compost	1.44*	2.21***	1.76*	1.51***
Crop dummies				
Fruits	16.24***	19.48***	12.03**	12.15***
Vegetables	2.99*	5.5***	0.6	2.28**
Cash Crops	1.51	-7.76***	-0.43	0.91
Pseudo R-squared	0.53	0.52	0.47	0.49
	Note:	*p<0.1;	**p<0.05;	***p<0.01

Discussion

- The study hypothesized that Kyrgyzstan holds the inverse relationship hypothesis, but we failed to accept that hypothesis.
- The findings of the panel quantile regression and panel pooled regression suggest that there is a highly positive significant relationship between land size and agriculture productivity in the case of Kyrgyzstan.
- Thus, developing countries can also have positive land size and productivity relationship.

Limitations

- In the LiK data, there was no information available about family labor.
- Also, the dataset did not contain information about the infrastructure of the country, which is one of the main obstacles the agriculture sector of Kyrgyzstan faces.
- LiK data does not provide information about the amount of input used in the field, such as kgs of fertilizers, number of labor, and bottles of insecticides.

Conclusion

- Overall, the findings of this study suggest that the relationship between land size and productivity in Kyrgyzstan is positive: even though studies show that developing countries have inverse relationship.
- The factors that affect this relationship are crop types, demographic factors, input cost and quantity, the distance of the field from the household, and characteristics of the household head.

Descriptive Statistics

Land types (ha)	Crop Types	Harvest-2016(kg)	Harvest-2019(kg)	Crop-value_2016 (Ks/kg)	Crop-value2019(KS/kg)
0-0.3	Fruits	66719.3	NA	363902	NA
0.3-0.6	Fruits	20050	7770.5	80588	29000
0.6-0.9	Fruits	0	1350	0	5038.3
0.9-1.2	Fruits	100	0	360	0
1.2+	Fruits	2000.2	0	13563.6	0
0-0.3	Grains and pulses	21075.14	2620	290470.8	35552
0.3-0.6	Grains and pulses	54243.68	900	1484960.4	10848
0.6-0.9	Grains and pulses	25231.46	0	666490	0
0.9-1.2	Grains and pulses	34624.36	50000	1208220	2004000
1.2+	Grains and pulses	62905.88	0	1494069	0
0-0.3	Vegetables	124117.66	26410.48	250811	84513.536
0.3-0.6	Vegetables	29607.8	6000	181014	39320
0.6-0.9	Vegetables	12352	5001.6	118041.4	25510
0.9-1.2	Vegetables	27026.4	63240	175257	408593.15
1.2+	Vegetables	90483.84	45000	937190.5	466089.55