Geographical Roots of Comparative Development

Ömer Özak

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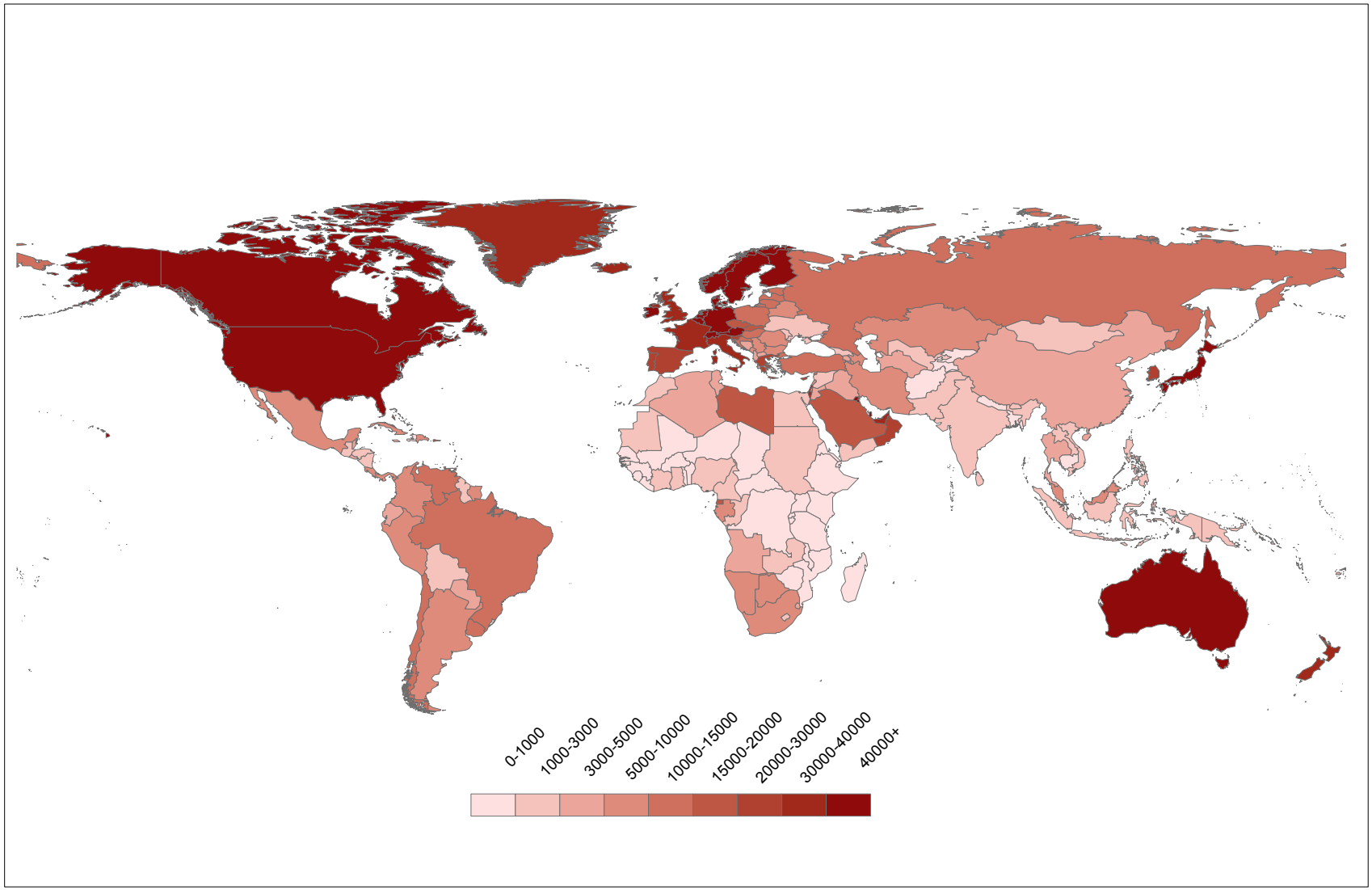
Economic Growth and Comparative Development

The Origins of Inequality in Income per Capita across the Globe in 2010



Deep Roots of Comparative Development

- Persistent effects of variations geographical and human characteristics
  - Biogeographical conditions that led to the onset of the Neolithic Revolution (Diamond, 1997)
  - Migratory distance from Africa and its impact on the distribution of genetic diversity across the globe (Ashraf-Galor, AER 2013)
  - Geographical characteristics (climate, soil quality, disease environment, UV radiation, bounty of the sea, latitude)
    - Productivity (Sachs et al, 1999; Andersen-Dalgaard-Selaya, RES 2016)
    - Institutions conducive to development (AJR, AER 2001)
    - Cultural characteristics conducive for development (Alesina-Giuliano-Nunn, QJE 2013; Dalgaard-Knudsen-Selaya, 2016, Galor-Özak, AER 2016)

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The Neolithic Origins of Comparative Development – Diamond's Hypothesis

- The transition from hunter-gatherer tribes to agricultural communities:
  - Emergence of non-food-producing class:
    - $\Longrightarrow$ Knowledge creation (science, technology & written languages)
  - Technological head start and its persistent effect via:
    - Urbanization, nation states, colonization
- Variations in biogeographical characteristics conducive for the NR :
  - $\Longrightarrow$ Origins of the observed patterns of comparative development

