The Impact of Horse Adoption on Native American Nations

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Introduction and Motivation

- The path of Indigenous nations was shaped by the rapid spread of European diseases and the speed of recovery likely shaped their interactions with European colonizers
- We seek to understand how a potentially mitigating factor, the **diffusion of the horse** across North America, may have impacted the recovery of these nations
- What suggests there might have been a meaningful impact?
  - Indigenous peoples in the Great Plains were arguably the "tallest people in the world" (Prince and Steckel, 2001) & the horse was known to be valuable to many of these peoples, transforming hunting & trade
  - It granted significant military advantages in combat on the open plains (Kumagai, 2022)

What We Do

- We empirically test whether the horse had short run impacts on population & food production and longer run impacts on heights, income, land cessions, & conflict
- In this early stage of research, we:
  1. Digitize historical maps of the spread of the horse in North America and interpolate the presence of the animal Horse Map
  2. Estimate the relationship between horse adoption and Indigenous populations
  3. Consider the effects of horse adoption on heights, food production, conflict, and land cessions
  4. Interpret the results through the lens of a Malthusian-style model with technology Model Summary

Brief Historical Background

- The horse originated in the Americas, but was driven to extinction roughly 12,000 years ago, likely as a result of climate change or overhunting
- The animal was reintroduced to the Americas by European colonizers in the late 15th and early 16th centuries and spread rapidly (Delsol et al 2022)
- After re-introduction, the animal spread in the plains and the west primarily through **Indigenous trading routes** rather than through trade with Europeans (Taylor et al., 2023)
- By the time of European encroachment into the Great Plains, there were many well-established Indigenous, horse-dependent nations using the animal for hunting, travel, and warfare

Expected Impacts

- From the qualitative literature:
  - Improvements in transportation and hunting, leading to richer communities
  - Increased conflict and state size among Indigenous nations
  - Strengthened Indigenous power relative to colonial states, leading to later land cessions & more favourable treaty terms
- From our model:
  - Population booms, particularly in the short run
  - Greater specialization in subsistence modes
  - Limited long run improvements in well-being

Data and Methods

Data:

- **Sample:** 150 Indigenous nations in or around the Great Plains with controls from Feir et al. (2023) Homelands Descriptive Statistics
- **Horse adoption:** Wissler (1914), Haines (1938) , Brooke et al (1980), and others $\rightarrow$ interpolated horse presence Interpolation
- **Outcomes:** population (Smithsonian Handbook and Statistical Records of Native North Americans), food production (Murdock 1967), heights (Jantz 1995), land cessions (BAE 1899), income (Leonard et al 2020) Population

Methods:

- TWFE and event study specifications for population
- OLS and IV for cross-sectional outcomes LCP with Water Bodies

Panel Results: Population & Horse Adoption

	(1)	(2)	(3)
Horse	0.211**	0.221***	0.210***
	(0.08)	(0.076)	(0.078)
Epidemic		-0.130*	-0.124*
		(0.069)	(0.068)
Dummy 1776			0.208**
			(0.085)
Dummy 1830			-0.179
			(0.158)
Regional Controls	No	No	Yes
Observations	448	448	448
R-squared	0.105	0.12	0.124
Number of nations	67	67	67

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

TWFE

Cross Section Analysis & Endogeneity

- Understanding that, a nation with more dependency on hunting may have had an incentive to adopt horses, leading to earlier adoption
- We proceed with two distinguished methodologies to address the issue:
  1. First, assessed the exogenous variation in *Year With Horses* (YWH) explained by exogenous geographical characteristics
  2. Second, an instrumental variable approach, using exogenous variation in YWH explained by the least cost path augmented by water bodies

Cross Sectional Results: Foods & Horse Adoption OLS

	Hunting	Gathering	Fishing	Animal	Agriculture
Years with Horse	0.03*	0.02	-0.01	-0.01	-0.03
	(0.02)	(0.02)	(0.01)	(0.00)	(0.02)
Years with Horse Sqr.	-0.00**	-0.00	0.00	0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Geo. Controls	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.29	0.35	0.62	0.31	0.41
Observations	120	120	120	120	120

Robust standard errors are clustered at the language level. *** p<0.01, ** p<0.05, * p<0.1

Cross Sectional Results: Foods & Horse Adoption IV

	Hunting	Gathering	Fishing	Animal	Agriculture
Years with Horse	0.14***	-0.37	-11.72**	-2.6***	-5.67
	(0.05)	(0.02)	(0.05)	(0.02)	(0.14)
Years with Horse Sqr.	-0.00**	-0.26	4.32**	1.14***	2.80
	(0.00)	(0.02)	(0.00)	(0.05)	(0.10)
First-Stage F-Stat (First Endo. Var.) IV	8.54	8.54	8.54	8.54	8.54
First-Stage F-Stat (Second Endo. Var.)	18.00	18.00	18.00	18.00	18.00
Observations	120	120	120	120	120

First-stage F-statistics are calculated for each endogenous variable, *** p<0.01, ** p<0.05, * p<0.1

Cross-Sectional Results: Horse Adoption & Heights

	(1)	(2)	(3)	(4)	(5)	(6)
Time since Horse Adoption	0.0156	0.0239	0.00973	0.0364	0.00500	0.0294
	(0.025)	(0.044)	(0.023)	(0.043)	(0.030)	(0.055)
Individual Controls	X	X	X	X	X	X
Spatial and Nation Controls		X		X		X
Men	X	X			X	X
Women	X	X	X	X		
Observations	11487	10348	4242	3861	7245	6487
Adjusted R^2	0.864	0.868	0.859	0.863	0.877	0.883
N_clust	113	108	108	103	109	104

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Cross-Sectional Results: Horse Adoption & Land Cessions

	(1)	(2)	(3)
Time since Horse Adoption	-0.417***	-0.382***	0.102
	(0.134)	(0.110)	(0.187)
Bison dependence		-8.473*	-11.569***
		(4.963)	(4.031)
Regional dummies	No	No	Yes
Observations	321	321	252
R-squared	0.042	0.081	0.380

