

The influence of climate change on crop and livestock choices in Mexico



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Outline

1 Motivation

2 Literature

3 Methods and materials

4 Results

5 Conclusions

Motivation: food supply



Figure: Mexico produces 27 and 1.91 million tonnes of maize and beef. People in Mexico consume 85 (233 grammes) and 15 kilograms of tortilla and beef per capita per annum.



Figure: Changes in temperature and rainfall are predicted to range between 1.73°C and 3.56°C and -5.54% - -9.33% respectively.

Will climate change influence farmers' production decisions?

At points *b*, *d*, and *g*, each farmer can move their production efforts to a more profitable activity or continue with the same activity and loose potential profits (adapted from Mendelsohn and Dinar, 2009):

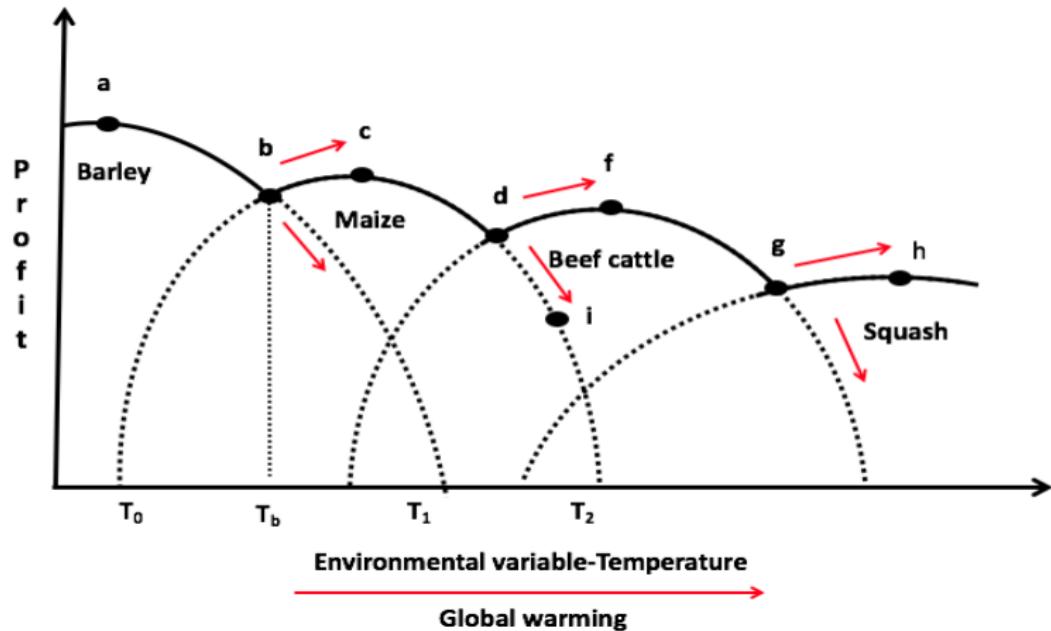
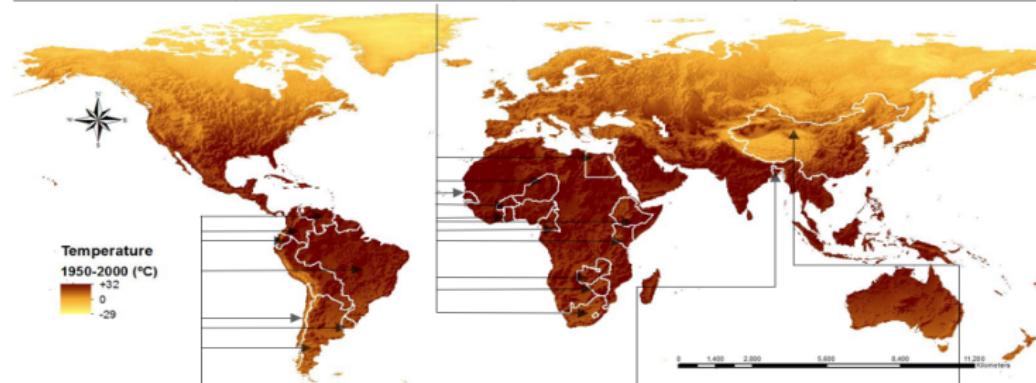


Figure: Profit-value function

Seo and Mendelsohn (2007)	Seo et al. (2008b)	Kurukulasuriya and Mendelsohn (2008)	Hassan and Nhémachena (2008)	Seo et al. (2008a)
↑ <u>Temperature</u>	↑ <u>Temperature</u>	↑ <u>Temperature</u>	↑ <u>Temperature</u>	↑ <u>Temperature</u>
↓ beef, dairy cattle, and chickens	↓ crop-only rainfed	↓ cowpea, maize-beans, fruits and vegetables	↓ mono-cropping	↓ wheat, maize, millet-groundnuts, millet sorghum
↑ goats, sheep	↑ mixed-irrigated	↑ millet-groundnut	↑ multiple cropping, mixing crop and livestock	↑ fruits-vegetables, fruits-vegetables-maize, millet, groundnut-maize
↑ Rainfall	↑ Rainfall	↑ Rainfall	↑ Rainfall	↑ Rainfall
↓ beef, dairy cattle, and sheep	↓ crop-only irrigated, mixed-irrigated, livestock-only	↓ maize-millet, sorghum and millet-groundnut	↓ mono-cropping	↓ groundnut-millet and maize
↑ goats, chickens	↑ crop-only rainfed	↑ cowpea, cowpea-sorghum	↑ dryland crop systems	↑ fruits-vegetables-maize, maize-groundnut and millet



