Measuring Adaptation in Agriculture

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March 11, 2013
USAID-UNDP
First Regional Training Workshop
"Assessing Costs and Benefits of Adaptation: Methods and Data"

Outline

- Part 1: theory of efficient adaptation
- Part 2: cross-sectional econometric models to study adaptation
- Part3: case studies
  - China: crop choice
  - Africa: irrigation choice

Part 1

Theory of efficient adaptation

Adaptation in agronomic models

- Simulate responses of crops to climate
- Data intensive: calibration problematic
- Focus on yields or total revenues rather than profits
- Farm level adaptation is treated exogenously
- Assume no or arbitrary responses by farmers
- Choices not based on net revenues

Examples

- Rosenzweig and Parry (1994) examine two levels of adaptation:
  1. small changes in planting date, water applications on existing irrigated land, crop-switching
  2. large changes in planting dates, increase fertilizer, adopt irrigation, crop-switching
- Rosenzweig and Parry (1994) are suspicious of their own list of adaptations
- Crop models assume the adaptation is made regardless of whether or not it will increase the net revenue of each farmer.
  – agronomic models have not done a good job of identifying efficient adaptations
- Agronomic model + farm model: possible but difficult

Are all adaptations desirable?

- Desirable adaptations provide benefits that exceed their cost
- Optimal adaptation: marginal cost is equal to marginal benefit
- Optimal adaptation maximizes net benefits

- Society should encourage only efficient adaptation
- “Climate proofing” generally inefficient
- The evaluation metric should not be resource mobilization but welfare impact

Private vs Public adaptation

- Private adaptation yields benefits at individual level
- Studies show that
  - Farmers have adapted to present climate
  - Farmers are expected to invest in private adaptation

- Public adaptation yields benefits at society-wide level
  - Farmers are expected to invest sub-optimally

Observing farmers

- Assumption that present adaptation to climate change is efficient
  - Uses information from individual cost-benefit analysis
- Use cross-sectional econometric methods to estimate relationship between climate and farmers choices
- Use present regional variation in climate to estimate future response to climate change

Why econometrics?

- Economists can rarely use “laboratory experiments”
- Based on observed farmers’ behavior
  - Important to cover a large variety of climates
- Controls factors other than climate
  - Challenge is control for all confounding factors
- Efficient treatment of random factors that affect farmers’ choices
  - Large number of observations (usually thousands)

Objection 1

Farmers have not optimally adapted to present climate

- Generally false:
  - Farmers have adapted under present conditions
    - Credit constraints
    - Knowledge
    - Cultural norms
    - Absence of infrastructures
- The cross-sectional method
  - assumes that present conditions (favorable or unfavorable) will not change over time
  - The method does not imply that farmers are at the highest theoretically possible level of efficiency

Objection 2

Farmers will not optimally adapt to future climate

- Only partially true:
  - Farmers will adapt, given present constraints
  - Adaptation might increase constraints
    - Credit constraints might prevent investment in irrigation
  - Development might reduce constraints

Objection 3

Adaptation is going to be costly

- It depends...
  - on the speed of change
    - With slow climate change capital will be replaced when obsolete
    - Time to learn and adapt
  - On the need of costly infrastructures
- There is evidence that farmers can adapt quickly:
  - In the USA: quick change to respond to prices

Adaptation in Developing Countries

- Many studies show that farmers have adapted to long-run conditions
- Farmers are also able to quickly shift crops to respond to markets
- Conley and Udry (2010): 36% of farmers in the Akwapim South district of Ghana switched from a traditional system of maize and cassava intercropping for domestic consumption to an intensive production of pineapple for export in only 7 years.
- A few years before less than 10% of farmers were planting pineapple.
- Farmers learned through complex social interactions that pineapple was a more valuable crop and learned also to manage the new agricultural technology.

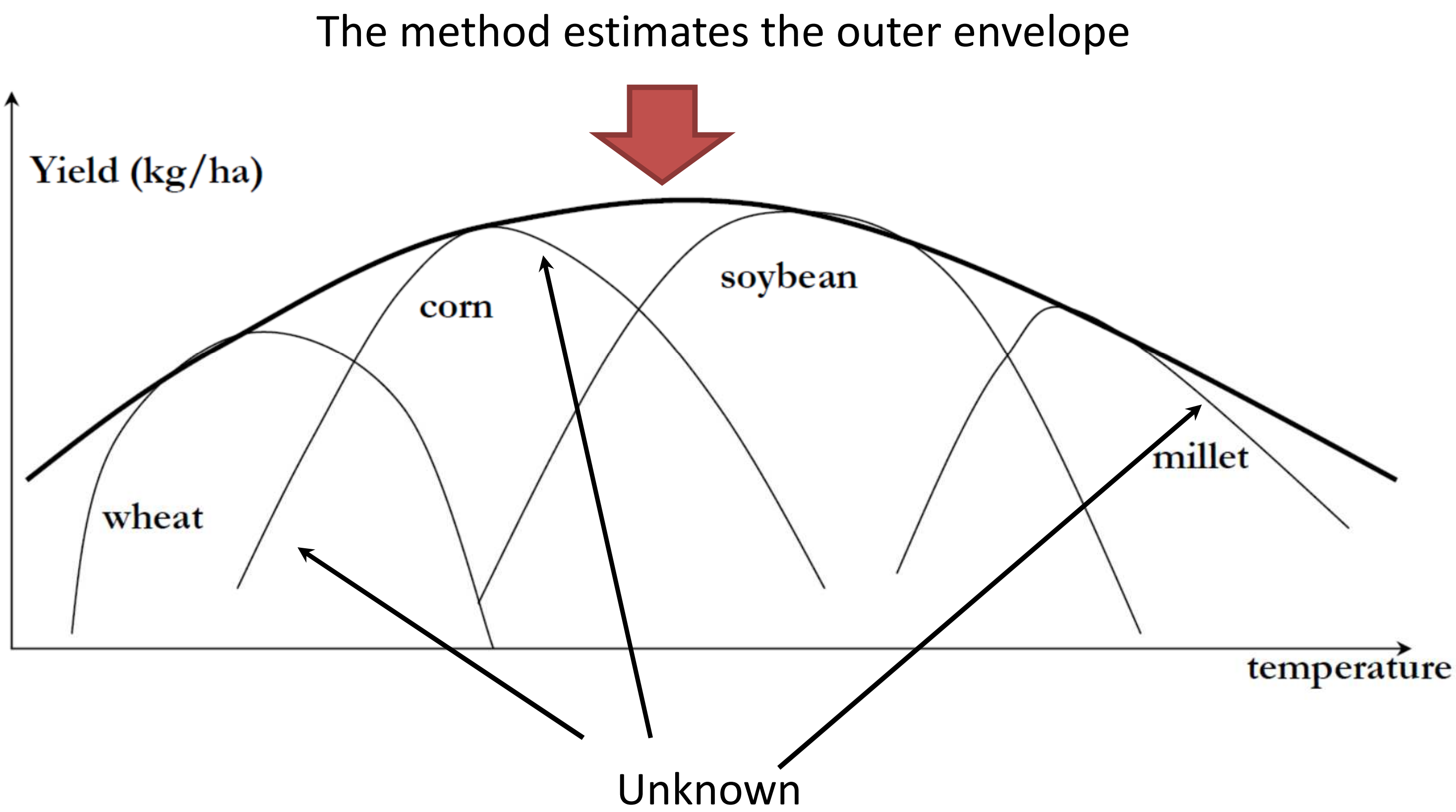
What role for donors?

- Important to (at least conceptually) separate adaptation to climate change from poverty alleviation
- Focus on removing barriers to adaptation
  - Typically poverty alleviation
- Focus on public adaptations
  - Large irrigation projects
  - Development of new seeds varieties
  - Knowledge generation and diffusion

Part 2

Cross-sectional econometric models to study adaptation

Adaptation in the Ricardian model



Structural Ricardian Model

- The structural Ricardian model considers how local climate conditions influence the choice of:
  - the farm type.
  - the decision to irrigate or not.
  - the selection of crops and animals.
- Standard Ricardian model:
  - climate-land value relationship.
- Structural Ricardian method:
  - characteristics of the underlying relationships between land values and single crops or farm types.