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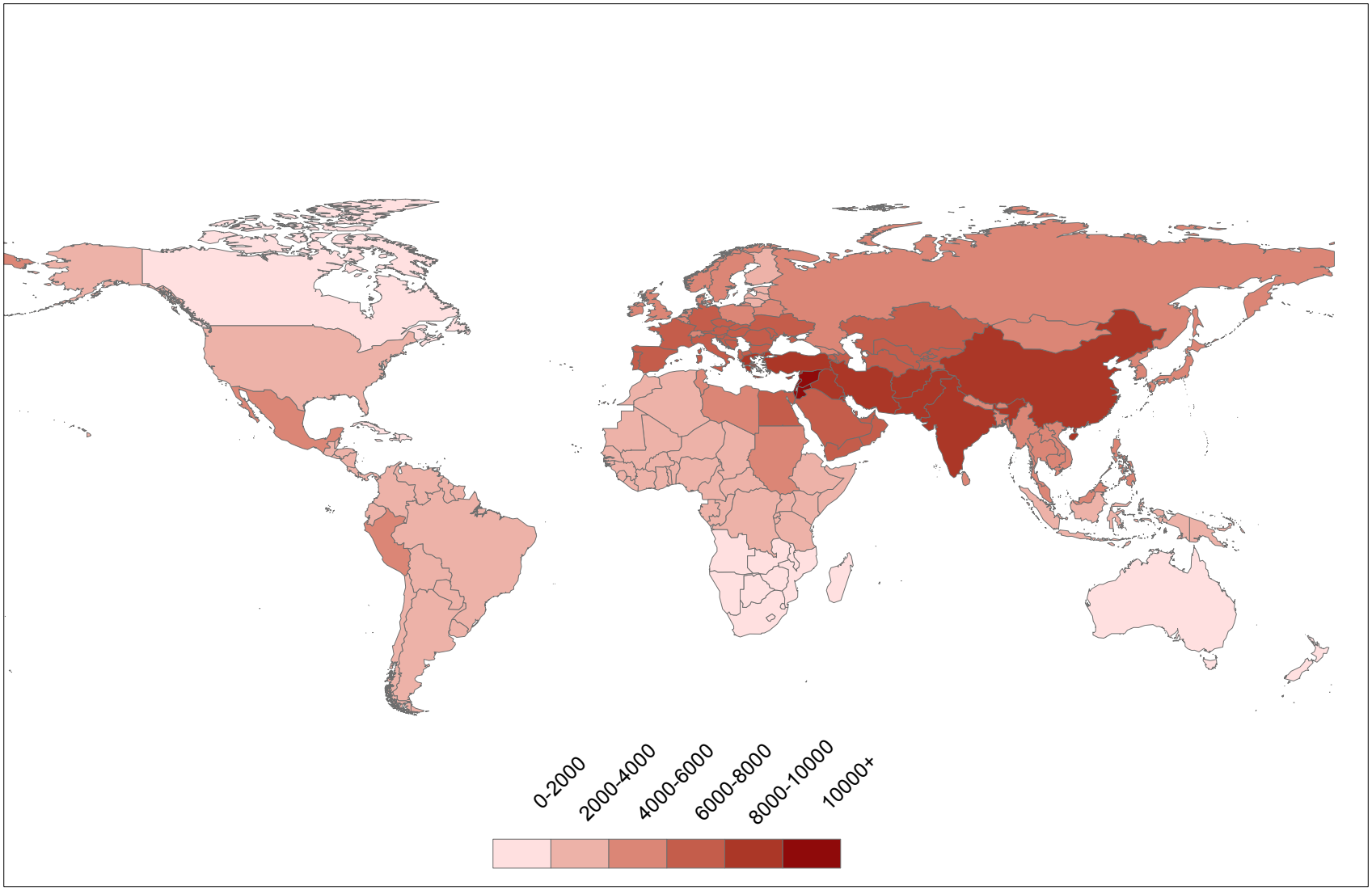
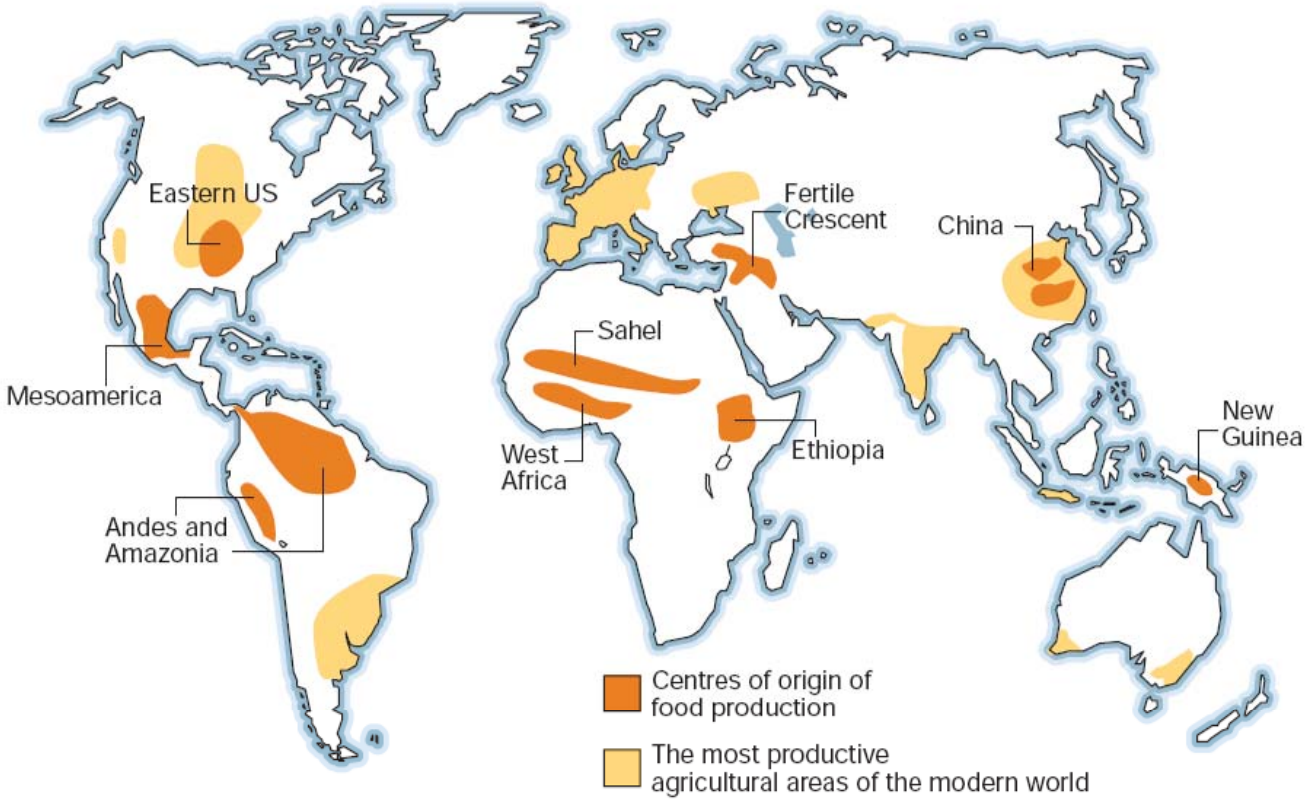
Variation in the Onset of the Neolithic Revolution