Seo and Mendelsohn (2008)	Seo et al. (2010)	Moniruzzaman (2015)	Wang et al. (2008)
↑ <u>Temperature</u>	↑ <u>Temperature</u>	↑ <u>Temperature</u>	↑ <u>Temperature</u>
↓ maize and wheat	↓ beef cattle and chickens	↓ Aman	↓ rice, vegetables, soybeans, potatoes, sugar
↑ potatoes, rice, soybeans, fruits	↓ dairy cattle, pigs, sheep	↑ Boro and Aus	↑ cotton, wheat, oil crops and maize
↑ Rainfall	↑ Rainfall	↑ Rainfall	↑ Rainfall
↓ maize, wheat and fruits	↓ beef cattle and sheep	↓ Boro	↓ maize, wheat and potatoes
↑ potatoes, rice and squash	↑ dairy cattle, chickens	↑ Aman	↑ rice, cotton, vegetables, soy, oil crops, sugar

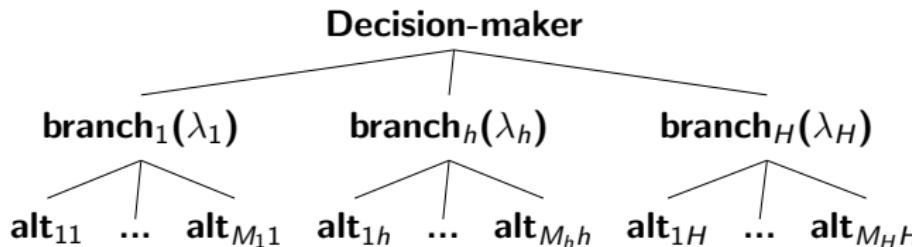
Identification strategy: across space rather than time

Contributions

- We test the validity of the IIA property and estimate a NL model grouping close substitutes (maize, beans, beef cattle),
- Plot-level rather than farm-level data: not only the 'main' crop grown or 'most prevalent' type of livestock raised (superior database: observations and alternatives),
- We use expected farm gate (own) prices rather than ex-post prices.

Nested Logit

Assuming that the elements in $\{\varepsilon_{i1}, \dots, \varepsilon_{iJ}\}$ follow a GEV distribution and the IIA holds within groups of alternatives but not between them, then we can group similar alternatives:



$$Pr_{hm} = Pr_h * Pr_{m|h} = \frac{e^{(z' \alpha_h + \lambda_h I_h)}}{\sum_{l=1}^H e^{(z' \alpha_l + \lambda_l I_l)}} * \frac{e^{((\tilde{z}' \beta_{mh}) / \lambda_h)}}{\sum_{o=1}^{M_h} e^{((\tilde{z}' \beta_{oh}) / \lambda_h)}} \quad (1)$$

choice among branches choice among alternatives

The alternative with the highest expected profit at the beginning of the agricultural year is chosen.

Nested Logit

The relationship between the bottom and top equations is captured by the *inclusive value* term(s), or I_h in equation 1 which is defined as:

$$I_h = \ln\left(\sum_{o=1}^{M_h} e^{(\tilde{z}' \beta_{oh})/\lambda_h}\right) \quad (2)$$

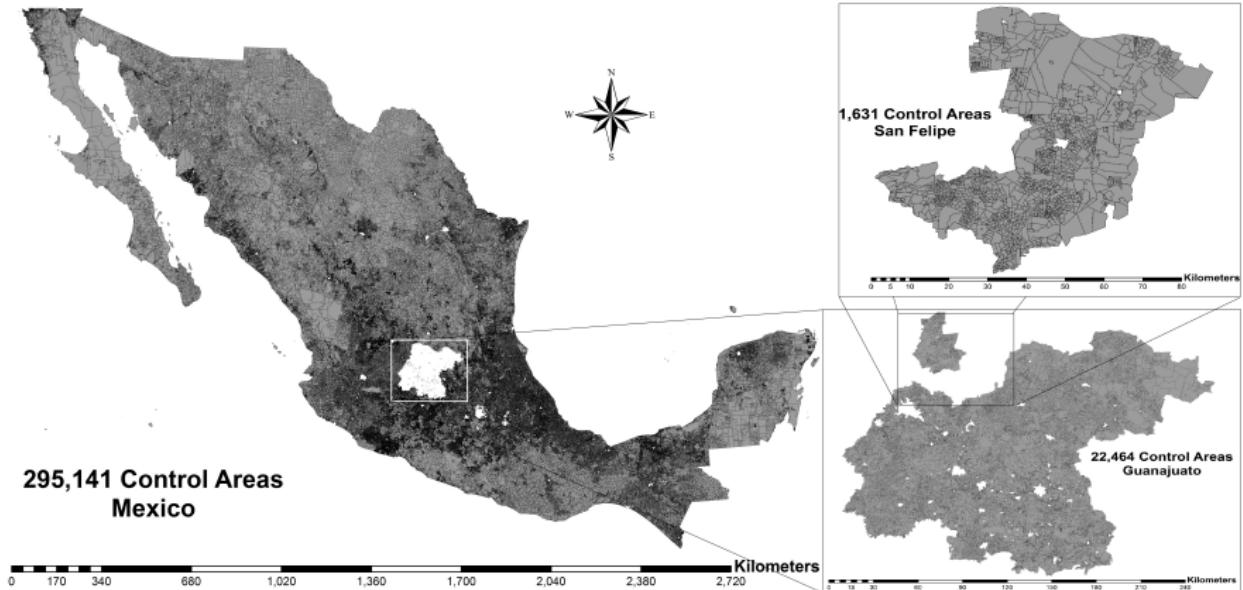
where λ_h is the (dis)similarity parameter of branch h , and if:

- $\lambda_h = 1$: the NL is equivalent to the MNL model
- $0 < \lambda_h < 1$: consistent with maximisation behaviour
- $\lambda_h = \sqrt{1 - \text{cor}(\varepsilon_{ijh}, \varepsilon_{ifh})}$
- $\lambda_h > 1$: consistent for certain values of the explanatory variables
(alternatives in h should not share the same nest)
- $\lambda_h < 0$: inconsistent with maximisation behaviour
(choosing sets/limbs with lower expected profits)

Parameters in 1 can be estimated either simultaneously (FIML) or sequentially (LIML).