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Cross-Sectional Results: Horse Adoption and Income

	(1)	(2)	(3)	(4)	(5)
Time since Horse Adoption	0.00179	0.00763*	0.00129	0.00820***	0.00232
	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)
Year Dummies	X	X	X	X	X
Spatial Controls		X			
Cultural Controls			X		
Colonial Controls				X	
Disruptive Controls					X
Observations	634	634	634	634	634
R-squared	0.574	0.596	0.618	0.629	0.586

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Discussion and Conclusion

- Horse adoption is strongly associated with a rapid re-population of Indigenous nations and selection into hunting for food production
- We observe no long run income/health effects as measured through heights
- However, nations with earlier horse access are more successful at resisting colonial powers, ceding their lands at later dates
- We hypothesize that this economic boom, and the associated positive military shock, likely delayed the time of conquest for these nations and increased the likelihood that these peoples persist into the present, although this work remains in progress

Future Work: Conflicts and Horse Adoption

- Data on bilateral and multilateral conflicts Conflicts
- Data on tribal and colonial conflicts Conflicts with Colonial power
- Intertribal conflicts after horse adoption Post horses conflicts
- Digitization of gun frontier maps

Renewable Resource Dynamics

Back to What We Do

- Assuming the production sector, the resource stock at time t is $S(t)$. It evolves according to:

$$\frac{dS}{dt} = G(S) - H \tag{1}$$

We assume a logistic function for $G(S)$:

$$G(S) = rS\left(1 - \frac{S}{K}\right) \tag{2}$$

where r is the intrinsic growth of the natural resource and K is the carrying capacity, i.e. the maximum possible size of the natural resource stock. When $S = K$, further growth in the natural resource cannot occur

Renewable Resource Dynamics

Back to What We Do

- Hunting is carried out according to the Schaefer harvesting production function:

$$H^p = \alpha S L_H \tag{3}$$

- This implies that the unit labor requirement in hunting is:

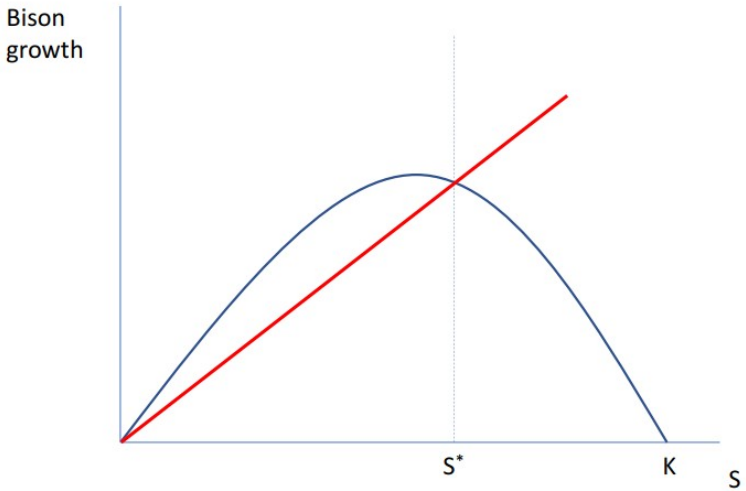
$$a_{LH}(S) = \frac{L^H}{H^P} = \frac{1}{\alpha S} \tag{4}$$

- There is free entry in the hunting sector. Open access implies that the rental cost for using S is the one that sets price equal to its marginal cost:

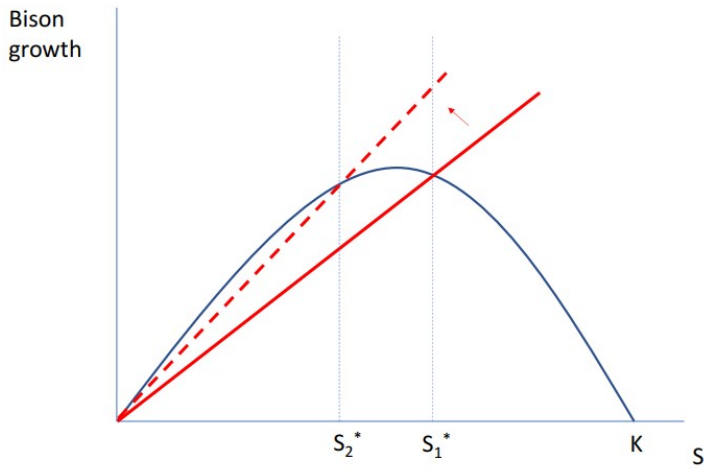
$$p = w a_{LH} = \frac{w}{\alpha S} \tag{5}$$

Renewable Resource Dynamics and Steady State

Back to What We Do



The Steady State number of Bison



The effect of Horse adoption on Bison stock

Utility Maximization Approach

Back to What We Do

- Consumer can maximize utility

$$u = h^{\beta} m^{1-\beta} \qquad \text{s.t} \qquad ph + m = w \tag{6}$$

yields the following for both commodities

$$h = w\frac{\beta}{p} \qquad \text{and} \qquad m = w(1-\beta) \tag{7}$$

- Total demand for both commodities are

$$H^D = \frac{w\beta L}{p} \qquad \text{and } M^D = w(1-\beta)L \tag{8}$$

- The full employment condition consists the following

$$H^P a_{LH}(S) + M = L \tag{9}$$

$$H = \alpha\beta LS \tag{10}$$

Malthusian Population Dynamics

Back to What We Do

- Our analysis assumes a fixed population size L initially to isolate resource dynamics. Also, underlying proportional birth rate, b, and death rate, d, with the net population increase rate as $(b-d)$,and $b-d<0$, implies NA population would vanish without bison or arable land, hence population growth:

$$\frac{dL}{dt} = L(b-d+F) \tag{11}$$

Here, $F = \phi\frac{H}{L}$ is fertility function, where ϕ is a positive constant,considering $\frac{H}{L} = \alpha\beta S$ from (10), equation (12) can be rewritten as:

$$\frac{dL}{dt} = L(b-d+\phi\alpha\beta S) \tag{12}$$

- PROPOSITION 1: The Ricardo-Malthus model exhibits three steady states. Steady state I is a corner solution at $(L = 0, S = 0)$. Steady state 2 is a corner solution at $(L = 0, S = K)$. Steady state 3 is an interior solution at

$$L = [\frac{r}{\alpha\beta}][1 - \frac{(d-b)}{(\phi\alpha\beta K}] \tag{13}$$

and

$$S = \frac{d-b}{\phi\alpha\beta}$$

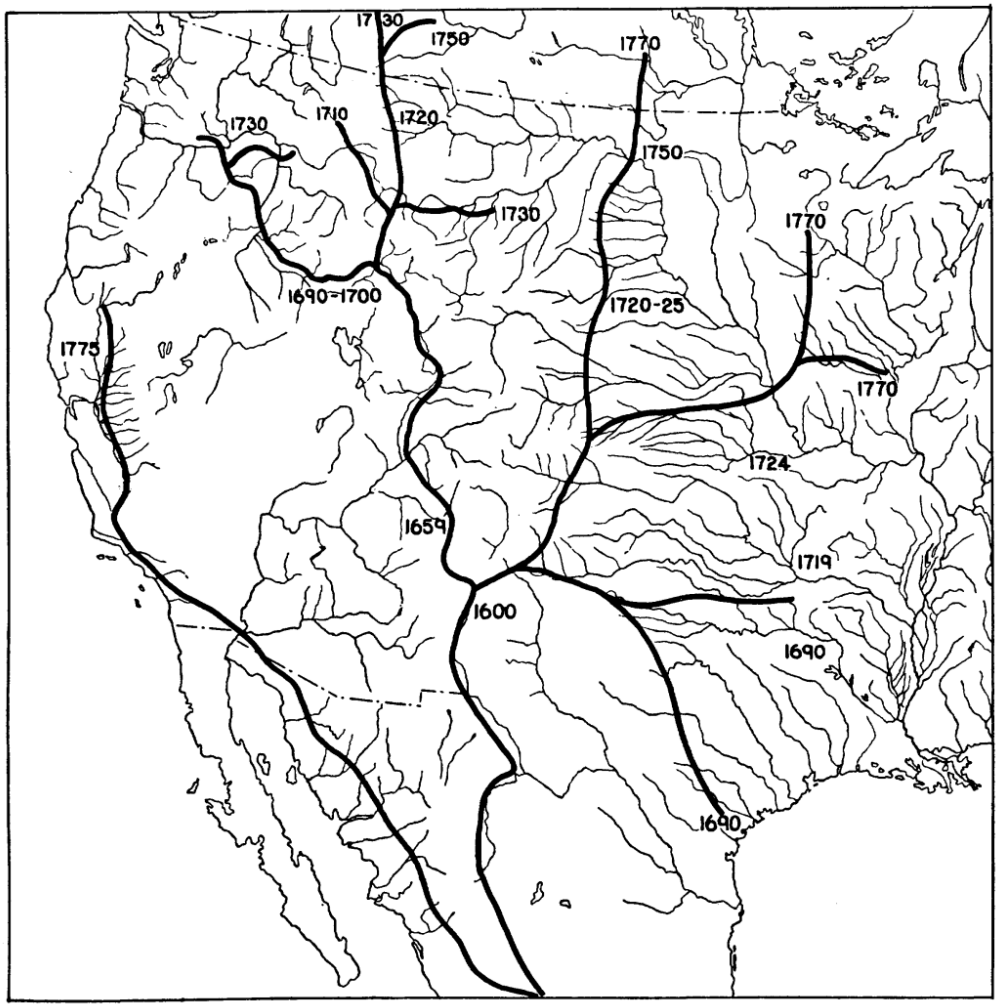
- PROPOSITION 2: The steady-state resource stock:
  1. rises if the mortality rate rises, the birth rate falls, or fertility responsiveness falls;
  2. falls if there is technological improvement in hunting; and
  3. is unaffected by changes in the intrinsic resource regeneration rate, r, or carrying capacity, K.

The adoption of the horse can be interpreted as permanent technological improvement in hunting.

- PROPOSITION 3: The steady-state population level:
  1. rises equiproportionately with an increase in the intrinsic rate of resource growth, r;
  2. falls when the hunting technology improves if $S < \frac{K}{2}$ and rises if $S > \frac{K}{2}$;
  3. falls when the taste for the resource good rises if $S < \frac{K}{2}$ and rises if $S > \frac{K}{2}$
  4. rises if the carrying capacity of the environment rises.