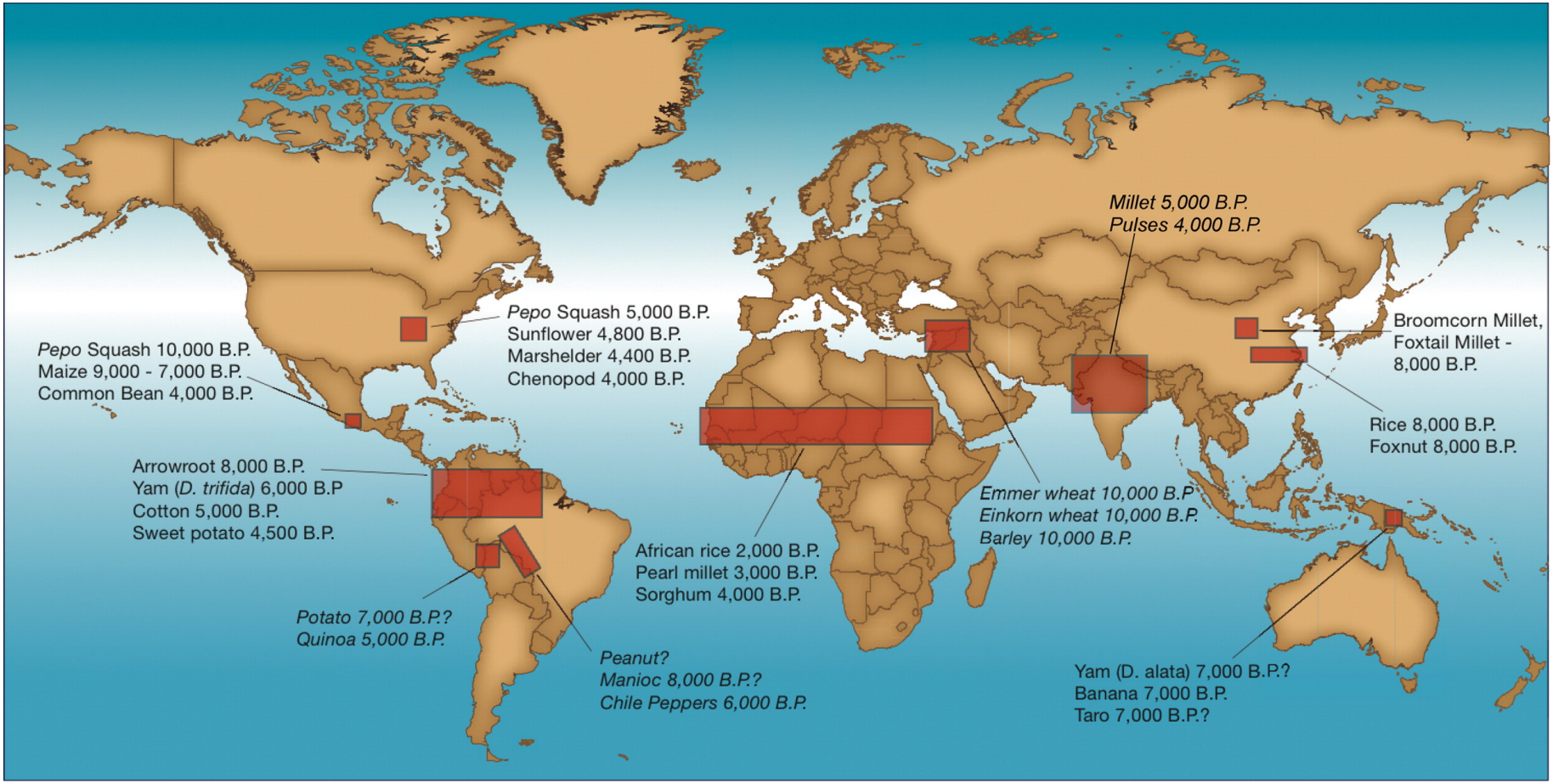


Independent Origins



Source: Diamond (Nature 2002)

Independent Origins - 2011



Biogeographical Origins of the Onset of the Neolithic Revolution

- Geographical factors that maximized biodiversity (climate, latitude, landmass)
  - Availability of domesticable species of plants and animals
    - $\Longrightarrow$ Onset of domestication
- Orientation of continents:
  - $\Longrightarrow$ Diffusion of agricultural practices along similar latitudes