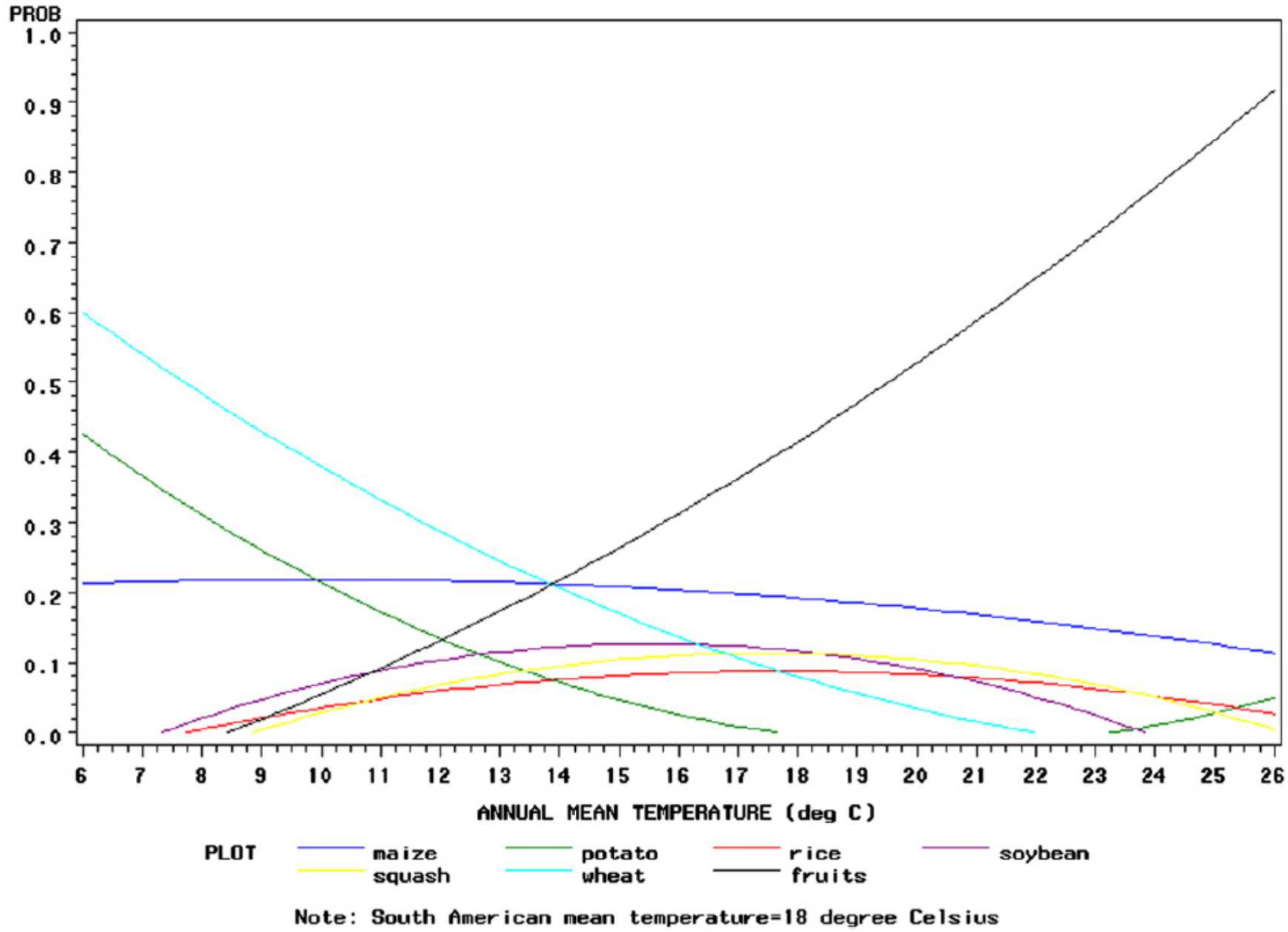
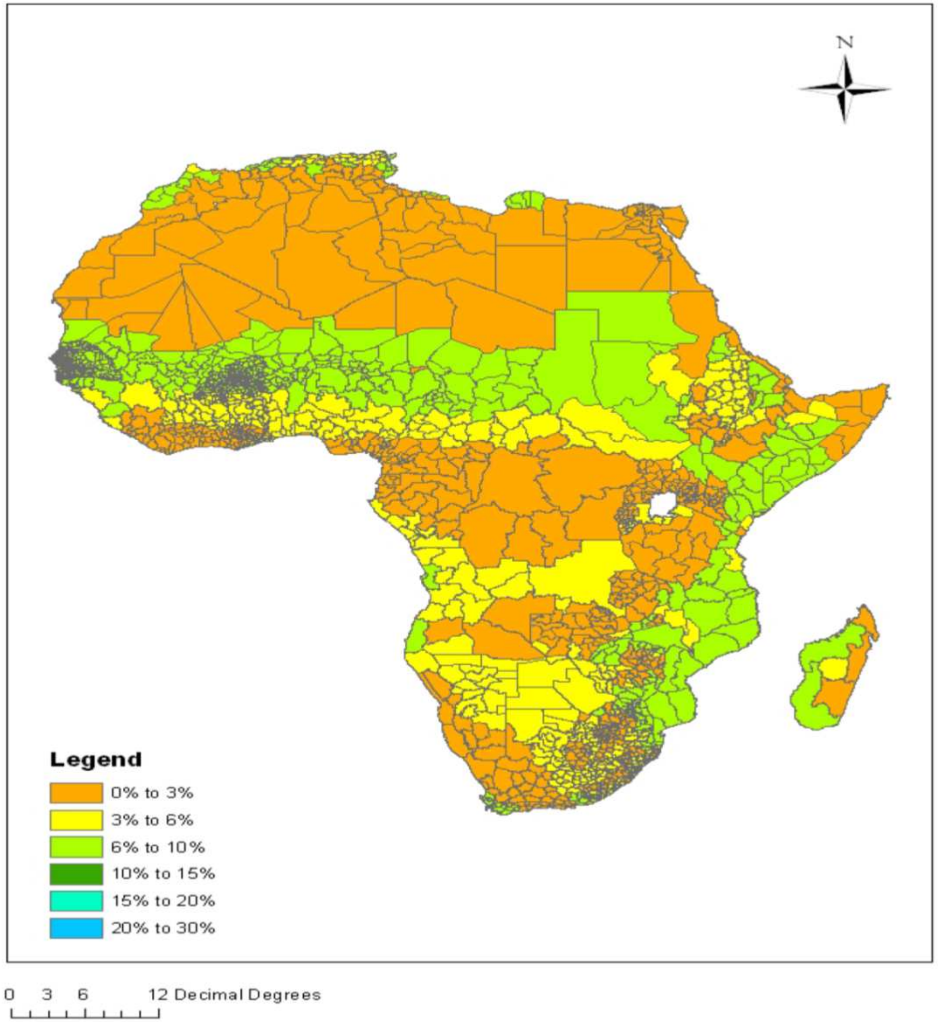


Fig. 1 – Estimated probabilities for crops to be chosen over temperature (°C).

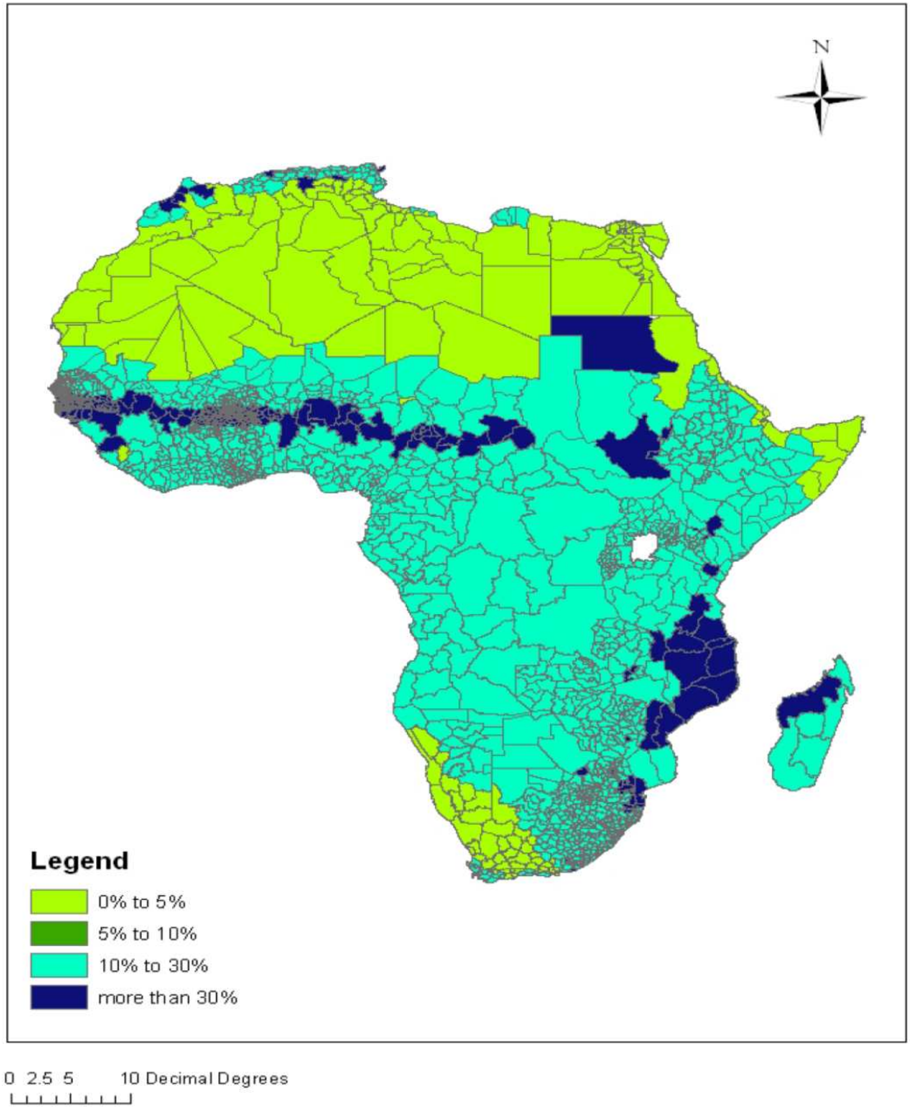
Seo and Mendelsohn (2008)