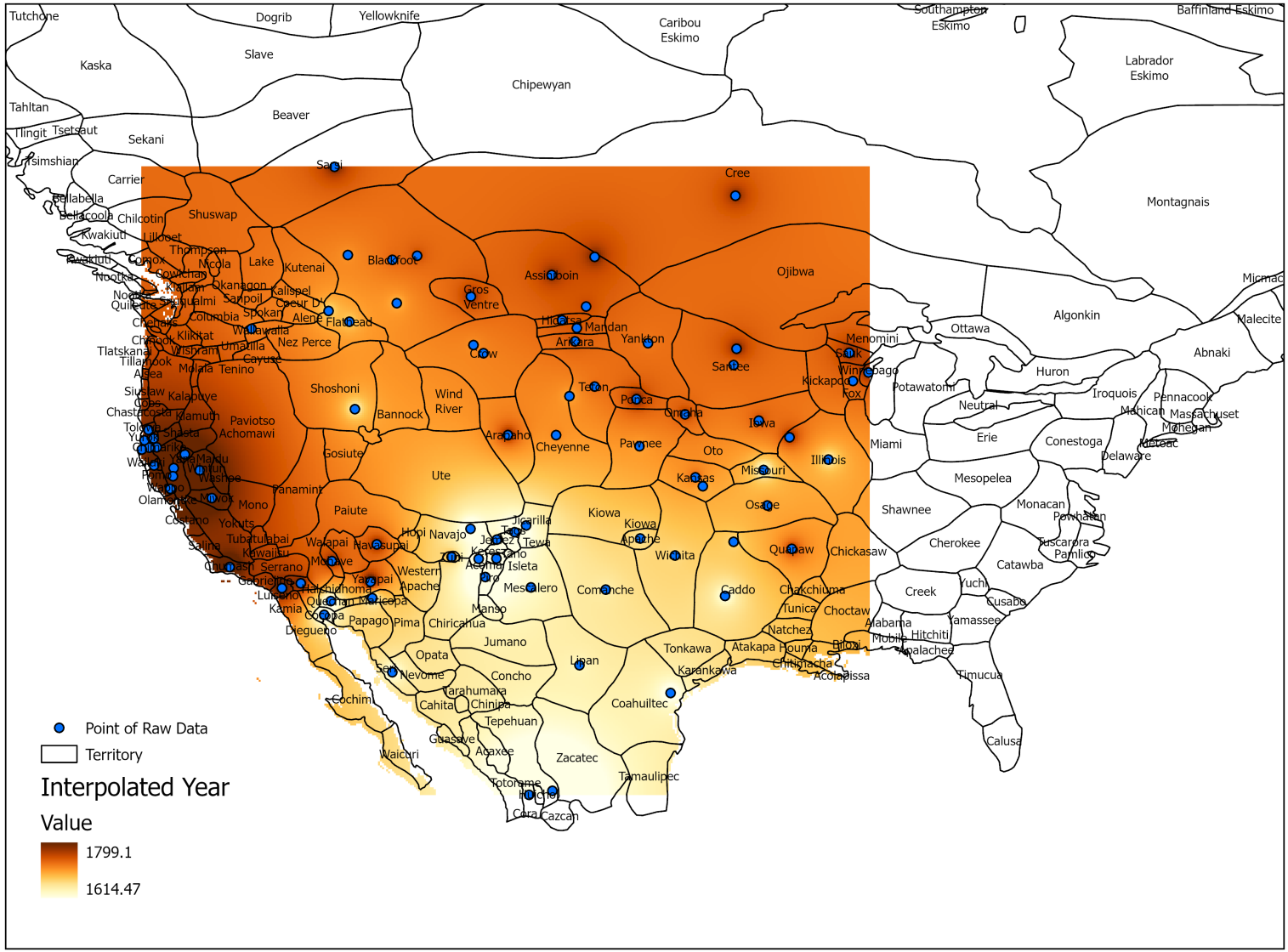
The Diffusion of the Horse (Haines, 1938)

Back to What We Do

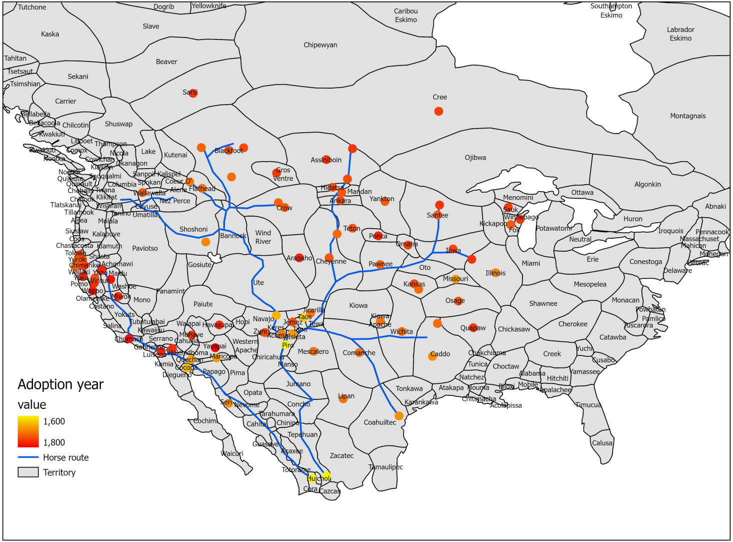


Homelands

Back to Data and Methods



Digitization and Interpolation



Population

Back to Data and Methods

Region	Nation	Year	Population	Source	Literature
Plains	Hidatsa	1700	5000	Wood and Thiessen, 1985_David Thompson(1797-98:146)	Matthews, W. (1877). Ethnography and philology of the Hidatsa Indians (No. 7). US Government Printing Office.
Plains	Hidatsa	1720	3500	Wood and Thiessen, 1985_David Thompson(1797-98:159)	Lowie, R. H. (1913). Societies of the Crow, Hidatsa and Mandan Indians (Vol. 11). The Trustees.
Plains	Hidatsa	1780	2500	Mooney 1928:138	Mooney, J. (1928). The aboriginal population of America north of Mexico. Smithsonian miscellaneous collections.
Plains	Hidatsa	1797	1730	Stewart(1975:78-80)	Stewart, F. H. (1974). Mandan and Hidatsa villages in the eighteenth and nineteenth centuries. Plains Anthropologist, 19(66), 287-302.
Plains	Hidatsa	1805	2700	Lewis and Clark (1806:26, 1814, 1:130)	Stewart, F. H. (1976). Hidatsa Origin Traditions Reported by Lewis and Clark. Plains Anthropologist, 21(72), 89-92.
Plains	Hidatsa	1820	4000	Bower(1965:36,287)Chardon (1932:126,145)	Hanson, J. R. (1993). HIDATSA ETHNOHISTORY: 1800-1845. The Phase I Archeological Research Program for the Knife River Indian Villages National Historic Site: Ethnohistorical studies, (27), 131.