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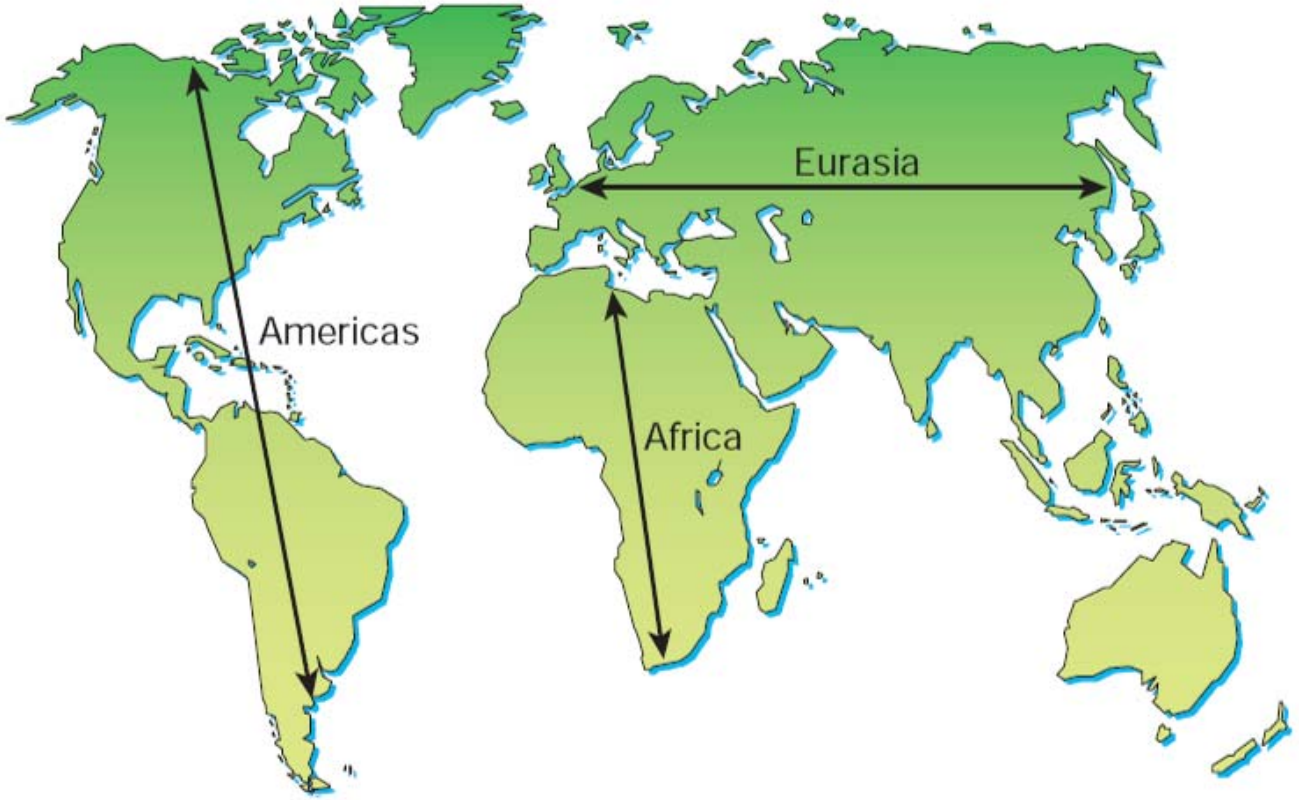
Orientation of Continents



Source: Diamond (Nature 2002)

The Diamond Hypothesis

- The domination of Euro-Asia in the pre-colonial era reflects:
  - Larger number of domesticable species of plants and animals
  - East-West orientation
    - $\Longrightarrow$ Technological head start and its effect on development
- The economic domination of Europeans and their offshoots in the post-colonial era reflects
  - Persistence of technological head start
  - Resistance to infectious diseases evolved in the aftermath of the NR
    - $\Longrightarrow$ Guns, Germs and Steel
- Variation in the timing of Neolithic Revolution:
  - Comparative development in 1491
  - Comparative development in the contemporary period

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Testable Predictions

- Earlier onset of the Neolithic Revolution:
  - During the Malthusian epoch
    - Technological superiority
    - Higher productivity (captured by population density)
  - During the contemporary era
    - Technological superiority
    - Higher income per capita (accounting for migration in the post 1500 period)

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The Neolithic Revolution & Technological Level: 1000 BCE–1500 CE

	Technology Level 1000BCE-1500CE					
	1000BCE		1CE		1500CE	
	(1)	(2)	(3)	(4)	(5)	(6)
Years Since Neolithic Revolution	0.72***	0.47***	0.56***	0.28**	0.74***	0.34***
	(0.06)	(0.12)	(0.06)	(0.12)	(0.06)	(0.10)
Continental FE	No	Yes	No	Yes	No	Yes
Additional Geographical Controls	No	Yes	No	Yes	No	Yes
Adjusted-R^2	0.51	0.60	0.31	0.63	0.55	0.82
Observations	112	111	134	133	113	112

Notes: Standardized coefficients from an Ordinary Least Squares (OLS) regression. Heteroskedasticity robust standard error estimates are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