Probability of having sheeps present climate

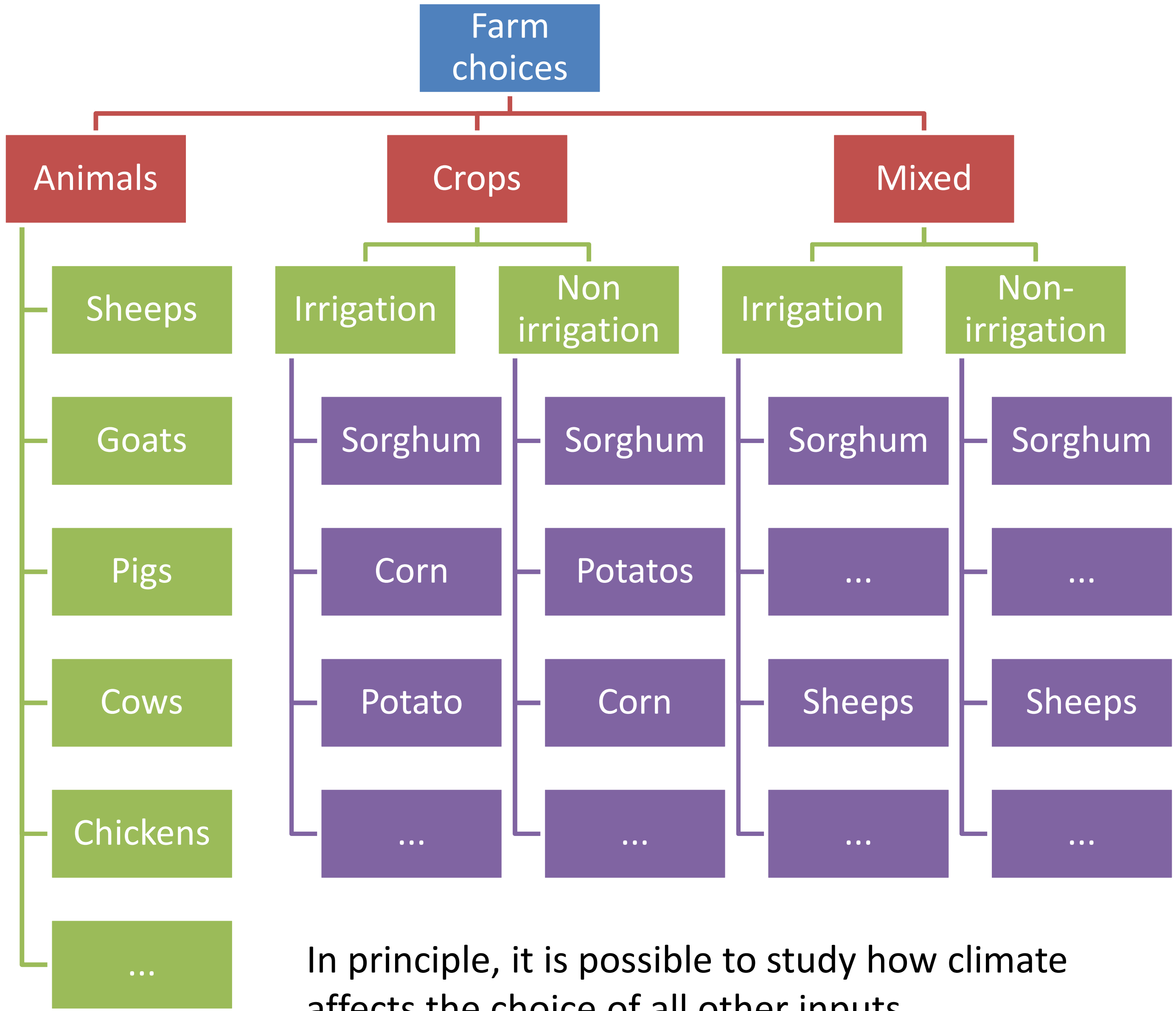


Seo and Mendelsohn

Probability of having sheeps future climate



Seo and Mendelsohn



In principle, it is possible to study how climate affects the choice of all other inputs

Part 3

Case study:

Changing crop choices to adapt to climate change in China

Based on:

Wang, J., Mendelsohn, R., Dinar, A., & Huang, J. (2010). How Chinese farmers change crop choice to adapt to climate change. Climate Change Economics, 1(03), 167-185.

Overview

- Use structural Ricardian model to study farm adaptation in China
- 8,405 farms across 28 provinces
- Multinomial logit regressions of crop choice
- Nine major crops:
  - wheat, rice, maize, soybean, potato, cotton, oil crops, sugar and vegetables
- Apply estimated relationship to different scenarios of climate change

Data

- Socio-economic data from Household Income and Expenditure Survey of 2001
  - household and village characteristics
  - irrigation (village level)
  - crop choice (farm level)
- 8,405 households in 124 counties from 28 provinces
  - climate data not available everywhere
  - with recent datasets this is not a problem
- Soil data from FAO
- Monthly temperature and precipitation from National Meteorological Information Center

Present and future adaptation

- Relationship between present climate and present crop choices

- Estimate of future adaptation using climate change scenarios
  - data on climate change scenarios
  - attribution of climate scenarios at farm level

Results

- As temperatures warm
  - more likely to choose cotton and maize
  - less likely to choose vegetable and potatoes
- As precipitation increases
  - more likely to choose wheat
  - less likely to choose vegetables and potatoes
- Magnitude of change depends on
  - amount of warming and precipitation change
  - distribution of warming and precipitations across counties

Table 1. Multinomial logit regression of crop choice.

	Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil Crops	Sugar
Spring temp	0.119	0.27	−0.025	−1.21	0.229	−1.191	−0.176	−0.181
	(0.82)	(1.84)*	(0.25)	(8.84)***	(2.03)**	(2.20)**	(1.38)	(0.46)
Spring temp sq	−0.013	−0.0048	−0.0034	0.0313	−0.0177	0.0158	−0.0094	0.0015
	(2.86)***	(1.07)	(1.11)	(7.05)***	(5.12)***	(0.77)	(2.39)**	(0.13)
Summer temp	−1.027	−0.681	−0.125	2.446	0.237	−2.541	0.436	1.457
	(6.22)***	(2.82)***	(0.88)	(10.03)***	(1.53)	(2.45)**	(2.56)**	(2.24)**
Summer temp sq	0.031	0.0078	0.0042	−0.0427	−0.0034	0.0903	0.0002	−0.0225
	(8.06)***	(1.57)	(1.32)	(8.37)***	(0.98)	(4.17)***	(0.07)	(1.56)
Fall temp	−0.118	1.05	0.177	−0.458	−0.445	−0.589	−0.9	−1.411
	(0.90)	(7.11)***	(1.88)*	(3.70)***	(4.03)***	(0.85)	(7.09)***	(3.22)***
Fall temp sq	−0.014	−0.024	−0.0113	−0.0016	0.0094	0.0025	0.0118	0.0044
	(2.81)**	(5.07)***	(3.13)***	(0.34)	(2.31)**	(0.09)	(2.67)**	(0.31)
Winter temp	0.347	−0.294	0.111	0.365	0.242	−0.307	0.542	0.813
	(6.83)***	(4.46)***	(2.50)**	(5.94)***	(4.54)***	(1.42)	(9.92)***	(4.94)***
Winter temp sq	0.0004	0.0094	0.007	−0.0023	0.0073	−0.0972	−0.0001	0.0136
	(0.20)	(4.94)***	(5.27)***	(1.17)	(4.79)***	(5.79)***	(0.06)	(2.26)**
Spring prec	0.831	0.11	−0.08	0.27	0.162	0.447	−0.189	0.64
	(8.43)***	(1.75)*	(1.40)	(3.64)***	(2.52)**	(1.84)*	(2.84)***	(3.40)***
Spring prec sq	−0.048	−0.0013	0.0038	−0.0127	−0.0017	−0.0002	0.0056	−0.0314
	(10.63)***	(0.58)	(1.81)*	(4.78)***	(0.72)	(0.02)	(2.31)**	(4.92)***
Summer prec	−0.213	−0.038	−0.108	0.021	−0.075	−0.253	−0.0052	−0.009
	(7.69)***	(1.32)	(5.19)***	(0.70)	(2.85)***	(2.81)***	(0.20)	(0.12)
Summer prec sq	0.00676	0.0003	0.0023	−0.0002	0.0002	−0.0028	−0.0008	0.001
	(7.17)***	(0.36)	(3.59)***	(0.18)	(0.28)	(0.66)	(1.01)	(0.53)
Fall prec	−0.522	0.416	0.129	0.218	0.247	−0.799	−0.223	−1.026
	(6.59)***	(5.57)***	(2.21)**	(2.97)***	(3.59)***	(3.61)***	(3.23)***	(3.93)***
Fall prec sq	0.0257	−0.0203	−0.0098	−0.0271	−0.016	0.0479	0.0083	0.0184
	(6.47)***	(5.76)***	(3.47)***	(7.62)***	(4.88)***	(3.92)***	(2.53)***	(1.41)

Table 1. (*Continued*)

	Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil Crops	Sugar
Winter prec	−0.173	0.892	0.892	0.194	0.201	2.771	1.293	1.198
	(1.10)	(7.13)***	(8.12)***	(1.33)	(1.56)	(4.91)***	(9.92)***	(2.58)***
Winter prec sq	0.0694	−0.0603	−0.057	0.0582	−0.0051	−0.3558	−0.0946	0.0177
	(3.55)***	(4.20)***	(4.40)***	(3.45)***	(0.35)	(5.52)***	(6.22)***	(0.35)
Share of land areas with clay soil	−0.69	−0.913	−0.528	−0.382	−0.2	0.873	−0.39	0.801
	(5.09)***	(8.03)***	(5.14)***	(2.82)***	(1.66)*	(2.77)***	(3.36)***	(2.26)**
Share of land areas with silt soil	−0.243	−0.67	−0.026	0.055	0.706	−0.207	−0.194	−0.894
	(2.77)**	(5.82)***	(0.32)	(0.50)	(6.63)***	(1.20)	(1.97)*	(2.28)**
Plain (1 = Yes; 0 = No)	−0.0412	−0.0968	−0.0028	−0.0761	−0.3192	1.6194	−0.3589	0.6544
	(0.59)	(1.53)	(0.05)	(1.13)	(4.95)***	(9.59)***	(5.56)***	(4.20)***
Road (1 = Yes; 0 = No)	0.362	0.449	0.376	0.002	0.427	−0.222	0.2709	0.0917
	(3.03)***	(4.11)***	(3.81)***	(0.01)	(3.79)***	(1.07)	(2.42)**	(0.29)
Distance to township government	0.0115	−0.0098	−0.0091	−0.0021	0.0004	−0.0166	−0.0115	−0.0182
	(2.15)**	(1.86)*	(2.07)**	(0.39)	(0.09)	(1.39)	(2.18)**	(1.29)
Share of irrigated areas in village	0.00501	0.005	0.0007	−0.0014	−0.004	−0.0004	0.0014	0.006
	(6.40)***	(6.32)***	(1.05)	(1.64)	(4.77)***	(0.32)	(1.82)*	(2.48)**
If participating in a production association	0.076	0.074	−0.116	−0.291	0.278	1.052	0.162	−0.433
	(0.55)	(0.57)	(0.95)	(1.72)*	(1.96)*	(5.17)***	(1.22)	(1.12)
Share of labors without receiving education	0.0005	0.0016	0.001	0.0037	0.0022	0.0026	0.0034	−0.0033
	(0.38)	(1.28)	(0.94)	(2.60)**	(1.80)*	(1.13)	(2.79)**	(0.85)
Cultivated land area per household	0.232	−0.164	−0.0967	0.009	0.06	0.422	0.305	0.26
	(7.22)***	(3.84)***	(3.53)***	(0.31)	(1.98)*	(5.37)***	(10.05)***	(4.17)***
Constant	11.64	−4.21	0.92	−19.87	−1.68	27.2	2.74	−6.7
	(7.91)***	(1.93)*	−0.74	(9.67)***	(1.29)	(2.88)**	(1.92)*	(1.17)

Note: Absolute value of z statistics in parentheses. Maize is the omitted choice. There are 8405 observations. The LR chi2 of the regression is 13347 and the Pseudo R squared is 0.1034.

Table 2. Marginal effect of climate change on crop choice.

	Change of probability of choosing crops								
	Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil crops	Sugar	Maize
Temperature (°C)									
Spring	−0.73	4.17	0.67	−1.61	−1.16	−1.13	−2.99	0.02	2.76
Summer	1.72	−5.27	−3.39	1.27	−1.34	8.60	2.25	0.09	0.09
Fall	−2.93	6.57	0.40	−2.54	0.05	−0.63	−3.38	−0.66	−0.66
Winter	1.57	−4.53	−1.43	1.77	0.73	−0.56	4.45	0.91	0.91
Annual	−0.37	0.94	−3.75	−1.11	−1.72	6.28	0.33	0.36	3.10
Precipitation (mm/mo)									
Spring	0.27	0.06	−0.17	0.00	0.08	0.08	−0.17	0.00	−0.16
Summer	5.56	−0.67	−1.27	−0.50	−1.16	−0.19	−0.64	−0.05	−0.05
Fall	−0.18	0.16	0.06	−0.08	0.06	−0.07	0.04	−0.05	−0.05
Winter	−0.38	0.01	0.24	0.16	−0.26	0.38	0.36	0.14	0.14
Annual	5.27	−0.44	−1.14	−0.42	−1.36	0.20	−0.41	0.04	−0.12

Note: The marginal effects reported are the mean marginal effects across the sample calculated using the coefficients from Table 1 and the climate at each observation.

Climate change scenarios

- Three GCM models:
  - PCM, HADCM3, CCM2
  - SRES A2 scenario
- Temperature change (national average):
  - PCM: +3.0°C
  - HADCM3: +4.9°C
  - CCM2: 5.2°C
- Precipitations change (national average):
  - PCM: +10%
  - HADCM3: +23%
  - CCM2: +5%

Table 3. Change in crop choice for China assuming uniform national climate change but alternative seasonal changes.

	Uniform climate change every season			Seasonal climate change		
	PCM	HADCM3	CCM2	PCM	HADCM3	CCM2
Wheat	3.35	4.81	8.38	11.85	−4.09	26.88
Rice	0.24	−0.34	−5.05	−6.26	−9.80	−9.43
Vegetable	−3.80	−6.22	−7.04	−1.37	−8.90	−3.26
Soybean	−2.09	−3.33	−3.84	−0.82	−5.69	−2.80
Potato	6.02	12.45	16.73	−3.14	58.03	−6.91
Cotton	−0.60	−1.10	−0.98	6.79	−5.60	5.47
Oil Crops	−0.18	−0.26	−0.26	0.06	−0.33	0.33
Sugar	−2.63	−4.89	−7.00	−3.55	−15.01	−6.87
Maize	−0.31	−1.12	−0.95	−3.56	−8.61	−3.41

Note: Analysis compares climate change between 1990–2000 and 2090–2100, using SRES A2 emission scenario. Data for each climate model is available at http://cera-www.dkrz.de/CERA/index.html.

Table 4. Regional change in crop choice based on uniform annual national forecast.

Model	Temp Δ (°C)	Precip Δ (%)	Percentage change of probability of crop								
			Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil crops	Sugar	Maize
Northeast											
PCM	2.95	10.42	8.61	2.21	−8.00	−3.34	1.75	−0.62	−0.16	−2.99	2.55
HADCM3	4.92	23.43	12.46	−0.27	−13.34	−6.36	30.08	−2.49	−0.20	−12.25	−7.63
CCM2	5.19	6.84	6.72	−3.73	−14.99	−7.39	55.64	−3.25	−0.20	−16.93	−15.88
Southeast											
PCM	2.95	10.42	2.59	−2.98	−3.52	−0.22	−0.23	4.08	−0.16	−0.48	0.91
HADCM3	4.92	23.43	4.08	−5.44	−5.50	−0.65	−0.32	7.20	−0.26	−0.56	1.45
CCM2	5.19	6.84	8.59	−11.44	−5.95	−0.68	−0.24	10.50	−0.23	−2.95	2.40
Middle											
PCM	2.95	10.42	−0.38	0.74	−3.57	−0.57	0.06	2.81	−0.64	0.74	0.81
HADCM3	4.92	23.43	−2.61	1.76	−5.71	−0.80	−1.27	5.68	−0.97	2.43	1.50
CCM2	5.19	6.84	4.75	−5.72	−6.81	−2.06	5.82	5.60	−0.88	−2.31	1.61
Northwest											
PCM	2.95	10.42	7.49	0.15	−1.07	−4.61	8.41	−3.96	−0.46	−3.81	−2.15
HADCM3	4.92	23.43	6.65	−0.11	−2.56	−7.29	28.50	−7.40	−0.59	−9.37	−7.83
CCM2	5.19	6.84	5.18	−0.43	−3.21	−8.00	36.64	−8.04	−0.60	−11.05	−10.49
Southwest											
PCM	2.95	10.42	−0.58	−0.96	−0.56	−1.73	0.00	1.29	−0.04	−0.15	2.72
HADCM3	4.92	23.43	−0.02	−2.08	−2.51	−3.67	0.00	2.92	−0.08	−0.02	5.45
CCM2	5.19	6.84	−0.31	−5.47	−0.82	−2.59	0.00	3.78	−0.01	−0.72	6.15

Note: A2 emission scenario for 2100. Assumes same climate change in each season and each region.

Table 5. Regional change in crop choice based on regional and seasonal variation in climate forecast.