Descriptive Statistics: Panel Analysis

Back to Data and Methods

Panel Analysis

	Obs	Means	Stand Dev.	Min	Max
Nations	82	–	–	–	–
Year	1089	1823	85.94	1540	1980
Horse Adoption Year	1089	1742	0.5713	1740	1743
Population	1089	3204	5413	19	62000
Land Cession Year	839	1897	67.34	1784	2010

Cross Sectional Analysis

	Obs	Means	Stand Dev.	Min	Max
Nations	115	–	–	–	–
Horse Adoption Year	161	1734	18.67	1676	1771
Gathering	161	23	16	0	60
Hunting	161	33	17	1	90
Fishing	161	26	20	0	80
Animal Husbandry	161	6	3	0	30
Agriculture	161	15	23	0	80
Homeland area 1600	254	75,717	133,497	737.5	1,246,482
Pop density in 1600	72	0.35	0.41	0	65

Two Way Fixed Effects

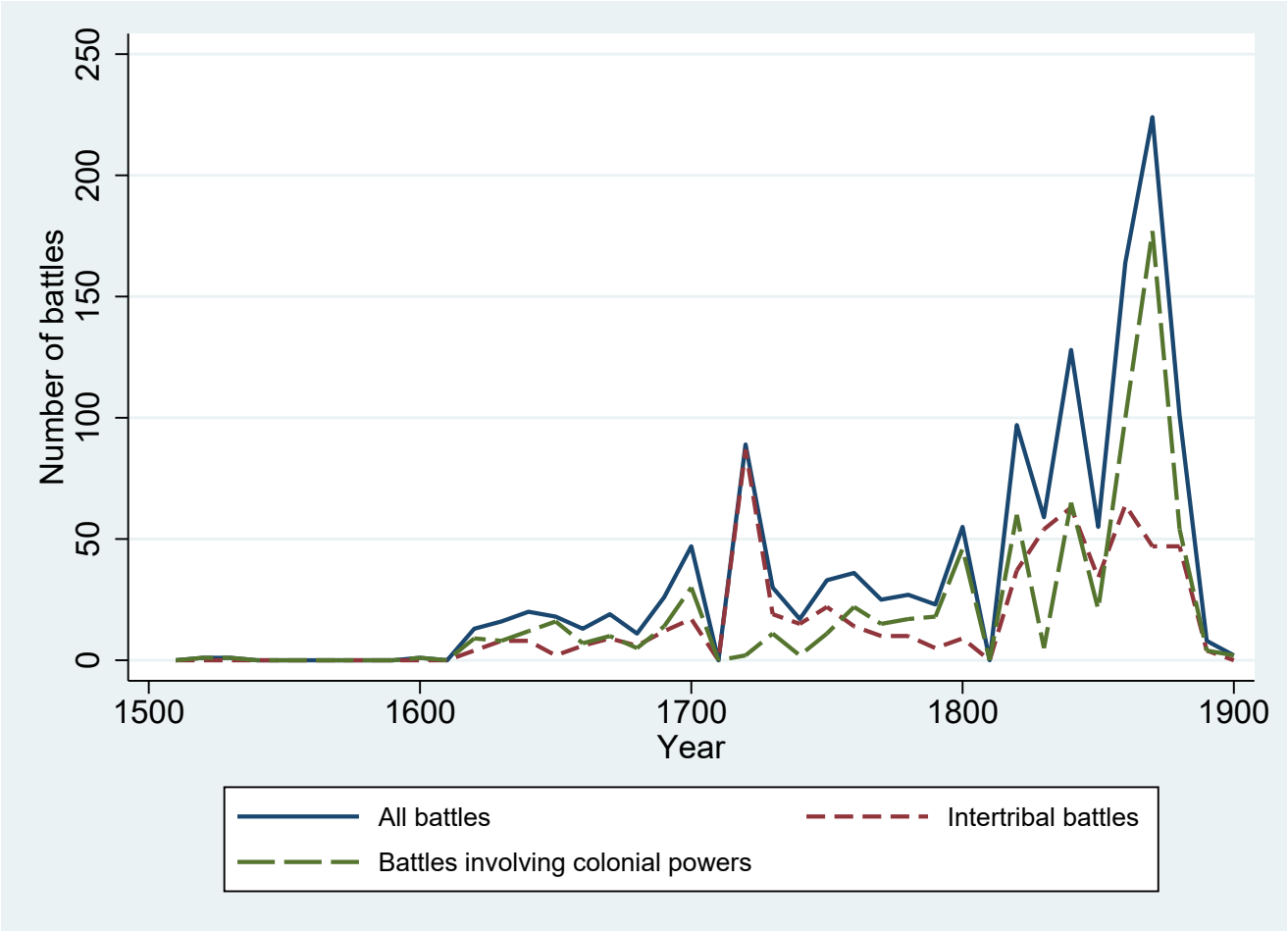
Back to Panel Results: Population & Horse Adoption

	(1)	(2)	(3)	(4)
Horse	0.211**	0.221***	0.210***	0.138**
	(0.08)	(0.076)	(0.078)	(0.053)
Epidemic		-0.130*	-0.124*	-0.009
		(0.069)	(0.068)	(0.038)
Dummy 1776			0.208**	0.154**
			(0.085)	(0.065)
Dummy 1830			-0.179	0.086
			(0.158)	(0.053)
Constant	7.820***	7.852***	6.987***	17.325***
	(0.04)	(0.036)	(0.226)	(5.783)
Observations	448	448	448	448
R-squared	0.105	0.12	0.124	0.84
Nation-specific trends	No	No	No	Yes
R-square between	0.0028	0.0106	0.00361	0.0161
R-square within	0.105	0.12	0.124	0.84
R-square overall	0.0156	0.0297	0.0244	0.0118