Data: GIS-databases

Figure: Agricultural areas in Mexico (CAs)



Identification across space not across time. INEGI provided us with the geographical location of 219,985 and 168,265 plots (2012 and 2014). Representative for the 31 major agricultural commodities.

Distribution of plots

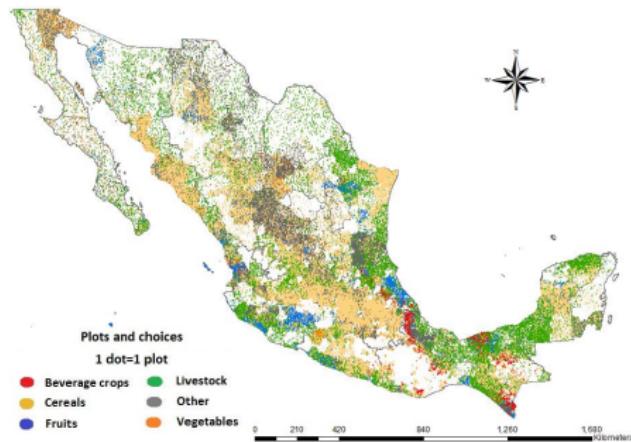


Figure: Plots and choices 2012
219,985 plots and 77,758 farms

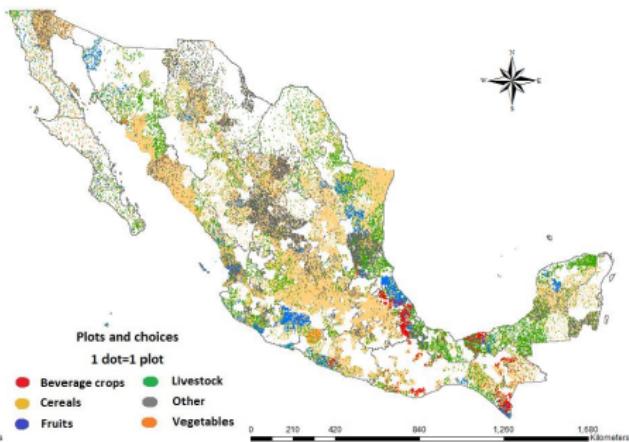


Figure: Plots and choices 2014
168,265 plots and 59,443 farms

Figure: Aggregated MNL model (8 alternatives)

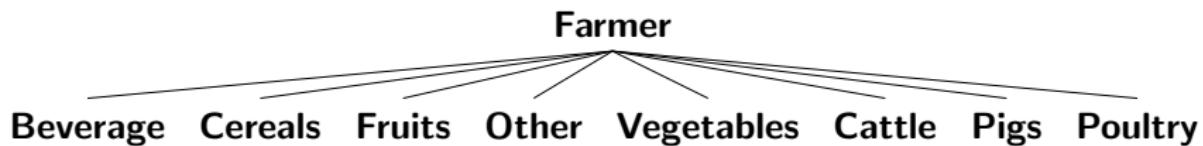


Figure: Aggregated NL model (8 alternatives)

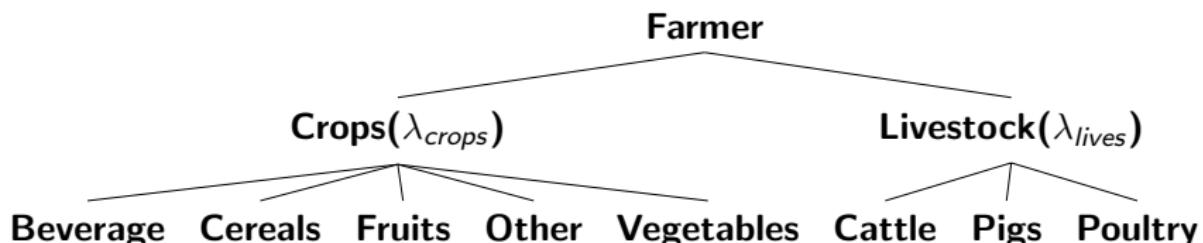


Figure: Disaggregated MNL model (31 alternatives)

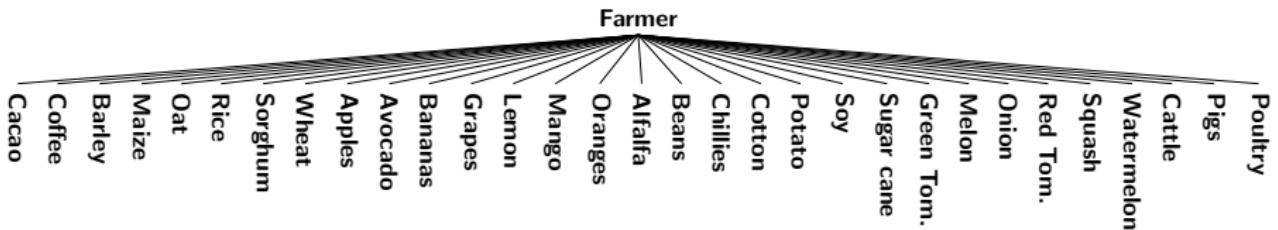


Figure: Disaggregated NL model (31 alternatives)

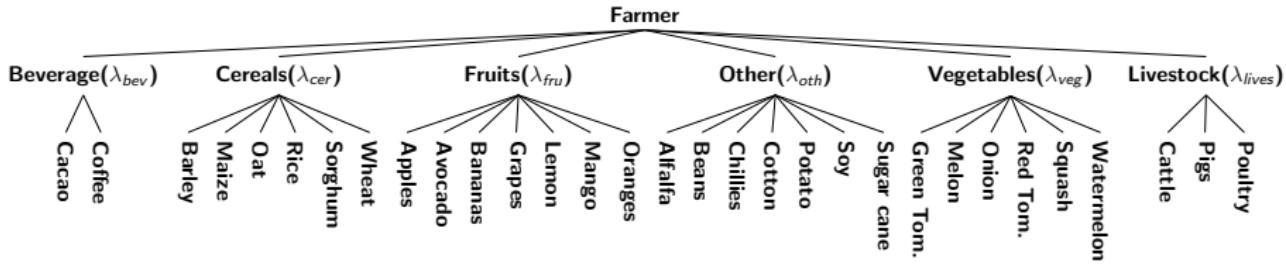


Table: MNL model 8 alternatives 2014 (base=cereals)