Model	Temp Δ (°C)	Precip Δ (%)	Percentage change of probability of crop								
			Wheat	Rice	Vegetable	Soybean	Potato	Cotton	Oil crops	Sugar	Maize
Northeast											
PCM	2.92	15.64	10.03	−0.43	−4.82	−3.38	1.92	0.87	−0.13	−4.66	0.59
HADCM3	5.07	34.68	0.94	−5.89	−16.13	−8.52	82.75	−4.55	−0.21	−22.17	−26.24
CCM2	5.05	6.68	18.95	−6.98	−11.96	−7.33	48.91	0.65	−0.13	−20.24	−21.88
Southeast											
PCM	2.09	11.45	−0.49	3.97	−2.10	−0.98	−0.39	−0.37	−0.13	0.01	0.47
HADCM3	4.09	24.6	1.04	−2.44	−3.80	−0.03	−0.37	6.64	−0.09	−0.20	−0.76
CCM2	4.67	8.24	−0.39	−6.30	2.19	−1.58	−0.41	−1.33	1.09	2.65	4.08
Middle											
PCM	2.59	13.87	−1.15	2.21	0.71	0.27	−12.29	5.77	0.71	3.92	−0.16
HADCM3	4.8	26.03	−6.94	−13.24	−9.49	−6.23	68.24	−9.66	−1.34	−16.05	−5.29
CCM2	5.54	8.13	3.02	−9.14	−1.56	−0.81	−13.62	12.16	4.36	3.47	2.12
Northwest											
PCM	3.36	10.77	10.34	−1.02	−0.99	−6.70	27.10	0.82	−0.21	−12.26	−17.08
HADCM3	5.37	14.55	−11.15	−1.14	−4.41	−9.71	79.29	−11.27	−0.64	−18.46	−22.50
CCM2	5.8	9.91	21.84	−0.85	−2.94	−8.31	24.91	−6.64	−0.45	−13.09	−14.46
Southwest											
PCM	2.51	6.36	−0.57	−3.31	1.84	0.62	0.00	−0.65	0.19	−0.93	2.82
HADCM3	4.57	26.69	−4.09	4.16	−4.28	−3.07	0.00	−0.67	−0.15	−1.62	9.73
CCM2	4.32	−4.46	−2.24	−8.07	5.70	−4.24	0.00	6.49	2.44	4.72	−4.81

Note: A2 scenario for 2100. Assumes different changes in each region and each season.

Summary

- Farmers choose crops (also) in response to climate
- Quadratic response functions:
  - There is an optimal climate for each crop
  - Climate change impacts depend on present and future climate
- It is possible to estimate climate marginal effects
- The adaptations are region-specific
  - Climate is different
  - Other socio-economic and geographic factors
- GCM scenarios show that planning adaptation is difficult:
  - Uncertain spatial distribution
  - Uncertain distribution over seasons

Part 3

Case study:
Irrigation and farm income in Africa

Based on:

Kurukulasuriya, P., Kala, N., & Mendelsohn, R. (2011). Adaptation and Climate Change Impacts: A Structural Ricardian Model of Irrigation and Farm Income in Africa. Climate Change Economics, 2(02), 149-174.

Outline

- Irrigation is important
  - delivers the optimal amount of moisture to crops
  - mitigates the effect of high temperatures
- Irrigation choice is a function of climate
- However irrigation is also a function of other variables that might be correlated with climate
- Irrigation is an «endogenous» variable
  - This leads to biased estimates of climate coefficients

Sample selection models

- Self-selection: the outcome of interest [profits] is determined in part by individual choice of whether or not to participate in the activity of interest [irrigation]

- Solution: two-step estimation
  - first: choice of irrigation (yes or not)
  - second: two ricardian equations for each farm type

Data

- Household survey of farms in 11 countries across Africa
- Wide sample of climate within each country
- Representative of population
- 8,463 households, 10,880 plots (1,752 irrigated)
- For each household, plot specific data on:
  - irrigation
  - crop production
  - crop costs
  - yields per hectare
  - hectares of farmland

Problems with net revenues

- No formal land markets, no land values
- Net revenue per hectare

- Land values reflect long-term productivity of land.
- Net revenues reflect fluctuations in yields and both input and output prices.

- Farmers were asked if weather was “typical”

Other Data

- Monthly temperature data from US Department of Defense satellite observations from 1988-2003 (two observations per day)
- Monthly precipitations from Africa Rainfall and Temperature Evaluation System (ARTES)
- Soil data from FAO
- Elevation data from USGS
- Water flows from hydrological model for Africa (IWMI and University of Colorado)

Table 4. Marginal climate impacts.

Season	Irrigation	Choice	Model
	Temperature	Precipitation	Flow
Winter	0.0627	−0.000528	−0.445
	(0.1721)	(0.004779)	(1.707)
Spring	−0.0946	−0.001643	0.273
	(0.1808)	(0.004412)	(1.543)
Summer	0.0133	0.001383	−0.181
	(0.1548)	(0.003324)	(0.300)
Fall	0.0291	−0.000308	0.172
	(0.1901)	(0.002991)	(0.275)

Season	Conditional income — Irrigated farms		Conditional income — Dryland farms	
	Temperature	Precipitation	Temperature	Precipitation
Winter	42.0	11.43	48.9	−1.85
	(174.6)	(6.84)	(53.8)	(1.14)
Spring	−132.8	−4.98	−95.8	3.07
	(206.7)	(6.78)	(89.6)	(1.06)
Summer	301.0	7.43	68.3	0.81
	(335.6)	(5.52)	(69.2)	(0.77)
Fall	−274.1	−8.26	−32.2	1.09
	(419.5)	(5.11)	(58.1)	(0.62)

Note: Marginal effects calculated from Table 2 and "corrected coefficients" in Table 3 mean African climate.

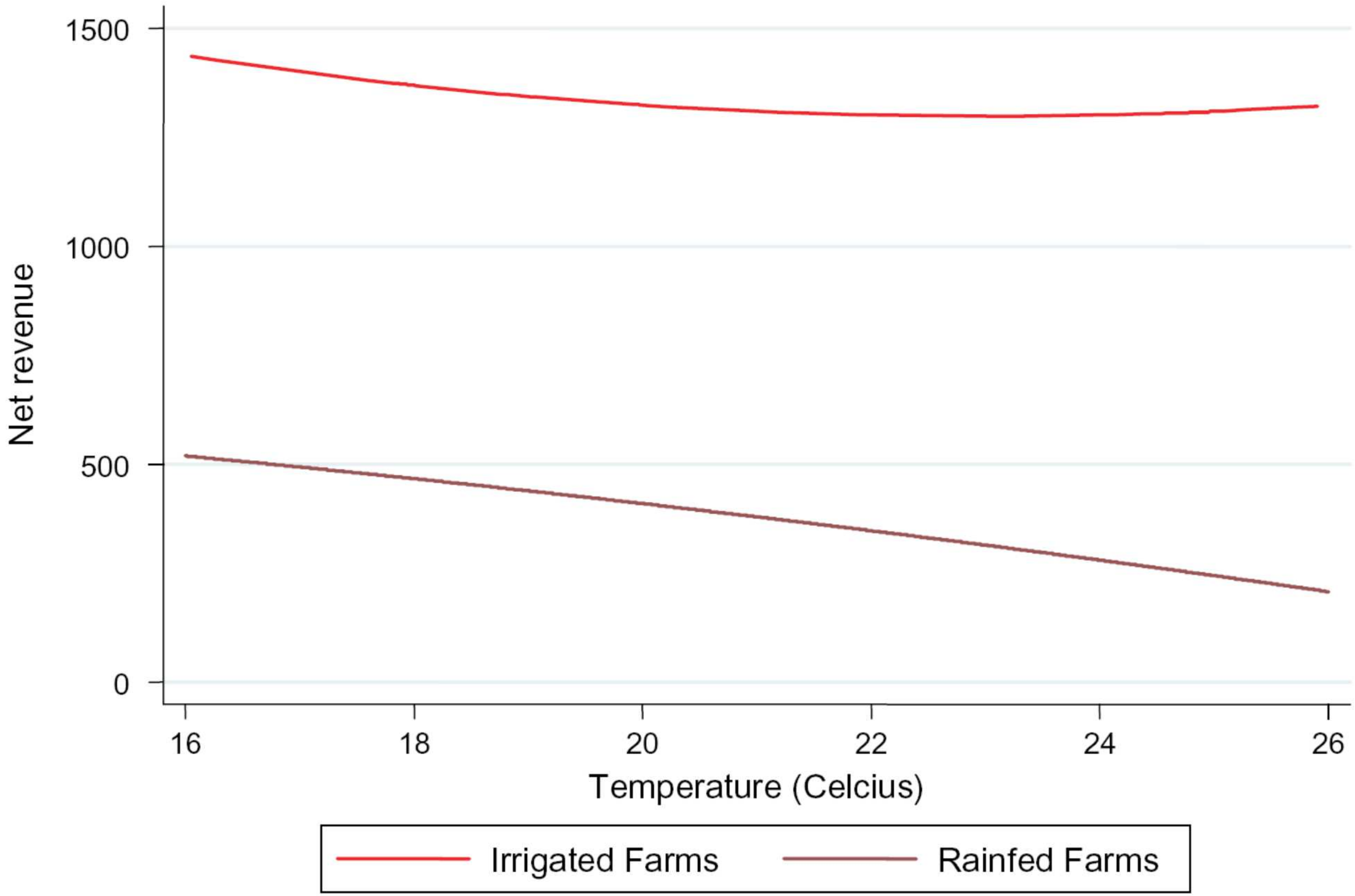
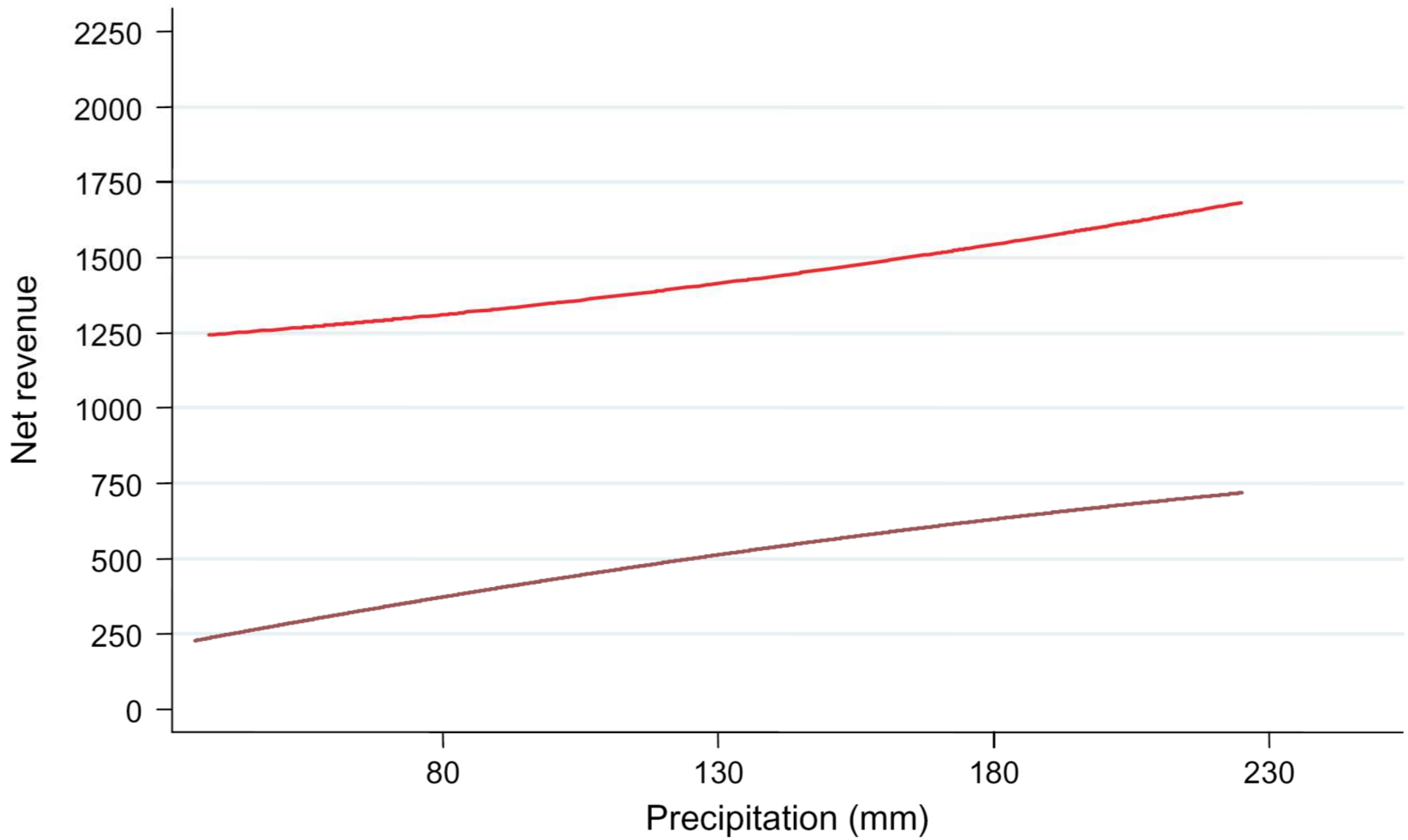