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

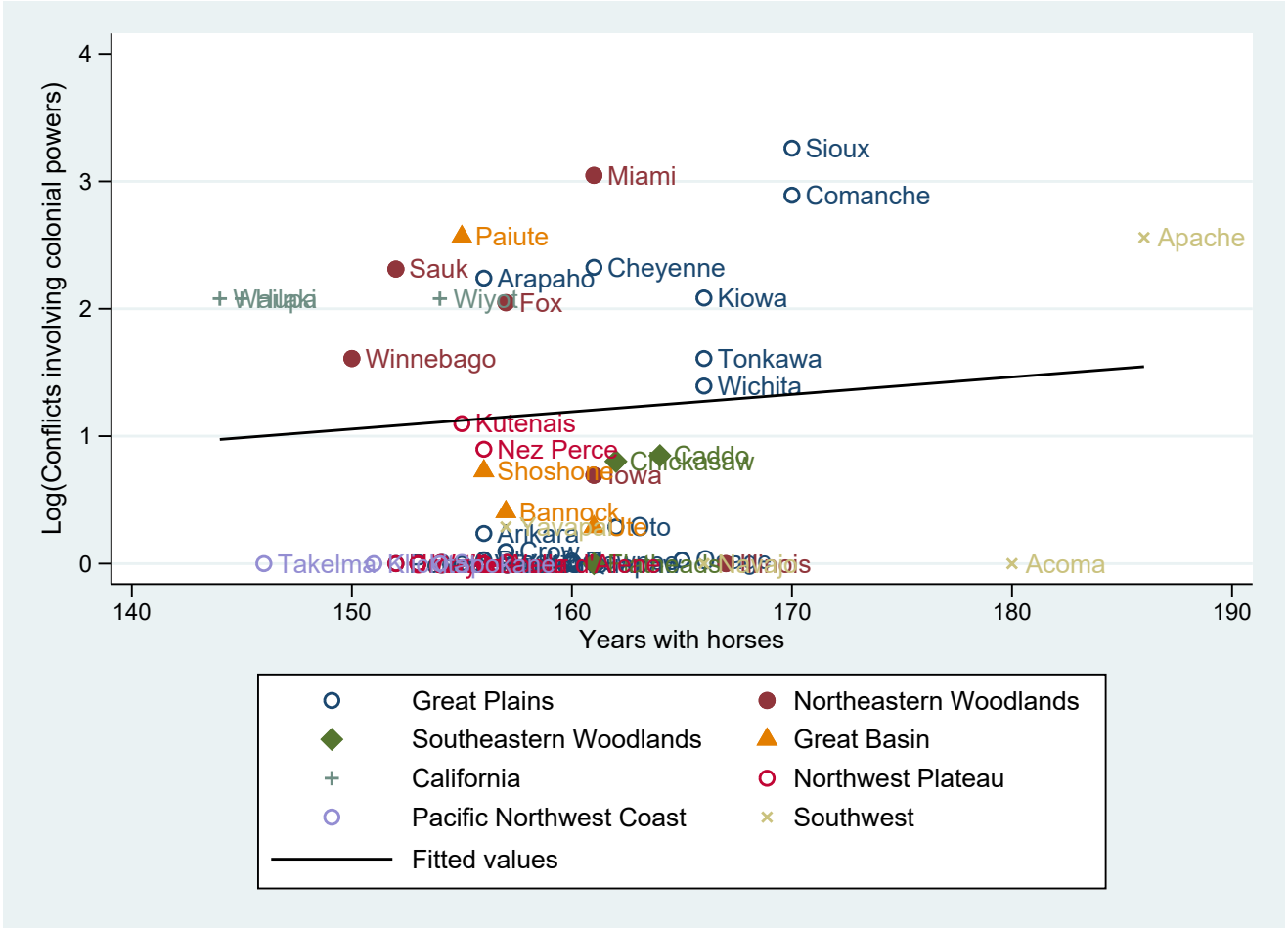
Conflicts

Back to Future Work: Conflicts and Horse Adoption



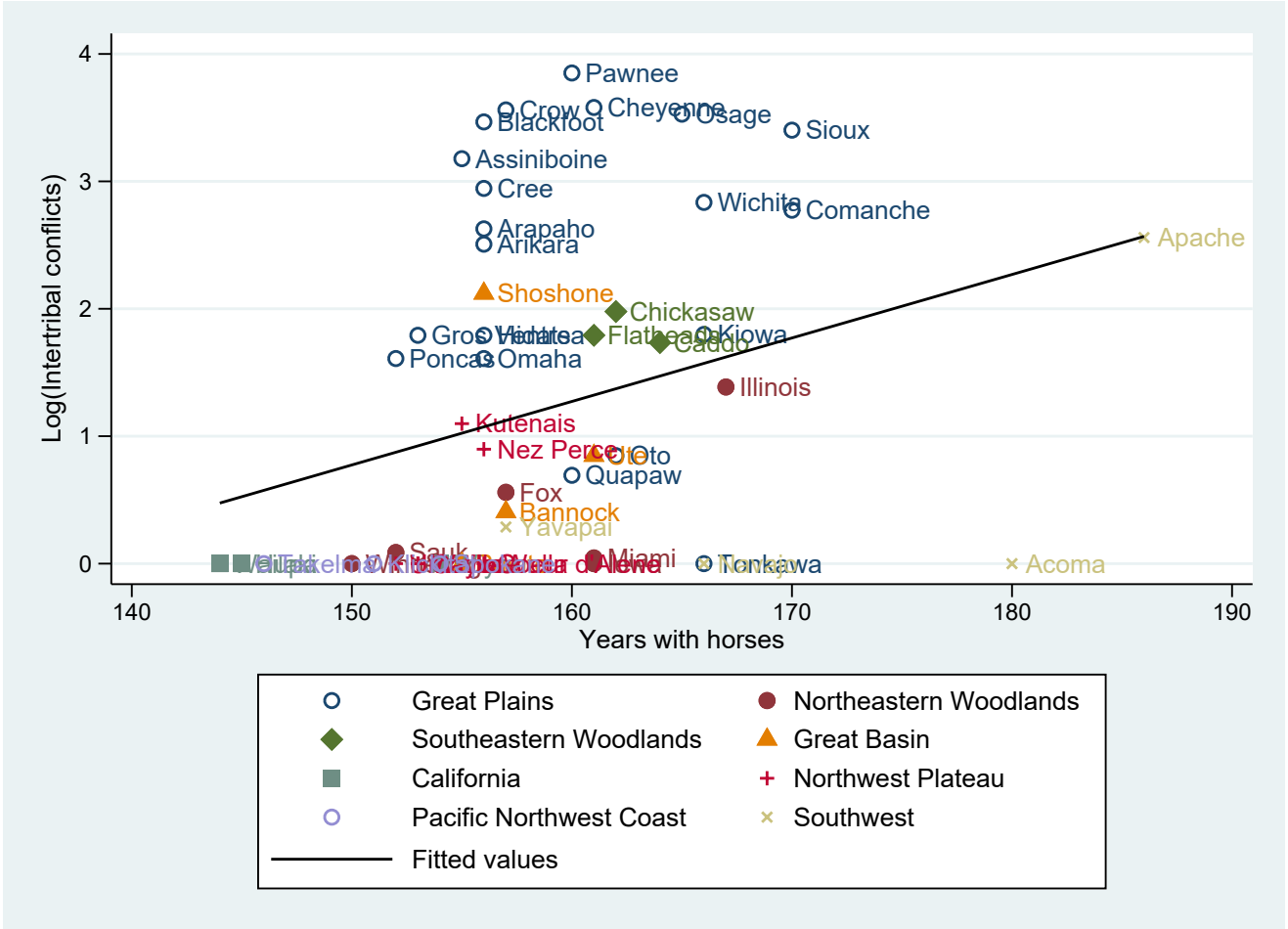
Conflicts with Colonial power

Back to Future Work: Conflicts and Horse Adoption



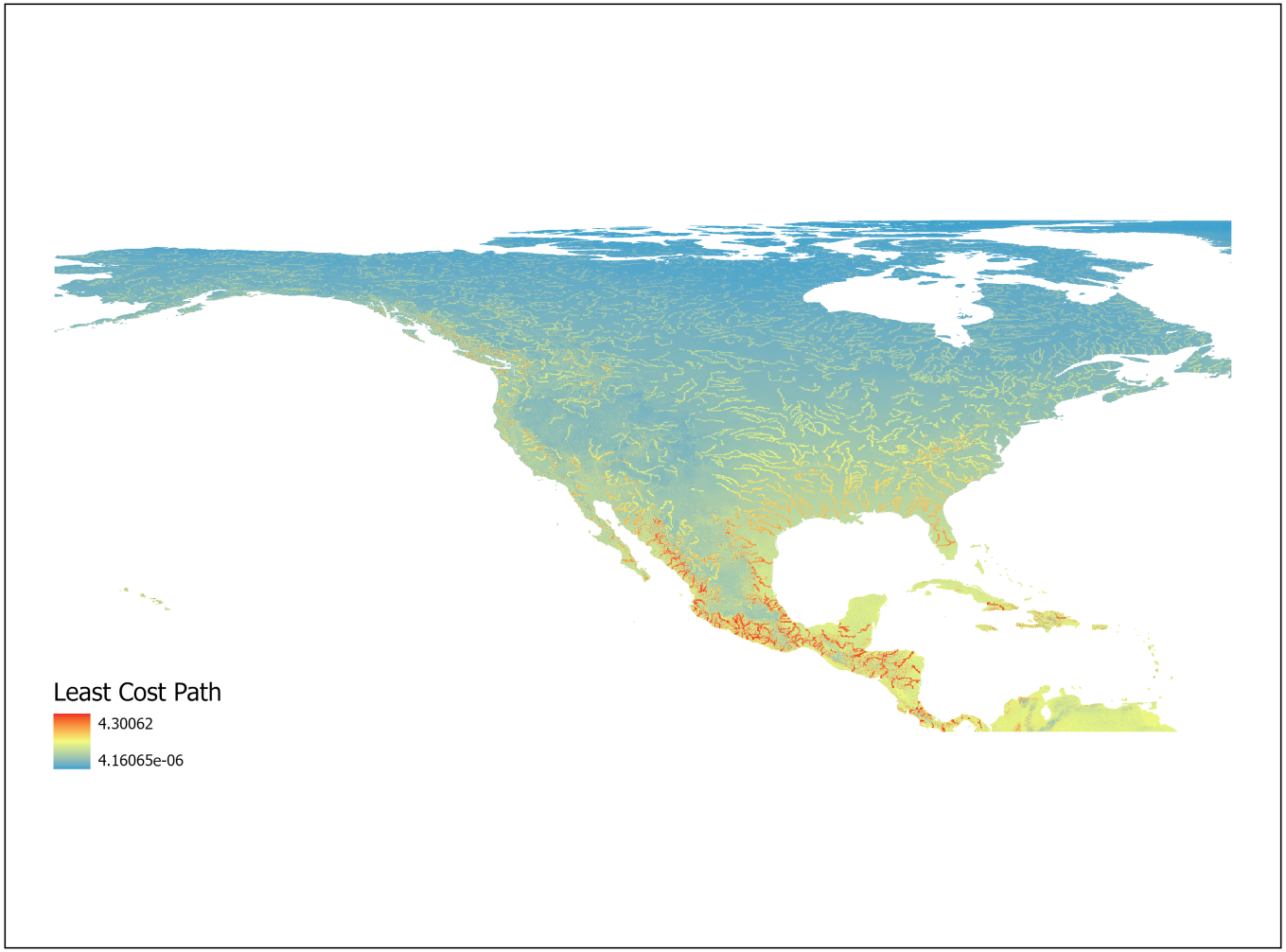
Post horses conflicts

Back to Future Work: Conflicts and Horse Adoption



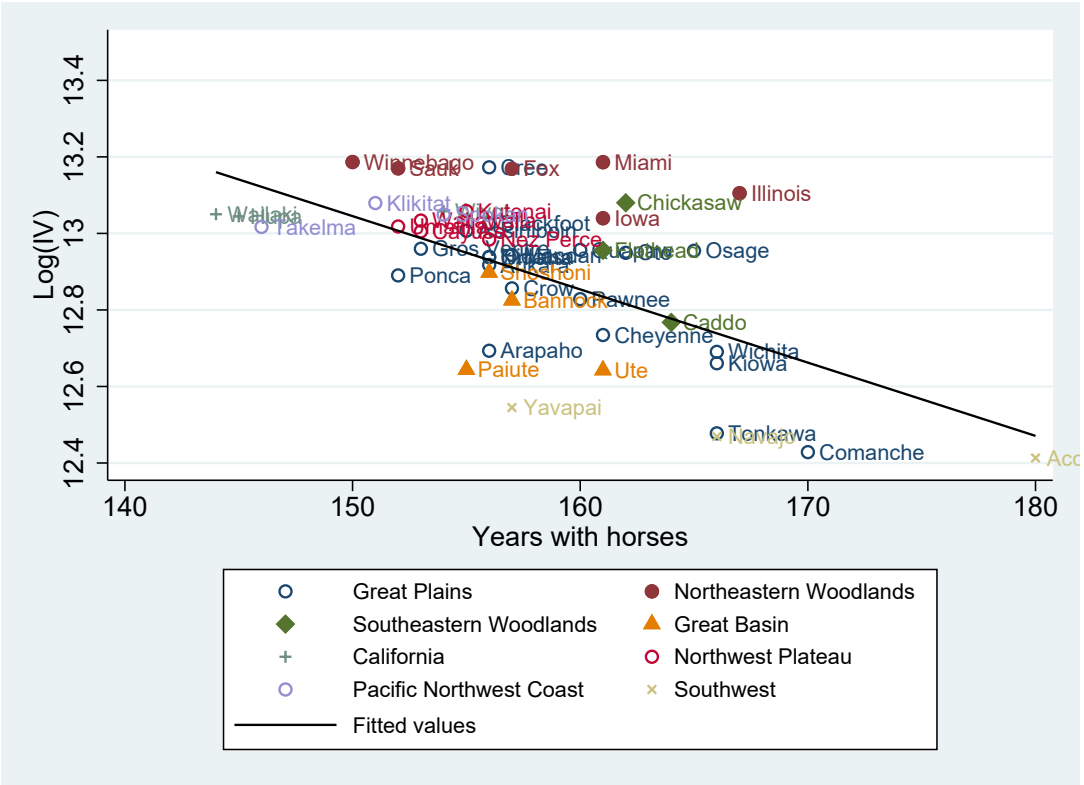
An instrument: Least Cost Path with Water Bodies

Back to Data and Methods



First Stage:An Instrument

Back to Cross Sectional Results: Foods & Horse Adoption IV



Cross-Sectional Results: Horse Adoption & Hunting

	Hunting Dependency			
	(1) OLS	(2) OLS	(3) OLS	(4) 2SLS
Time since Horse Adoption	2.88**	2.91***	2.90***	17.30***
	(1.04)	(0.94)	(0.83)	(5.84)
Time since Horse Adoption Sqr.	-1.22***	-1.19***	-1.21***	-6.58***
	(0.39)	(0.37)	(0.34)	(2.30)
Latitude		-0.69	-1.97	-3.36
		(2.24)	(2.40)	(6.17)
Longitude		1.65	2.29	3.17
		(1.24)	(1.39)	(4.22)
Latitude × Longitude		-2.03	-3.75	-4.10
		(3.21)	(3.49)	(8.32)
Terrain Ruggedness		-0.56	-0.57*	-0.34