VARIABLES	beverage	cattle	cereals	fruits	other	pigs	poultry	vegetables
Climate								
Temperature	3.4765*** (0.1580)	0.7134*** (0.0573)		-0.2828*** (0.0511)	0.4867*** (0.0656)	-0.0464 (0.4124)	0.8206** (0.3287)	0.1770 (0.3192)
Temperature sq.	-0.0833*** (0.0036)	-0.0155*** (0.0014)		0.0086*** (0.0013)	-0.0121*** (0.0017)	0.0007 (0.0089)	-0.0182** (0.0079)	-0.0013 (0.0085)
Rainfall	0.0650*** (0.0029)	0.0237*** (0.0017)		0.0210*** (0.0025)	-0.0051*** (0.0019)	0.0565*** (0.0202)	0.0370*** (0.0126)	-0.0040 (0.0066)
Rainfall sq.	-0.0001*** (0.0000)	-0.0000*** (0.0000)		-0.0001*** (0.0000)	0.0000*** (0.0000)	-0.0004*** (0.0001)	-0.0001** (0.0000)	-0.0001 (0.0000)
Diurnal	-0.1950*** (0.0233)	-0.0971*** (0.0130)		-0.1586*** (0.0135)	-0.0165 (0.0114)	-0.2057 (0.1518)	0.0950 (0.0915)	-0.1035*** (0.0339)
Output prices								
Price beverage	-0.0030** (0.0014)							
Price cattle		-0.0049*** (0.0016)						
Price fruits			0.0083*** (0.0012)					
Price other				0.0156*** (0.0024)				
Price pigs					-0.0173*** (0.0055)			
Price poultry						0.0178 (0.0132)		
Price vegetables							0.0011 (0.0039)	
Observations	168,265	168,265	168,265	168,265	168,265	168,265	168,265	168,265

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

Table: MNL model 8 alternatives 2014 (base=cereals)

VARIABLES	beverage	crops	cattle	cereals	fruits	other crops	pigs	poultry	vegetables
Inputs									
Wage rate	-0.0212*** (0.0027)	0.0015 (0.0017)		-0.0007 (0.0013)	0.0049*** (0.0010)	-0.0002 (0.0084)	-0.0110** (0.0055)	0.0028 (0.0035)	
Plot size	0.0025*** (0.0007)	0.0053*** (0.0002)		0.0015*** (0.0004)	-0.0010*** (0.0003)	0.0010 (0.0012)	0.0024*** (0.0009)	0.0006 (0.0006)	
Socio-demographic characteristics									
Age	0.0136*** (0.0024)	0.0220*** (0.0015)		0.0235*** (0.0022)	0.0033** (0.0014)	0.0126** (0.0053)	0.0258* (0.0133)	-0.0109*** (0.0039)	
Schooling	0.0163* (0.0085)	0.0363*** (0.0052)		0.0422*** (0.0069)	0.0145** (0.0062)	-0.0018 (0.0256)	0.0210 (0.0322)	-0.0167 (0.0141)	
Indigenous	-0.6365*** (0.0750)	-0.5494*** (0.0538)		0.1884*** (0.0533)	-0.2409*** (0.0508)	-0.0280 (0.2029)	-0.1796 (0.3182)	-0.2577*** (0.1298)	
Access to markets									
Mobile	-0.4293*** (0.0944)	0.3982*** (0.0426)		0.3575*** (0.0563)	0.4716*** (0.0386)	0.7296*** (0.1723)	0.0482 (0.2733)	0.0358 (0.1602)	
Internet	-0.1120 (0.2225)	-0.2407** (0.1128)		0.2531** (0.1122)	0.0272 (0.1029)	2.0255*** (0.2980)	1.8171*** (0.4264)	0.9249*** (0.1439)	
City	-0.0477*** (0.0047)	0.0260*** (0.0026)		-0.0400*** (0.0038)	0.0026 (0.0020)	-0.0387** (0.0151)	0.0101 (0.0174)	0.0190** (0.0089)	
Road density	1.0416*** (0.1188)	-1.3231*** (0.1501)		-1.3930*** (0.1245)	-1.8169*** (0.1259)	-0.9387*** (0.2850)	0.2801 (0.4614)	-0.0616 (0.3187)	
Subsidies									
Procampo	-0.9643*** (0.0739)	-0.9449*** (0.0481)		-1.3593*** (0.0603)	-0.4271*** (0.0683)	-2.6778*** (0.2958)	-1.9653*** (0.3387)	-1.1041*** (0.1225)	
Progan	-0.3611** (0.1573)	1.7208*** (0.0500)		-0.8660*** (0.1164)	-0.2430*** (0.0623)	-0.0727 (0.3191)	-0.0015 (0.4492)	-1.2501*** (0.1898)	
Constant	-39.8933*** (1.8406)	-10.5467*** (0.6515)		-1.1379* (0.6063)	-7.5437*** (0.5467)	-0.7931 (8.4130)	-22.1503*** (5.6576)	-4.0001 (2.4577)	
Observations	168,265	168,265	168,265	168,265	168,265	168,265	168,265	168,265	168,265

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

Table: Hausman tests 2012 and 2014

Equation	Exclusion (2012)						
	Beverage	Cattle	Fruits	Other	Pigs	Poultry	Vegetables
Beverage	-	199.64***	321.28***	904.56***	28.38	33.25**	156.22***
Cattle	302.20***	-	719.05***	1,039.07***	41.42***	35.95**	149.12***
Fruits	322.05***	361.58***	-	1,038.79***	44.88***	30.37*	139.32***
Other	199.19***	332.15***	357.54***	-	55.02***	35.30**	135.57***
Pigs	88.28***	136.33***	86.73***	173.80***	-	13.24	72.46***
Poultry	47.44***	103.55***	92.73***	108.04***	16.59	-	43.31***
Vegetables	87.17***	180.04***	201.54***	301.63***	26.61	25.49	-