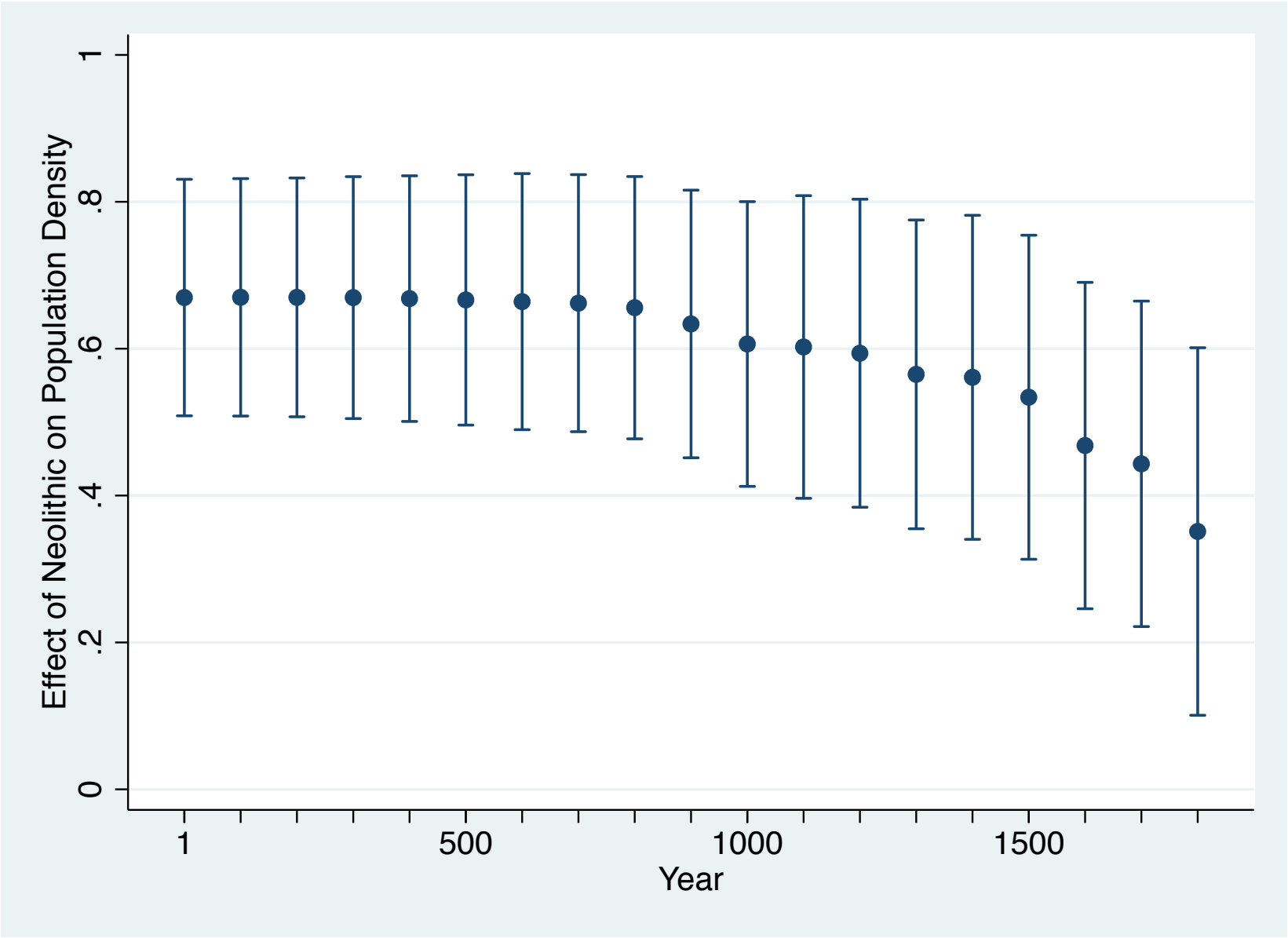
The Neolithic Revolution & Technological Level: 2000

	Technology Level 2000CE					
	(1)	(2)	(3)	(4)	(5)	(6)
Years Since Neolithic Revolution	0.15*	-0.09	-0.09			
	(0.09)	(0.08)	(0.11)			
Years Since Neolithic Revolution (Ancestors)				0.32***	0.09	0.09
				(0.07)	(0.07)	(0.10)
Continental FE	No	No	Yes	No	No	Yes
Additional Geographical Controls	No	Yes	Yes	No	Yes	Yes
Adjusted-R^2	0.02	0.55	0.59	0.10	0.55	0.59
Observations	132	131	131	132	131	131

The Neolithic Revolution and Population Density 1-1500

	Log [Population Density]							
	1CE	500CE	1000CE	1500CE	1CE	500CE	1000CE	1500CE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years Since Neolithic Revolution	0.73***	0.68***	0.58***	0.47***	0.67***	0.67***	0.61***	0.53***
	(0.05)	(0.06)	(0.06)	(0.07)	(0.08)	(0.09)	(0.10)	(0.11)
Caloric Suitability (pre-1500CE)					0.22***	0.28***	0.36***	0.45***
					(0.06)	(0.07)	(0.09)	(0.09)
Continental FE	No	No	No	No	Yes	Yes	Yes	Yes
R^2	0.54	0.46	0.33	0.22	0.63	0.57	0.48	0.42
Adjusted-R^2	0.54	0.45	0.33	0.21	0.61	0.54	0.45	0.39
Observations	169	169	169	169	169	169	169	169

