Constructing Rigorous Relative Price Indices of Agricultural Land in the Developed and Developing World

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Introduction

- Soil properties and growing conditions differ substantially by country and region:
  1. Moisture stress in the U.S. primarily occurs in arid or semi-arid areas in western states.
  2. In Europe, moisture stress is most common in Spain.
- Geographic differences in land and soil characteristics contribute to important quality differences in agricultural output, which prevents direct comparison of observed prices.
- In models with cross-section data, failure to account for this substantial heterogeneity generally leads to biased estimates of relative land inputs.

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Survey of Recent Literature

- Recent studies have provided international comparisons of global agricultural productivity (Ball et al., 2001, 2010, 2016).
- Comparisons of the growth and relative levels of productivity were provided in these studies for the United States and member countries of the European Union. They found that prices of land of constant quality in selected European countries relative to the United States are significantly different than those derived from nominal land prices given exchange rates.
- However, this set of studies omitted information from three important countries in the global agricultural economy: Argentina, Brazil, and India.
- An extension of the global productivity analysis permits inclusion of these important developing countries as well as the developed world. This extension relies on the construction of relative land prices using hedonic methods.

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Research Objective

- **We estimate quality-adjusted land prices by regressing nominal land prices (by country) on common soil and population characteristics using hedonic methods.**
- Our research extends the work of Ball et al. (2008) by employing a much richer dataset covering more agriculturally-productive regions.
- Regression analysis includes data on 23 soil types across 3,553 districts in 17 countries (Sanchez, 2003).
- We present an example of data and techniques used to quality-adjust land values in the U.S. and select OECD countries using regional price and quantity data for 2005.

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Methods: Hedonic Regression Analysis

- Under the hedonic approach, the price of land is a function of its underlying characteristics.
- As such, the hedonic function may be expressed as $W = W(X,D)$, where W represents the price of land, X is a vector of characteristics, and D is a vector of control variables.
- Characteristics include soil acidity, salinity, and moisture stress, among others.
- In areas with extreme moisture stress, agriculture is generally not possible without irrigation; hence, irrigation is included as a separate variable. We also control for population density.
- Because irrigation mitigates the negative impact of acidity on plant growth, the interaction between irrigation and soil acidity is also included.
- Country dummies are also included and capture constant-quality land price.

Empirical Approach

- Most empirical studies adopt the semilog or double-log form of the hedonic price function.
- However, economic theory places few if any restrictions on the form of the hedonic price function.
- We adopt a generalized linear form where the dependent variable and each of the continuous independent variables are represented by the Box-Cox transformation.
- This expression can assume both linear and logarithmic forms, as well as intermediate non-linear forms.

Box-Cox Regression Model

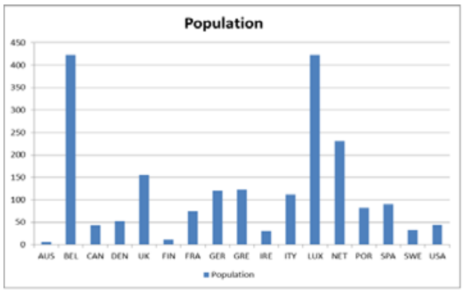
- For region *i* (e.g., county, district) of country *c*:

$$P_i(\lambda_1) = X_i(\lambda_2) + D_c + \varepsilon_i \ ,$$

$P_i(\lambda_1)$ is the Box-Cox transformation of land price,
$X_i(\lambda_2)$ is the Box-Cox transformation of continuous regressors,
D_c are country indicator variables,
$\lambda_.$ is the value used to transform continuous variables, and
ε_i is the normally-distributed error term.