Equation	Exclusion (2014)						
	Beverage	Cattle	Fruits	Other	Pigs	Poultry	Vegetables
Beverage	-	254.36***	291.06***	615.22***	30.08*	22.93	157.20***
Cattle	293.59***	-	757.25***	743.60***	74.24***	35.22**	88.91***
Fruits	296.66***	240.44***	-	911.37***	71.59***	28.70*	126.89***
Other	154.26***	320.35***	294.25***	-	65.45***	27.41	55.11***
Pigs	111.84***	41.67***	85.43***	240.95***	-	22.56	42.59***
Poultry	119.21***	94.58***	59.70***	177.10***	31.90**	-	62.38***
Vegetables	139.90***	167.82***	128.87***	119.04***	54.34***	18.97	-

Note: Hausman tests estimated via the suest command in Stata 14.2 (clusters at the farm level)

Null hypothesis: difference in coefficients not systematic

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

Chi2(d.f.): 20

Table: Dissimilarity parameters

Lambda parameters (λ_h)	All prices (cross and own)		Own-prices	
	2012	2014	2012	2014
8 alternatives (2 groups)				
Crops=Livestock	0.4852*** (0.0115)	0.4064*** (0.0123)	0.5160*** (0.0113)	0.4394*** (0.0112)
31 alternatives (6 groups)				
Beverage crops	0.4696*** (0.0121)	0.1249*** (0.0050)	0.5144*** (0.0131)	0.2797*** (0.0086)
Cereals	0.0497*** (0.0024)	0.0590*** (0.0040)	0.0595*** (0.0030)	0.0589*** (0.0039)
Fruits	0.1059*** (0.0030)	0.0501*** (0.0029)	0.0979*** (0.0028)	0.1033*** (0.0055)
Livestock	0.4832*** (0.0104)	0.3977*** (0.0108)	0.5225*** (0.0108)	0.4306*** (0.0110)
Other crops	0.0491*** (0.0087)	0.0435*** (0.0118)	0.0512*** (0.0100)	0.0864*** (0.0134)
Vegetables	0.1057*** (0.0370)	0.0363 (0.1143)	0.1426*** (0.0281)	0.1874 (0.2099)

Top-level: robust standard errors in parentheses using bootstrap

Clusters at the farm level and 400 replications

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

Climate change scenarios: MIROC5-2012

Table: Predicted probabilities 2061-2080 (2012-8 alternatives)

Choice	Baseline	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
		MNL	NL	MNL	NL	MNL	NL	MNL	NL
Beverage crops	1.51	0.89	2.14	0.72	1.91	0.68	1.88	0.53	1.65
Cattle	18.26	18.60	16.84	18.67	16.79	18.19	16.77	18.08	16.68
Cereals	54.03	53.40	39.50	53.24	39.37	53.70	39.48	53.57	39.34
Fruits	4.02	5.23	10.23	5.85	10.74	5.77	10.61	7.24	11.84
Other crops	19.53	18.81	21.98	18.29	21.53	18.39	21.56	17.16	20.48
Pigs	0.22	0.20	1.02	0.20	1.08	0.20	1.09	0.19	1.23
Poultry	0.20	0.20	0.82	0.19	0.82	0.20	0.81	0.18	0.77
Vegetables	2.24	2.67	7.47	2.84	7.78	2.87	7.79	3.04	8.02
Total	100	100	100	100	100	100	100	100	100
GCM: MIROC5	Temperature*	+1.66		+2.37		+2.29		+3.40	
	Rainfall*	-3.14%		-6.02%		-6.24%		-7.82%	

Average probabilities using data from 2012

*Average changes in the entire sample

Climate change scenarios: MIROC5-2014

Table: Predicted probabilities 2061-2080 (2014-8 alternatives)

Choice	Baseline	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
		MNL	NL	MNL	NL	MNL	NL	MNL	NL
Beverage crops	2.56	1.80	3.38	1.56	3.09	1.49	3.04	1.23	2.70
Cattle	11.88	11.81	9.75	11.89	9.74	11.43	9.71	11.36	9.69
Cereals	58.72	58.49	39.27	58.27	39.14	58.75	39.22	58.31	38.92
Fruits	5.16	6.48	13.06	7.16	13.56	7.03	13.42	8.55	14.52
Other crops	19.08	18.28	22.84	17.74	22.45	17.89	22.50	16.73	21.61
Pigs	0.38	0.35	1.52	0.33	1.54	0.33	1.56	0.31	1.61
Poultry	0.12	0.12	1.10	0.11	1.10	0.11	1.09	0.11	1.07
Vegetables	2.11	2.68	9.06	2.93	9.39	2.97	9.44	3.39	9.88
Total	100	100	100	100	100	100	100	100	100
GCM: MIROC5	Temperature*	+1.69		+2.41		+2.32		+3.46	
	Rainfall*	-3.83%		-5.94%		-7.00%		-8.32%	

Average probabilities using data from 2014

*Average changes in the entire sample

Main findings:

- climate influences crop and livestock choices,
- the Hausman test and the dissimilarity parameters show that the IIA does not hold,
- In the event of a warmer and drier future Mexican agriculturalists will move from cattle and cereals to other activities, especially to fruits and vegetables,
- the predictions for the remaining set of alternatives differs between models.

Policy implications:

- land use changes: ↓ beef cattle ⇒ ↓ deforestation rates?
- access to information could enhance farmers' adaptation strategies (crop and livestock choices)
- evaluate the effect of PROCAMPO and PROGAN on crop and livestock choices

Further steps:



Thanks to the Agricultural Economics Society for supporting the dissemination of this research.



Agricultural Economics Society

Thank you!

- capital constraints
- water availability
- new species
- alternative nesting structures: climate or typical bundles in the sample.