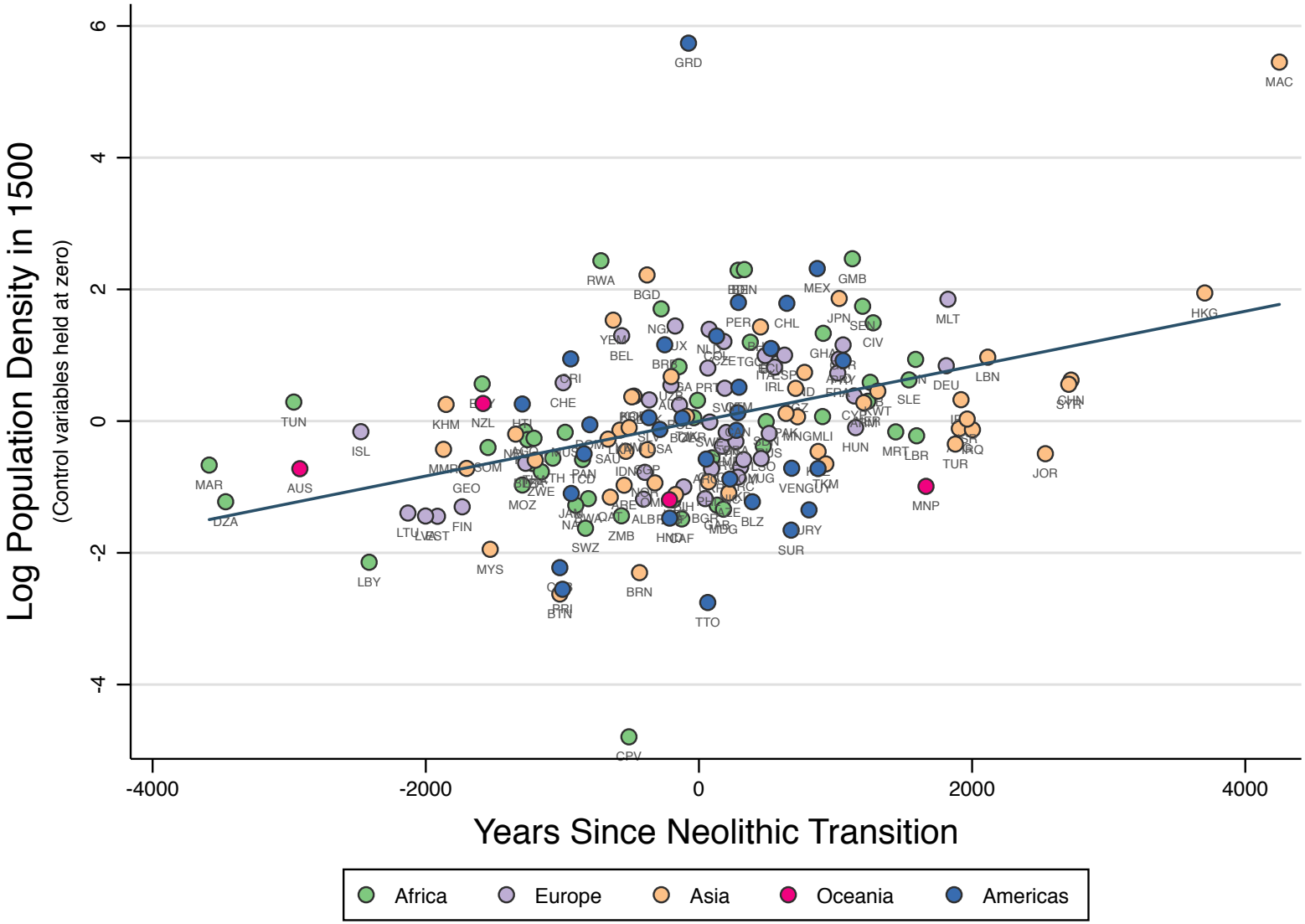
The Neolithic Revolution and Population Density 1-1500



The Neolithic Revolution on Population Density in 1500

	Log [Population Density 1500CE]			
	(1)	(2)	(3)	(4)
Years Since Neolithic Revolution	0.47***	0.54***	0.55***	0.56***
	(0.07)	(0.12)	(0.12)	(0.12)
Caloric Suitability (pre-1500CE)		0.45***	0.43***	0.43***
		(0.09)	(0.09)	(0.08)
Predicted Genetic Diversity				7.42**
				(3.34)
Predicted Genetic Diversity Squared				-6.83**
				(3.37)
Continental FE	No	Yes	Yes	Yes
Additional Geographical Controls	No	No	Yes	Yes
Adjusted-R^2	0.21	0.39	0.49	0.52
Observations	168	168	168	168

The Neolithic Revolution on Population Density in 1500



The Neolithic Revolution on Urbanization in 1-1500

	Log [Urbanization 1-1500CE]		
	1CE	1000CE	1500CE
	(1)	(2)	(3)
Years Since Neolithic Revolution	0.52**	0.35**	-0.15
	(0.23)	(0.16)	(0.13)
Caloric Suitability (pre-1500CE)	-0.06	0.08	0.27**
	(0.18)	(0.18)	(0.13)
Continental FE	Yes	Yes	Yes
Additional Geographical Controls	Yes	Yes	Yes
Adjusted-R^2	0.14	0.20	0.23
Observations	125	125	125

The Neolithic Revolution on Urbanization in 1500

	Log [Urbanization 1500CE]			
	(1)	(2)	(3)	(4)
Years Since Neolithic Revolution	0.38***	0.11	-0.07	0.02
	(0.09)	(0.11)	(0.10)	(0.12)
Caloric Suitability (pre-1500CE)		0.01	0.27**	0.31***
		(0.15)	(0.12)	(0.09)
Predicted Genetic Diversity				21.00***
				(6.55)
Predicted Genetic Diversity Squared				-20.06***
				(6.97)
Continental FE	No	Yes	Yes	Yes
Additional Geographical Controls	No	No	Yes	Yes
Adjusted-R^2	0.13	0.25	0.45	0.68
Observations	84	84	84	84