Land Price (Dependent Variable)

Population Density (people/km^2)

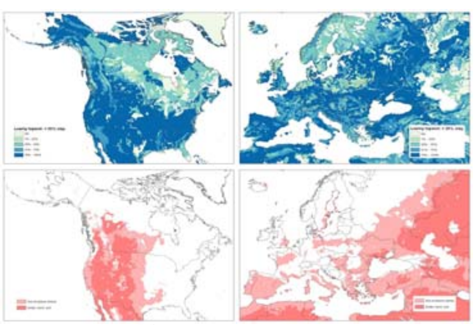


Variables used in Hedonic Estimation

Variable	Unit	Definition
Land price	Local currency per hectare	Price of agricultural land
Land area	Hectares	Total land area
Population density	Index	A measure of the size and proximity of nearby population centers
Irrigation	Percent of total land area	Irrigated
Aluminum	“	Soils with aluminum toxicity
Calcareous	“	Soils with calcareous reactions
Sulfidic	“	Sulfidic soils
Moisture stress	“	Experiencing continuous soil moisture stress
Aridic torric	“	Aridic or torric soil moisture regime too dry to grow a crop without irrigation
Leaching	“	High leaching potential
Waterlogging	“	Soils experiencing waterlogging
Phosphorus	“	High phosphorus fixation
Alkalinity	“	Soil alkalinity
Salinity	“	Soil salinity
Cryic frigid	“	Cryic and frigid (<8jC mean annual), non-iso soil temperature regimes, where management practices can help warm topsoils for short-term cereal production
Permafrost	“	Permafrost with 50cm gelisols; no cropping possingle
Cracking	“	Cracking clays
Volcanic	“	Volcanic soils
Organic	“	Organic soil: >12% organic C to a depth of 50 cm or more (histosols and histic groups)
Clayey top	“	Clayey topsoil >50% (dummy)
Loamy top	“	Loamy topsoil >50% (dummy)
Clayey sub	“	Clayey subsoil
Loamy sub	“	Loamy subsoil
Rock	“	Rock or other hard root-restricting layer within 50 cm
Sandy top	“	Sandy subsoil
Sandy sub	“	Sandy topsoil

Source: World Soils Group, Natural Resource and Conservation Service.

Loamy Topsoil, Soil Moisture Stress, and Aridic Soils requiring irrigation in the U.S. and Europe



Hedonic Regression Results

Variable	Coefficient	t-value	Variable	Coefficient	t-value
D1 (US)	8.780***	68.33	Irrigation	0.044***	3.47
D2 (Canada)	8.715***	62.91	Moisture stress	-1.407**	-2.89
D3 (Australia)	8.147***	25.70	Irrigation*moisture stress	0.049***	4.37
D4 (France)	8.267***	39.39	Population accessibility	0.378***	30.71
D5 (Finland)	8.538***	8.48	Aluminum toxicity	0.011***	0.84
D6 (UK)	8.048***	10.26	Salinity	0.001	0.18
D7 (Ireland)	9.577***	3.92	Aridic torric	-0.070***	-9.47
D8 (Belgium)	8.819***	4.52	Waterlogging	0.075***	3.32
D9 (Denmark)	10.987***	9.16	High phosphorus	0.021	0.14
D10 (Lux.)	9.019	0.36	Alkalinity	0.027	0.71
D11 (Netherlands)	9.400***	5.03	Cryic frigid	0.044	1.15
D12 (Germany)	8.397***	14.93	Permafrost	-0.120	-1.21
D13 (Italy)	9.236***	18.99	Cracking clays	0.002	0.04
D14 (Spain)	9.162***	22.99	Volcanic soils	-0.016	-0.60
D15 (Greece)	8.942*	3.29	Organic content	0.023	0.60
D16 (Portugal)	8.910***	3.89	Rock	0.063**	2.47
D17 (Sweden)	10.525***	3.76			
Clayey topsoil	2.598	1.37	λ-Clay top	6.049	1.38
Loamy topsoil	0.288***	3.02	λ-Sandy top	0.596***	3.10
Sandy topsoil	0.011	1.89	λ-Irriper	1.355***	7.17
Loamysubd	-0.048	-1.07	λ-Soilmoist	3.091	2.99
Claysubd	-0.011	-0.46	λ-Pop	0.088***	4.32
Sandysubd	0.045	0.79	λ-Alum	0.572	1.25
			λ-Salinity	2.450	0.98
Observations	3579		λ-Arid	0.265***	3.55
Schwarz Criterion	5355		Log Likelihood -2506		
AIC	5095		Sigma	0.480817 (84.32)	

Land Prices and Purchasing Power Parity for selected countries relative to the U.S., 2005

Country	Land Price		Purchasing Power Parity[b]	PPP/EX
	Nominal	Quality-Adjusted[a]		
U.S.	7,535	7,259	1.00	--
France	21,525	17,327	2.38	1.87[a]
Belgium	18,326	7,708	1.06	0.83[a]
Spain	30,100	10,509	1.44	1.13[a]

[a] Quality-adjusted price of land based on value of country indicator from hedonic estimation.