Data

Table: Definitions and summary statistics

Variable	Definition	Units	Level	Mean		S.D.		Min.		Max.	
				2012	2014	2012	2014	2012	2014	2012	2014
Dependent variable											
Choice	Chosen alternative	Categorical	Plot	-	-	-	-	1	-	31	-
Climate											
Temperature	Temperature normal 1950-2000	Celsius	CA	20.48	20.67	4.46	4.20	7.21	6.51	29.34	29.40
Rainfall	Rainfall normal 1950-2000	mm/month	CA	71.07	66.35	46.82	46.79	4.30	4.30	387.82	384.43
Diurnal	Temperature range 1950-2000	Celsius	CA	15.19	15.22	2.43	2.47	7.94	7.97	20.32	20.50
Output prices											
Price of beverage	Fisher index 07-11 09-13*	%	Mun.	171.70	214.85	20.23	13.96	56.72	123.85	319.14	301.32
Price of cattle	Fisher index 07-11 09-13*	%	Mun.	108.51	116.85	13.58	16.72	63.83	76.01	168.93	173.72
Price of cereals	Fisher index 07-11 09-13*	%	Mun.	159.87	180.73	11.11	13.79	118.69	129.40	203.71	247.05
Price of fruits	Fisher index 07-11 09-13*	%	Mun.	135.33	153.59	11.13	16.96	102.37	97.44	180.21	210.62
Price of other	Fisher index 07-11 09-13*	%	Mun.	135.00	148.46	10.45	17.81	107.46	114.57	154.43	183.07
Price of pigs	Fisher index 07-11 09-13*	%	Mun.	113.56	126.28	15.23	20.94	53.77	52.60	176.61	200.81
Price of poultry	Fisher index 07-11 09-13*	%	Mun.	130.74	149.81	16.87	22.46	71.15	82.20	196.11	239.33
Price of vegetables	Fisher index 07-11 09-13*	%	Mun.	116.98	123.48	16.27	18.55	57.97	39.58	184.95	223.43
Inputs											
Wage rate	Average wage rate	\$/hour	Mun.	36.49	29.08	24.63	19.64	6.25	3.08	293.35	124.19
Plot size	Size of the plot	ha	Plot	29.38	25.81	115.86	100.37	0.00	0.00	1000.00	1000.00

*Base period 2002-2006

Plots=219,985-168,265. Farmers=77,758-59,443.

Data

Table: Definitions and summary statistics

Variable	Definition	Units	Level	Mean		S.D.		Min.		Max.	
				2012	2014	2012	2014	2012	2014	2012	2014
Socio-demographic characteristics											
Age	Age of the farmer	years	Farm	56.92	57.71	13.40	12.73	18.00	18.00	90.00	100.00
Indigenous	1= if indigenous, 0=otherwise	binary	Farm	0.07	0.15	0.26	0.36	0.00	0.00	1.00	1.00
Schooling	Years of study	years	Farm	8.41	7.89	5.38	4.82	0.00	1.00	29.00	28.00
Access to markets											
Mobile	1=uses of a mobile phone, 0=otherwise	binary	Farm	0.43	0.54	0.49	0.50	0.00	0.00	1.00	1.00
Internet	1=access to internet, 0=otherwise	binary	Farm	0.13	0.19	0.34	0.39	0.00	0.00	1.00	1.00
Near city	Distance to the nearest urban area	km	CA	8.63	9.29	9.70	10.22	0.00	0.00	141.62	135.69
Road density	Roads length/total area	km/km2	Mun.	0.34	0.31	0.28	0.25	0.00	0.01	2.62	2.06
Soils											
Vertisol	Area of vertisol soils	%	CA	21.45	22.49	38.44	39.14	0.00	0.00	100.00	100.00
Feozem	Area of feozem soils	%	CA	15.57	15.19	32.95	32.65	0.00	0.00	100.00	100.00
Regosol	Area of regosol soils	%	CA	12.09	11.19	29.37	28.27	0.00	0.00	100.00	100.00
Cambisol	Area of cambisol soils	%	CA	8.93	7.81	25.88	24.07	0.00	0.00	100.00	100.00
Subsidies											
Procampo**	1= if receives procampo, 0=otherwise	binary	Farm	-	0.56	-	0.50	-	0.00	-	1.00
Progan***	1= if receives progan, 0=otherwise	binary	Farm	-	0.10	-	0.30	-	0.00	-	1.00

**A cash transfer to the farmer for the eligible sown area (\$1,300 per rain-fed hectare up to 5 has and \$963 for the remaining plots)

***A cash transfer to the farmer per head (\$250-\$300 per head of cattle and \$93-\$117 per head of pigs)

Plots=219,985-168,265. Farmers=77,758-59,443.