		(0.33)	(0.32)	(0.40)
Land Suitability (Avg.)			0.26	0.35
			(0.20)	(0.38)
Elevation (Avg.)			0.35	0.32
			(0.25)	(0.34)
Avg. of Dependent Var.	3.470	3.470	3.470	3.470
Std. of Dependent Var.	1.893	1.893	1.893	1.893
Optimal Years since Adoption	1.182	1.222	1.197	1.314
Adjusted R^2	0.055	0.254	0.275	
First-Stage F-Stat (First Endo. Var.)				13.116
First-Stage F-Stat (Second Endo. Var.)				17.367
Observations	115	115	115	115

Cross-Sectional Results: Horse Adoption & Other Food Production Modes

	Gathering		Fishing		Animal Husbandry		Agriculture	
	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS
Time since Horse Adoption	1.02	-0.37	-1.35*	-11.72**	-0.57**	-2.36***	-1.88	-5.67
	(1.13)	(4.71)	(0.76)	(5.36)	(0.25)	(0.60)	(1.51)	(9.16)
Time since Horse Adoption Sqr.	-1.00*	-0.26	0.50*	4.32*	0.36**	1.14***	1.32*	2.80
	(0.50)	(2.08)	(0.28)	(2.21)	(0.14)	(0.27)	(0.71)	(3.75)
Latitude	3.45	4.18*	-0.56	-0.23	-0.32*	0.11	-0.77	-0.40
	(2.59)	(2.37)	(3.76)	(5.70)	(0.17)	(0.69)	(4.01)	(3.54)
Longitude	-3.59**	-4.12***	-0.19	-0.35	0.18	-0.13	1.41	1.16
	(1.61)	(1.53)	(2.07)	(3.80)	(0.13)	(0.48)	(2.37)	(2.02)