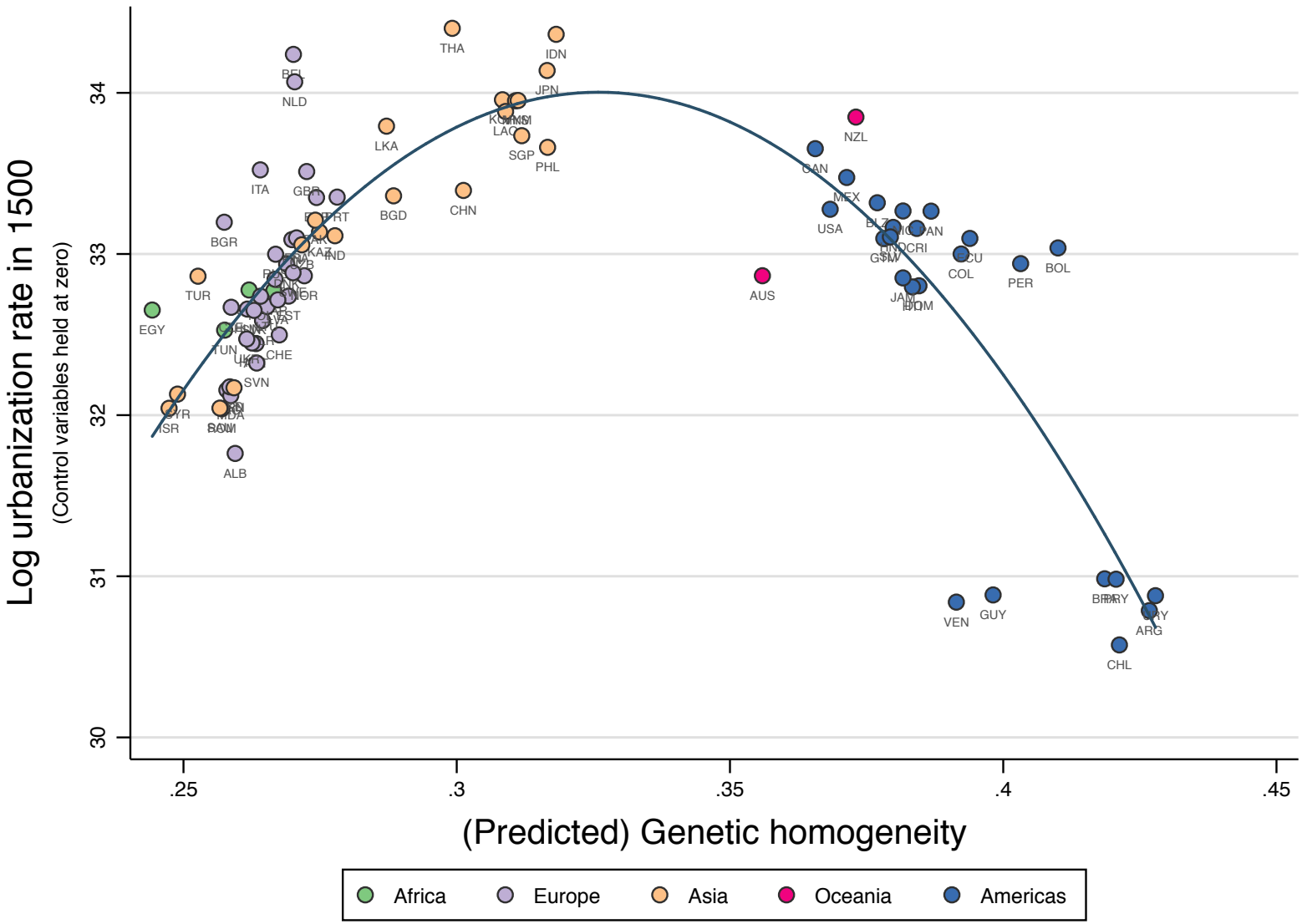
The Effect of the NR on Population Density and Urbanization in 1500

	Development in 1500CE			
	Log [PD]		Log [UR]	
	(1)	(2)	(3)	(4)
Years Since Neolithic Revolution	0.37***	0.48***	-0.07	0.02
	(0.09)	(0.12)	(0.10)	(0.12)
Caloric Suitability (pre-1500CE)	0.39***	0.44***	0.27**	0.31***
	(0.11)	(0.09)	(0.12)	(0.09)
Predicted Genetic Diversity		16.97***		21.00***
		(5.62)		(6.55)
Predicted Genetic Diversity Squared		-16.68***		-20.06***
		(5.94)		(6.97)
Continental FE	Yes	Yes	Yes	Yes
Additional Geographical Controls	Yes	Yes	Yes	Yes
Adjusted-R^2	0.66	0.76	0.45	0.68
Observations	84	84	84	84

The Effect of the NR on Population Density and Urbanization in 1500

	Development in 1500CE Semi-Partial R^2			
	Log [PD]		Log [UR]	
	(1)	(2)	(3)	(4)
Years Since Neolithic Revolution	0.05***	0.05***	0.00	0.00
Caloric Suitability (pre-1500CE)	0.05***	0.06***	0.03**	0.03***
Predicted Genetic Diversity		0.03***		0.05***
Predicted Genetic Diversity Squared		0.03***		0.04***
Continental FE	Yes	Yes	Yes	Yes
Additional Geographical Controls	Yes	Yes	Yes	Yes
Adjusted-R^2	0.66	0.76	0.45	0.68
Observations	84	84	84	84