Additional material

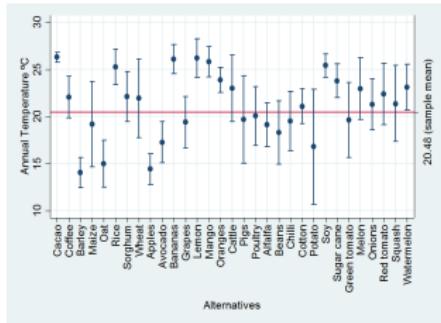


Figure: Temperature and choices 2012

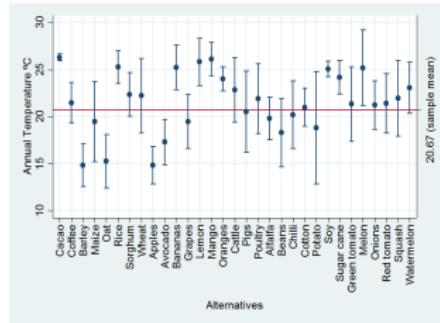


Figure: Temperature and choices 2014

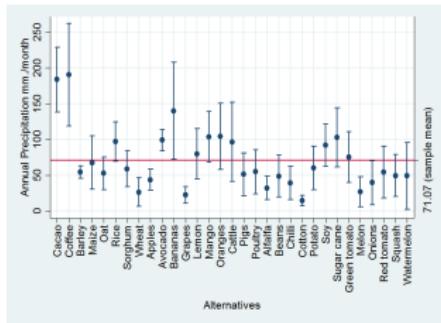


Figure: Precipitation and choices 2012

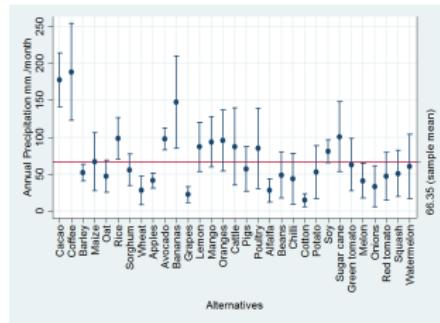


Figure: Precipitation and choices 2014

MNL 8 alternatives (top) 2012

VARIABLES	beverage	cattle	cereals	fruits	other	pigs	poultry	vegetables
Climate								
Temperature	3.0739*** (0.1405)	0.7584*** (0.0354)		-0.2931*** (0.0460)	1.0057*** (0.0465)	-0.1863 (0.3079)	2.4694*** (0.3439)	0.8962** (0.4038)
Temperature squared	-0.0729*** (0.0033)	-0.0157*** (0.0009)		0.0091*** (0.0011)	-0.0244*** (0.0012)	0.0033 (0.0066)	-0.0612*** (0.0084)	-0.0181* (0.0105)
Rainfall	0.0738*** (0.0027)	0.0307*** (0.0012)		0.0330*** (0.0028)	-0.0009 (0.0014)	0.0231 (0.0205)	0.0252** (0.0128)	-0.0279*** (0.0030)
Rainfall squared	-0.0001*** (0.0000)	-0.0001*** (0.0000)		-0.0001*** (0.0000)	0.0000*** (0.0000)	-0.0001 (0.0001)	-0.0001 (0.0001)	0.0001*** (0.0000)
Diurnal	-0.1003*** (0.0327)	-0.0661*** (0.0105)		-0.1769*** (0.0133)	-0.0744*** (0.0108)	-0.2384* (0.1371)	-0.1049 (0.0790)	-0.1546*** (0.0350)
Output prices								
Price beverage	-0.0016 (0.0012)							
Price cattle		-0.0156*** (0.0013)						
Price fruits				0.0179*** (0.0019)				
Price other					0.0281*** (0.0018)			
Price pigs						-0.0180** (0.0070)		
Price poultry							0.0240*** (0.0089)	
Price vegetables								0.0084*** (0.0028)
Observations	219,985	219,985	219,985	219,985	219,985	219,985	219,985	219,985

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

MNL 8 alternatives (top) 2012

VARIABLES	beverage	cattle	cereals	fruits	other	pigs	poultry	vegetables
Inputs								
Wage rate	0.0042*** (0.0010)	0.0047*** (0.0006)		0.0071*** (0.0007)	-0.0002 (0.0007)	0.0106*** (0.0037)	0.0079*** (0.0021)	0.0095*** (0.0021)
Plot size	-0.0011 (0.0025)	0.0106*** (0.0004)		0.0034*** (0.0008)	-0.0014*** (0.0005)	0.0065*** (0.0011)	0.0066*** (0.0010)	0.0018 (0.0012)
Socio-demographic characteristics								
Age of the farmer	0.0057** (0.0026)	0.0145*** (0.0013)		0.0140*** (0.0023)	0.0030* (0.0017)	-0.0002 (0.0096)	-0.0243*** (0.0077)	-0.0161*** (0.0033)
Schooling	-0.0122 (0.0088)	0.0395*** (0.0049)		0.0418*** (0.0078)	0.0266*** (0.0048)	0.1686*** (0.0449)	0.1426*** (0.0343)	-0.0229** (0.0113)
Indigenous	-1.0511*** (0.0785)	-1.0582*** (0.0452)		-0.7104*** (0.0728)	-1.3971*** (0.0634)	-0.3953 (0.3430)	-2.5777** (1.0164)	-1.5015*** (0.1935)
Access to markets								
Mobile	-0.2154 (0.1322)	0.0558 (0.0409)		0.5418*** (0.0579)	0.2299*** (0.0381)	0.4613** (0.1988)	0.8461*** (0.3180)	-0.1117 (0.1068)
Internet	-0.0035 (0.2422)	-0.4196*** (0.0925)		0.2129* (0.1269)	-0.0534 (0.1079)	1.6981*** (0.1727)	1.1037*** (0.2896)	0.5201*** (0.1404)
City	-0.0487*** (0.0062)	0.0303*** (0.0020)		-0.0428*** (0.0037)	-0.0037* (0.0022)	-0.0159 (0.0146)	-0.0254 (0.0188)	0.0196** (0.0089)
Road density	1.5025*** (0.1332)	-1.1558*** (0.0768)		-1.9813*** (0.1338)	-1.7623*** (0.0874)	0.1157 (0.3060)	0.9812*** (0.3138)	0.1459 (0.2522)
Soils								
Vertisol	-0.0265*** (0.0020)	-0.0070*** (0.0005)		-0.0044*** (0.0009)	-0.0056*** (0.0005)	-0.0156*** (0.0026)	-0.0080*** (0.0029)	-0.0050*** (0.0013)
Feozem	-0.0162*** (0.0018)	0.0018*** (0.0005)		0.0059*** (0.0008)	-0.0032*** (0.0004)	-0.0051** (0.0022)	0.0076*** (0.0029)	0.0002 (0.0014)
Regosol	-0.0090*** (0.0010)	0.0023*** (0.0005)		-0.0005 (0.0012)	-0.0037*** (0.0009)	-0.0106*** (0.0036)	-0.0124*** (0.0040)	0.0084*** (0.0017)
Cambisol	-0.0125*** (0.0010)	-0.0057*** (0.0005)		-0.0085*** (0.0009)	-0.0070*** (0.0008)	-0.0220*** (0.0045)	-0.0015 (0.0078)	0.0005 (0.0021)
Constant	-39.3933*** (1.6050)	-10.4177*** (0.4567)		-3.0798*** (0.5445)	-13.2155*** (0.4913)	-0.9696 (6.2116)	-33.8803*** (4.6839)	-10.5185*** (3.1949)
Observations	219,985	219,985	219,985	219,985	219,985	219,985	219,985	219,985