[B] For example, France's quality-adjusted land price divided by U.S.' quality-adjusted land price (17,327/7,259) equals 2.38. These are estimates of country indicator variables from the hedonic regression.

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Conclusions

1. The hedonic regression results indicate that irrigation, population density, clayey topsoil, loamy topsoil, and sandy topsoil have a significant and positive impact on land price. Moisture stress and high leaching potential are significant and negative.
2. Constant-quality land prices in selected European countries relative to the U.S. are significantly different than what would be derived by using nominal land prices, given exchange rates.
3. Comparisons of purchasing power parity and the nominal exchange rate provide information on relative land prices:
   - For example, constant-quality land price in France was nearly double that of the U.S. in 2005 (2.38/1.27=1.87), given an exchange rate of $1.27 per Euro.
4. Future work will incorporate additional land price and soil data for Argentina, Brazil, China, and India.

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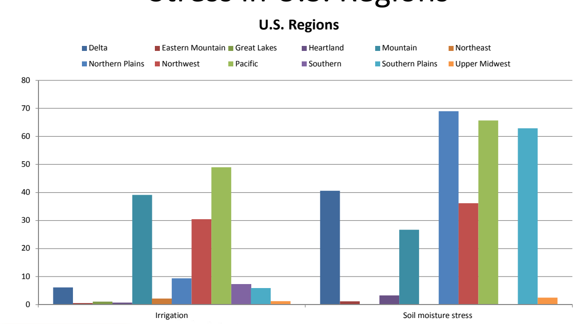
Appendix: Irrigation and Soil Moisture Stress in U.S. Regions



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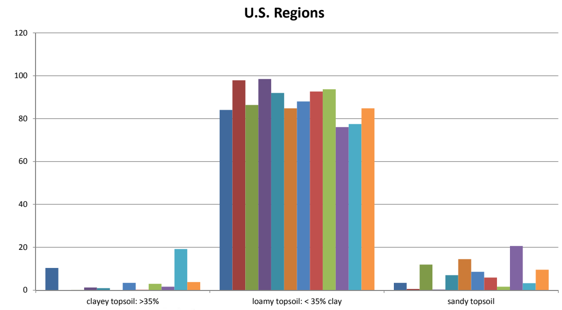
Appendix: Topsoil Characteristics in U.S. Regions



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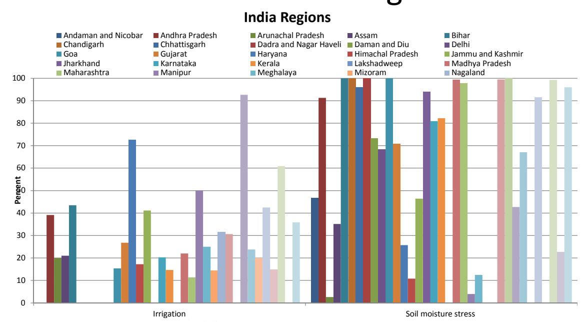
17

Appendix: Irrigation and Soil Moisture Stress in Indian Regions



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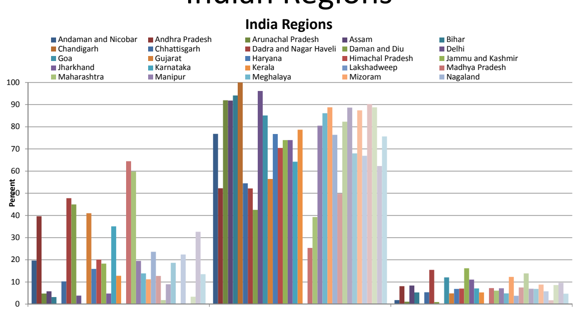
18

Appendix: Topsoil Characteristics in Indian Regions



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19