Figure 1. Temperature response functions of irrigated and rainfed farms.



2250
2000
1750
1500
1250
1000
750
500
250
0
Net revenue
80
130
180
230
Precipitation (mm)

Table 7. African climate change forecasts by model.

Season	PCM	CCSR	CCC
Temperature			
Winter	1.72	2.24	5.53
Spring	1.78	3.02	5.17
Summer	1.76	2.60	4.87
Fall	1.49	1.50	5.20
Precipitation			
Winter	1.08	1.07	1.51
Spring	0.98	0.70	1.57
Summer	1.02	1.36	0.87
Fall	0.95	1.55	0.86

Note: Temperature change measured in additional Celsius above current and precipitation change is measured as ratio of future divided by current precipitation. Separate estimates are made for each country.

Adaptation to climate change

- PCM model:
  - Low temperature increase,
  - Irrigation as today: +9% profits
  - Irrigation expands: +35% profits

- CCSR and CCC:
  - Much higher temperatures
  - Large losses

Part 3

Case study:

Adaptation in animal farms in Latin America

Based on:

Seo, S. N., McCarl, B. A., & Mendelsohn, R. (2010). From beef cattle to sheep under global warming? An analysis of adaptation by livestock species choice in South America. Ecological Economics, 69(12), 2486-2494.

Motivation

- Recent literature finds that
  - Animal husbandry in Africa is highly climate sensitive
  - African farmers adjust portfolio of livestock species to climate
  - A hotter and drier climate would cause a shift from crops to livestock
- South America:
  - Large beef cattle exports
  - Large per capita meat consumptions
  - Pastureland 4/8 times more than cropland
  - 15% farms specialize in animals

Overview

- Household surveys from 7 countries:
  - Argentina, Brazil, Uruguay, Chile, Ecuador, Colombia, and Venezuela
  - Large variety of climates and ecological regions
- 1300 farm surveys from producers who own some livestock
- Estimate farm type
- Multinomial logit choice model of the five primary livestock species:
  - beef cattle, dairy cattle, pigs, sheep, and chickens

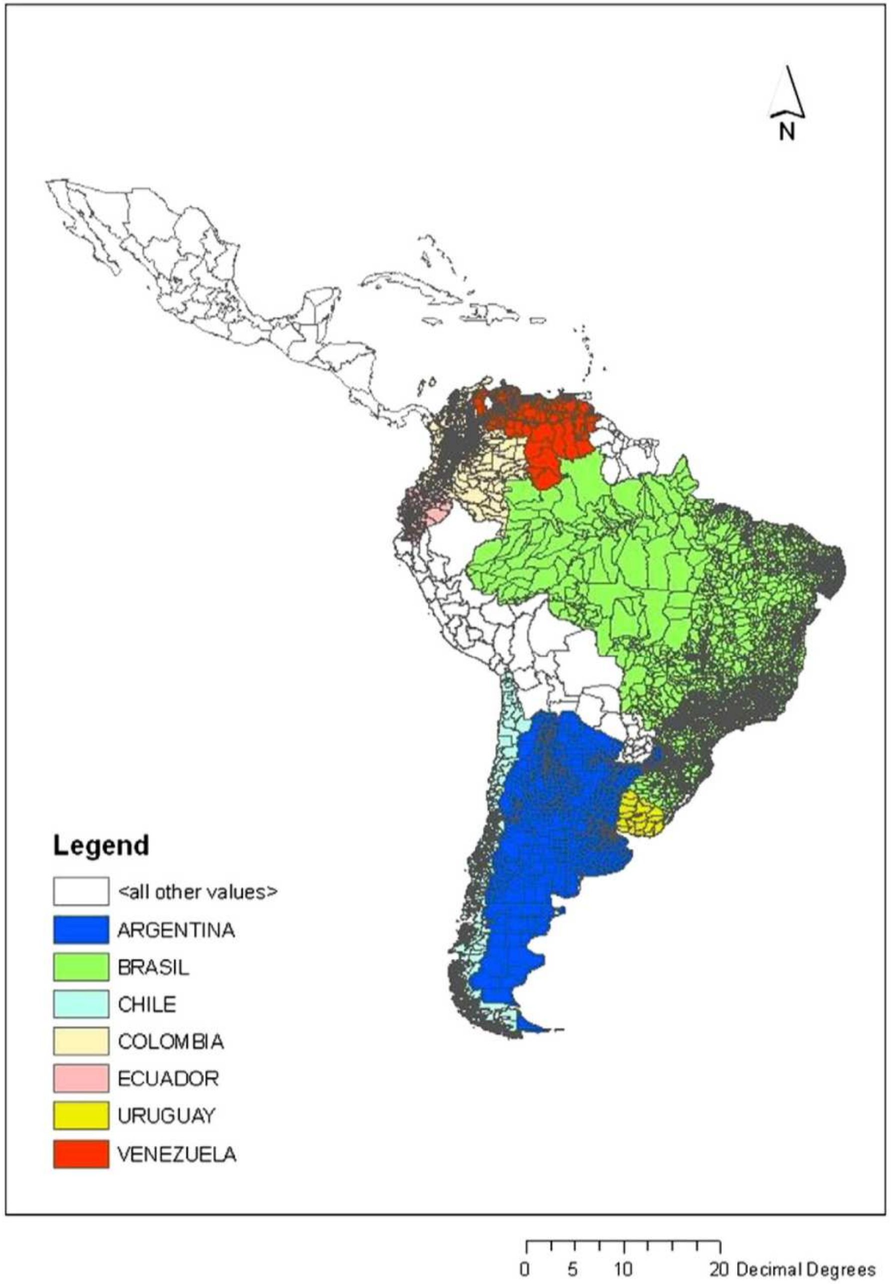


Fig. 1. Countries where Latin American sample was taken.