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

MNL 8 alternatives (top) 2014

VARIABLES	beverage	cattle	cereals	fruits	other	pigs	poultry	vegetables
Climate								
Temperature	3.5105*** (0.1571)	0.6184*** (0.0540)		-0.2970*** (0.0521)	0.5058*** (0.0670)	0.0758 (0.4369)	0.9037*** (0.3395)	0.1729 (0.3773)
Temperature squared	-0.0840*** (0.0036)	-0.0129*** (0.0013)		0.0091*** (0.0013)	-0.0124*** (0.0018)	-0.0025 (0.0090)	-0.0202** (0.0082)	-0.0010 (0.0101)
Rainfall	0.0674*** (0.0029)	0.0282*** (0.0016)		0.0248*** (0.0026)	-0.0047** (0.0019)	0.0495** (0.0243)	0.0412*** (0.0126)	-0.0060 (0.0067)
Rainfall squared	-0.0001*** (0.0000)	-0.0001*** (0.0000)		-0.0001*** (0.0000)	0.0000*** (0.0000)	-0.0003*** (0.0001)	-0.0001** (0.0000)	-0.0000 (0.0000)
Diurnal	-0.1900*** (0.0230)	-0.1048*** (0.0126)		-0.1585*** (0.0135)	-0.0180 (0.0115)	-0.1976 (0.1815)	0.0778 (0.0912)	-0.1047*** (0.0361)
Output prices								
Price beverage		-0.0026* (0.0015)						
Price cattle			-0.0038** (0.0016)					
Price fruits				0.0093*** (0.0011)				
Price other					0.0158*** (0.0024)			
Price pigs						-0.0125*** (0.0029)		
Price poultry							0.0179 (0.0132)	
Price vegetables								0.0005 (0.0040)
Observations	168,265	168,265	168,265	168,265	168,265	168,265	168,265	168,265

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

MNL 8 alternatives (top) 2014

VARIABLES	beverage	cattle	cereals	fruits	other	pigs	poultry	vegetables
Inputs								
Wage rate	-0.0208*** (0.0027)	-0.0003 (0.0017)	-0.0007 (0.0013)	0.0050*** (0.0011)	-0.0003 (0.0089)	-0.0100* (0.0054)	0.0031 (0.0037)	
Plot size	0.0028*** (0.0008)	0.0062*** (0.0003)	0.0021*** (0.0005)	-0.0007** (0.0003)	0.0023** (0.0012)	0.0035*** (0.0009)	0.0014** (0.0007)	
Socio-demographic characteristics								
Age of the farmer	0.0087*** (0.0024)	0.0210*** (0.0014)	0.0183*** (0.0022)	0.0014 (0.0014)	0.0052 (0.0055)	0.0190 (0.0135)	-0.0154*** (0.0042)	
Schooling	0.0141 (0.0086)	0.0456*** (0.0050)	0.0461*** (0.0070)	0.0154** (0.0063)	0.0037 (0.0272)	0.0236 (0.0336)	-0.0170 (0.0147)	
Indigenous	-0.6961*** (0.0757)	-0.5652*** (0.0523)	0.1201** (0.0524)	-0.2437*** (0.0510)	0.0063 (0.1811)	-0.2476 (0.3226)	-0.3363** (0.1520)	
Access to markets								
Mobile	-0.4899*** (0.0934)	0.4353*** (0.0410)	0.2483*** (0.0543)	0.4388*** (0.0375)	0.5910*** (0.1753)	-0.0405 (0.2751)	-0.0880 (0.1795)	
Internet	-0.0604 (0.2239)	-0.2590** (0.1042)	0.3228*** (0.1136)	0.0581 (0.1112)	2.1534*** (0.3353)	1.9474*** (0.4418)	1.0001*** (0.1487)	
City	-0.0504*** (0.0050)	0.0300*** (0.0023)	-0.0482*** (0.0039)	0.0021 (0.0021)	-0.0446*** (0.0167)	0.0093 (0.0194)	0.0208** (0.0105)	
Road density	1.3619*** (0.1227)	-1.5048*** (0.1488)	-0.9940*** (0.1202)	-1.6666*** (0.1196)	-0.3832 (0.2440)	0.7530* (0.4524)	0.3407 (0.3606)	
Soils								
Vertisol	-0.0232*** (0.0013)	-0.0049*** (0.0007)	-0.0027*** (0.0008)	-0.0045*** (0.0006)	-0.0157*** (0.0020)	-0.0177*** (0.0034)	-0.0036** (0.0015)	
Feozem	-0.0136*** (0.0017)	0.0025*** (0.0006)	0.0034*** (0.0008)	-0.0021*** (0.0005)	-0.0031 (0.0024)	-0.0067 (0.0043)	0.0060*** (0.0017)	
Regosol	-0.0081*** (0.0010)	0.0049*** (0.0006)	0.0015 (0.0012)	-0.0002 (0.0010)	-0.0081*** (0.0026)	-0.0059* (0.0034)	0.0153*** (0.0021)	
Cambisol	-0.0020** (0.0009)	-0.0040*** (0.0007)	-0.0074*** (0.0011)	-0.0036*** (0.0008)	-0.0240*** (0.0045)	-0.0019 (0.0085)	0.0023 (0.0023)	
Constant	-40.8114*** (1.8368)	-10.1795*** (0.6045)	-1.8587*** (0.6086)	-8.0019*** (0.5375)	-3.2002 (9.1972)	-23.4909*** (5.5570)	-4.3685 (2.8690)	
Observations	168,265	168,265	168,265	168,265	168,265	168,265	168,265	168,265

Robust standard errors in parentheses (clustering at the farm level)

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

Base category: cereals