Latitude × Longitude	5.90*	6.70**	-1.62	-2.22	-0.44*	-0.06	-0.27	-0.18
	(3.39)	(2.87)	(5.23)	(7.55)	(0.22)	(0.91)	(4.93)	(4.25)
Terrain Ruggedness	0.03	0.02	0.58*	0.39	-0.01	-0.03	-0.04	-0.11
	(0.14)	(0.14)	(0.33)	(0.38)	(0.04)	(0.03)	(0.14)	(0.19)
Land Suitability (Avg.)	-0.40**	-0.33	0.05	-0.07	0.02	0.05	0.06	0.04
	(0.17)	(0.22)	(0.27)	(0.32)	(0.03)	(0.04)	(0.24)	(0.28)
Elevation (Avg.)	0.11	0.07	-0.71***	-0.61**	0.07***	0.06	0.20	0.22
	(0.15)	(0.17)	(0.23)	(0.31)	(0.02)	(0.06)	(0.27)	(0.23)
Avg. of Dependent Var.	2.765	2.765	2.191	2.191	0.078	0.078	1.496	1.496
Std. of Dependent Var.	1.667	1.667	1.933	1.933	0.354	0.354	2.389	2.389
Optimal Years since Adoption	0.514	-0.725	1.363	1.357	0.797	1.032	0.711	1.012
Adjusted R^2	0.453		0.554		0.350		0.363	
First-Stage F-Stat (First Endo. Var.)		12.507		12.507		12.507		12.507
First-Stage F-Stat (Second Endo. Var.)		14.401		14.401		14.401		14.401
Observations	115	115	115	115	115	115	115	115

Note: Robust standard errors clustered at the language group level. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.