Farm type

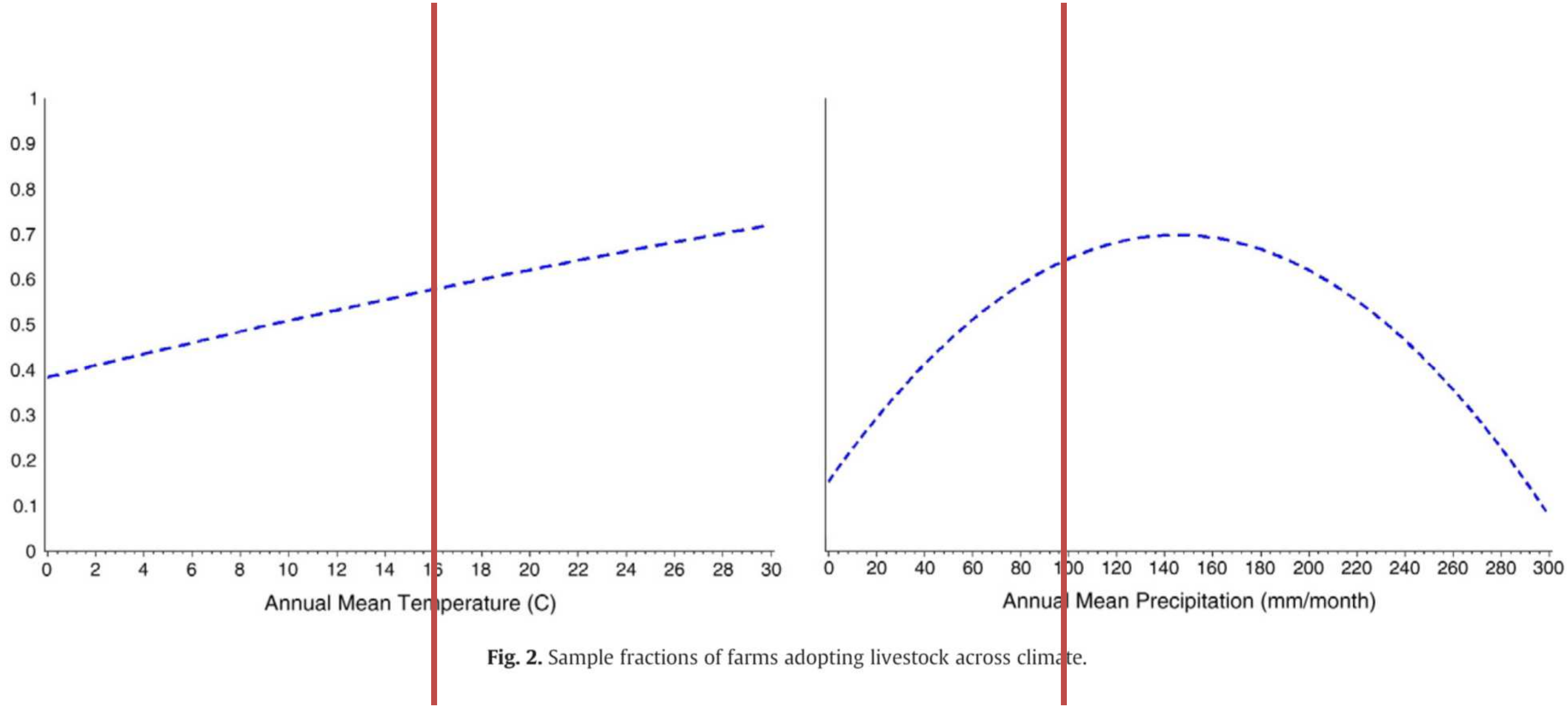
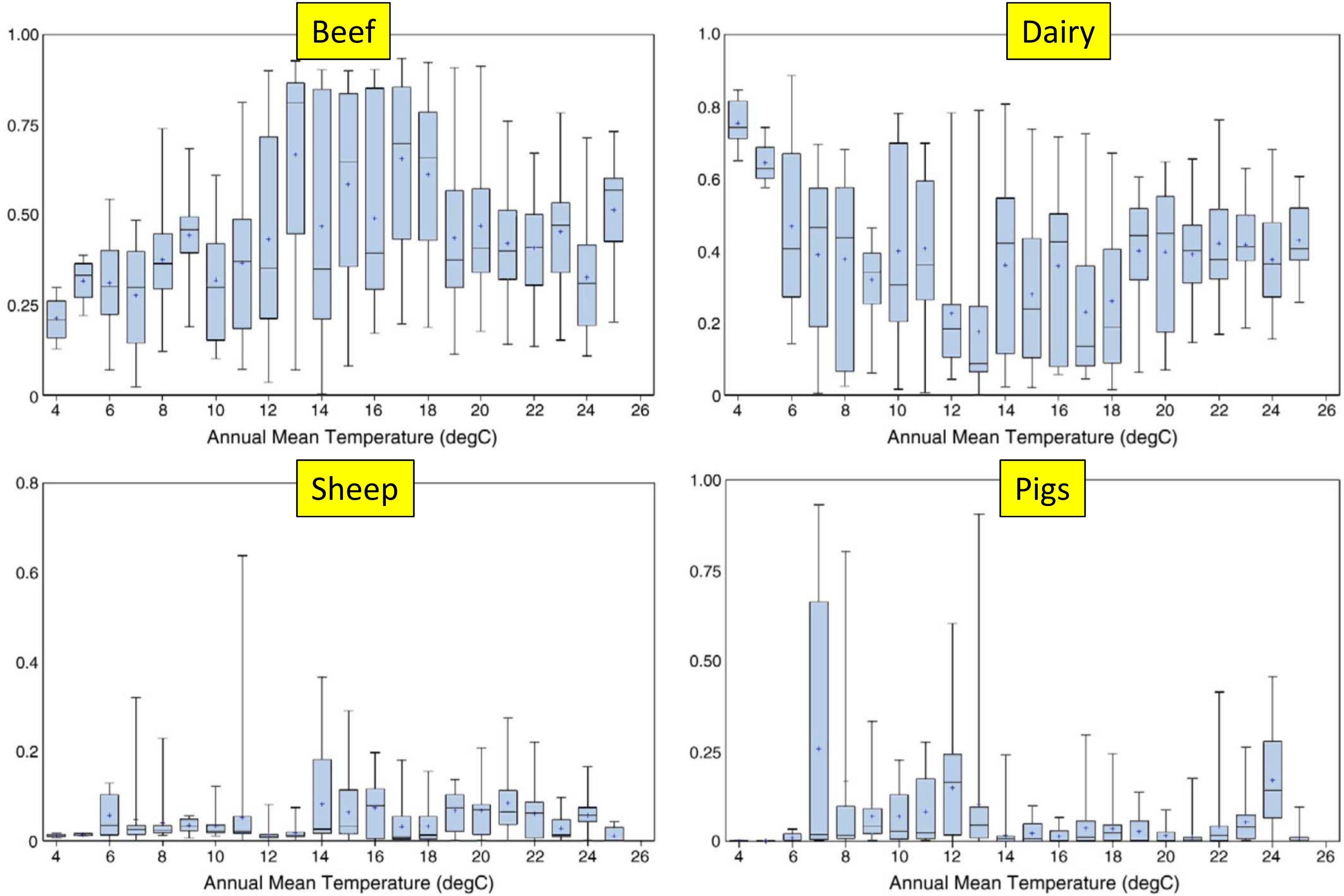


Fig. 2. Sample fractions of farms adopting livestock across climate.

Average temperature and precipitations across all countries



3. Estimated probability for adopting primary species across temperature (clockwise: beef, dairy, sheep, and pigs). Note: the lower and upper ends of each box plot show the ‹imum and the minimum, the box represents the lower and upper 2.5 percentiles, the middle bar in the box is the median, and the star represents the mean.

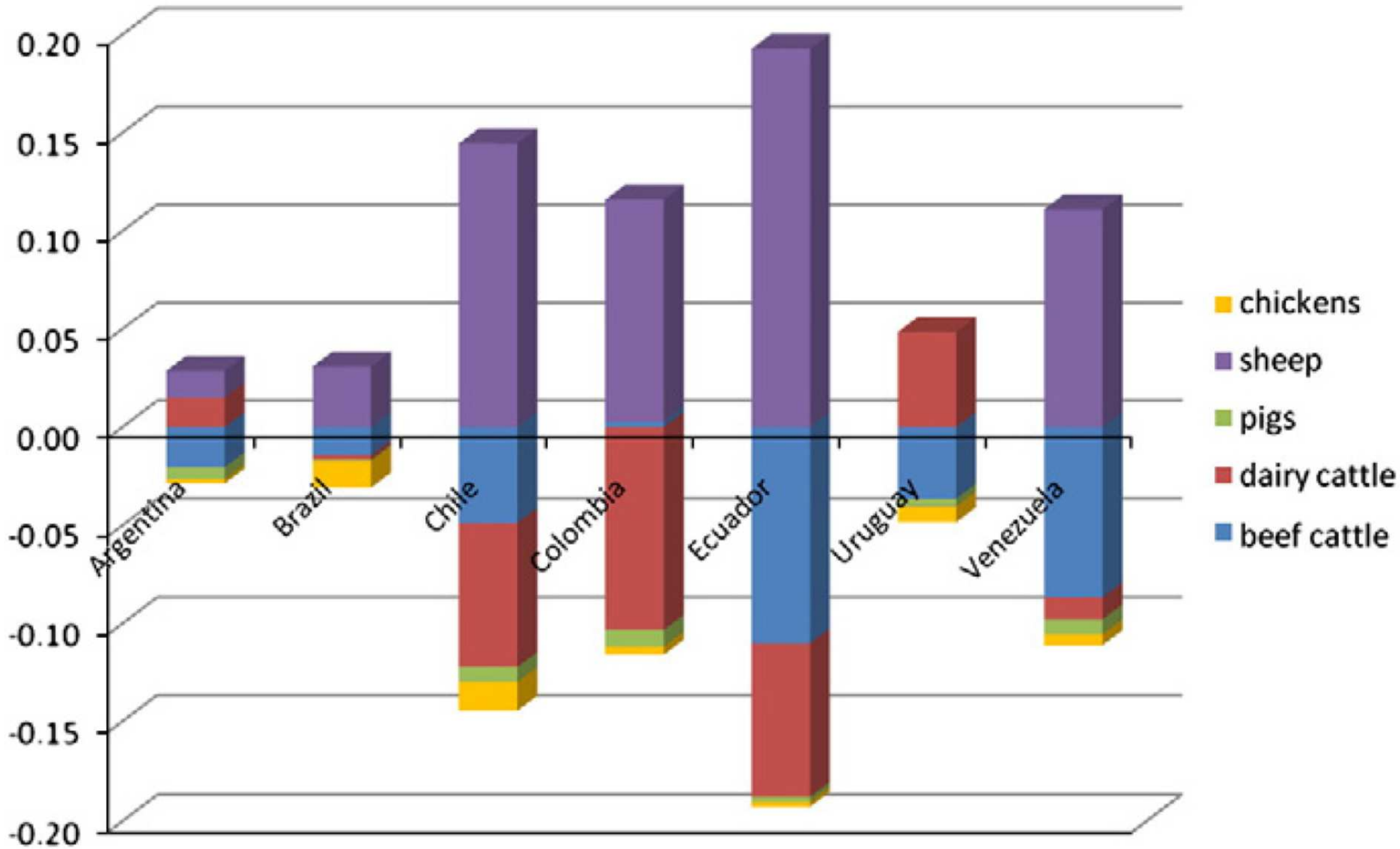
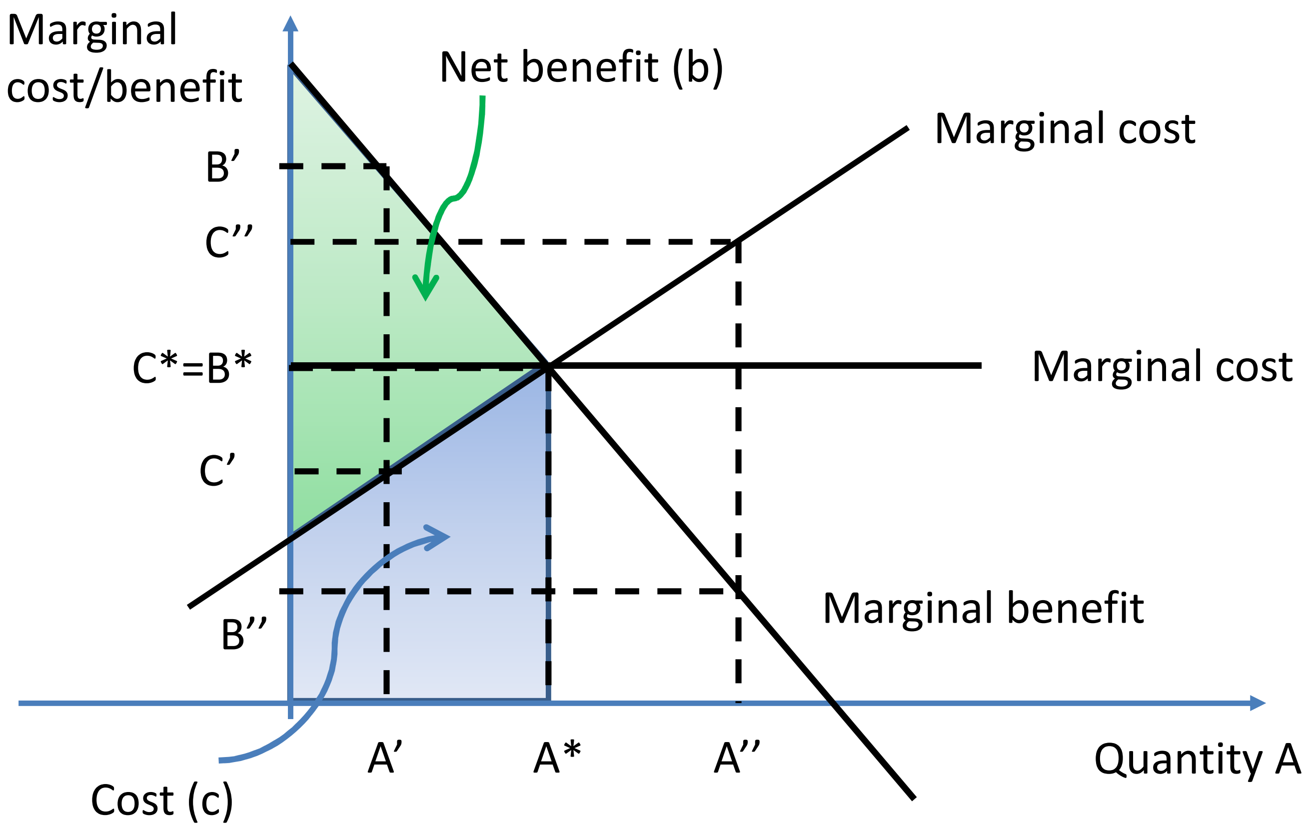


Fig. 5. Changes in the estimated probability to choose a primary livestock species by country under CCC the scenario.

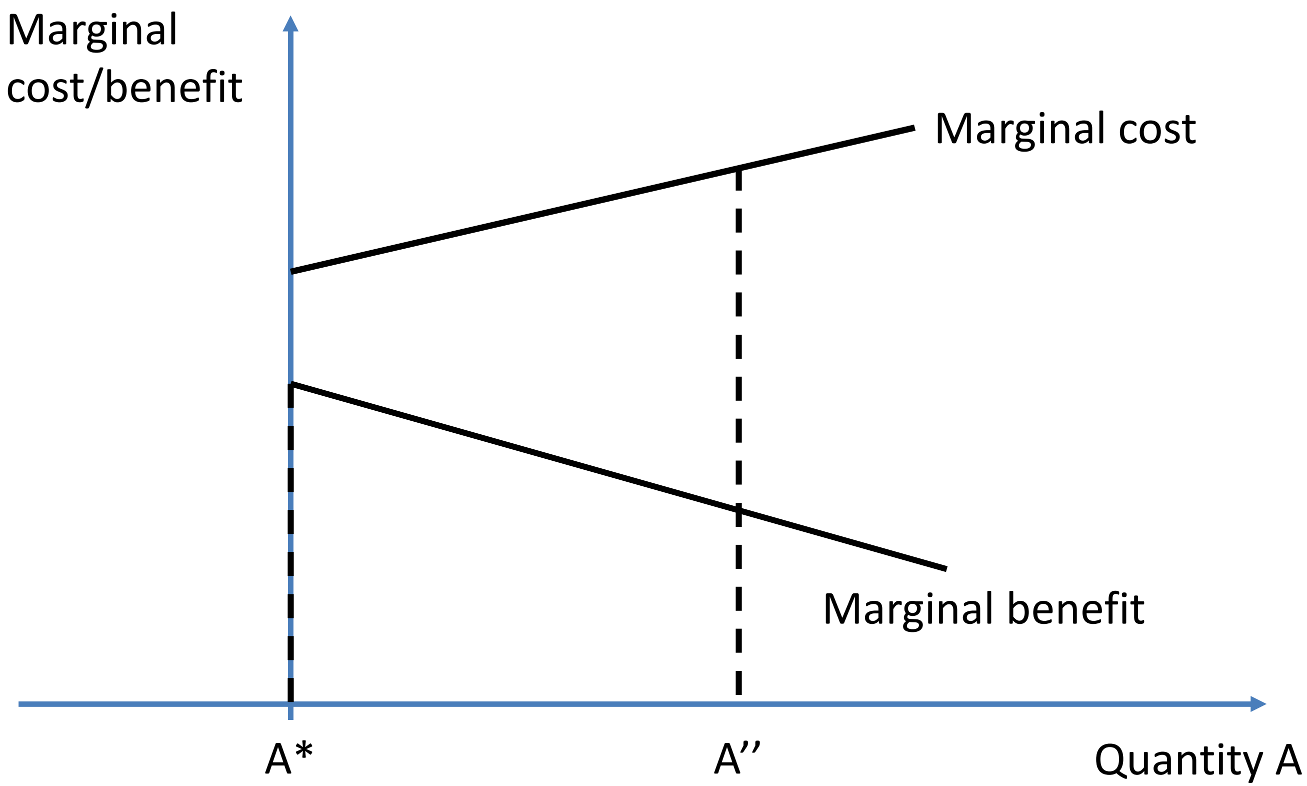
Summary

- There is evidence that farmers in developing countries have adapted to climate
- With climate change the optimal mix of crops and inputs will change
- Farmers are likely to adapt to future climate change, given present constraints
- Limiting present constraints to adaptation will likely increase future adaptation capacity
- Forecasting farmers' choices helps to remove future constraints

Farmers' choices / 1



Consumers' and firms' choices / 2



- Optimal action is... inaction