Genetic Diversity and Urbanization in 1500



Interpretation

- The Neolithic Revolution has a dual effect on development
  - Technological head start $\Longrightarrow$ higher population density
  - Comparative advantage in agriculture $\Longrightarrow$ higher population density
    - Positive overall effect on population density
  - Technological head start $\Longrightarrow$ higher urbanization
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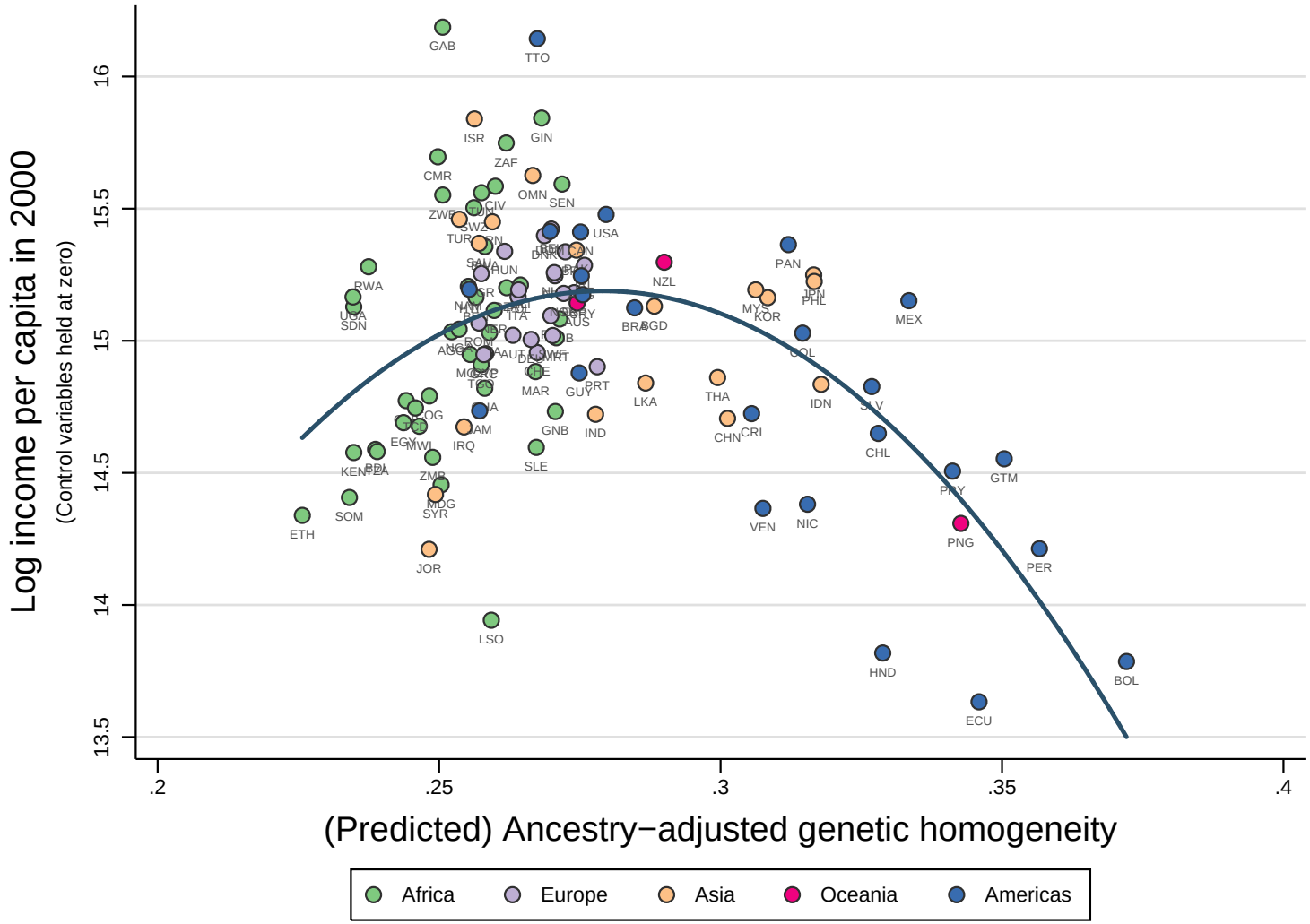
The Neolithic Revolution and Income per Capita in 2000

	Log [GDPpc 2000CE]						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Years Since Neolithic Revolution	0.40***	-0.07	0.01				-0.34**
	(0.08)	(0.10)	(0.09)				(0.15)
Years Since Neolithic Revolution (Ancestors)				0.59***	0.08	0.11	0.40***
				(0.08)	(0.10)	(0.09)	(0.14)
Caloric Suitability (pre-1500CE)		-0.26***	-0.18**		-0.26***	-0.16*	-0.13
		(0.09)	(0.09)		(0.09)	(0.09)	(0.09)
Predicted Genetic Diversity (Ancestors)			7.47***			7.52***	6.48***
			(2.33)			(2.29)	(2.18)
Predicted Genetic Diversity (Ancestors, Sq.)			-7.55***			-7.62***	-6.66***
			(2.36)			(2.32)	(2.20)
Continental FE	No	Yes	Yes	No	Yes	Yes	Yes
Additional Geographical Controls	No	Yes	Yes	No	Yes	Yes	Yes
Legal Origin FE	No	No	Yes	No	No	Yes	Yes
R^2	0.16	0.78	0.84	0.34	0.78	0.84	0.85
Adjusted-R^2	0.15	0.74	0.80	0.34	0.74	0.80	0.81
Observations	111	111	111	111	111	111	111

Genetic Diversity and Income per Capita in 2000



The Dual Effect of the NR on Life Expectancy

- The Neolithic Revolution increased the exposure and the vulnerability of humans to infectious diseases via the:
  - Rise in population density
  - Domestication of animals
  - Increase in work effort
- Natural selection of individuals who were genetically pre-disposed towards resistance to infectious diseases
  - Reduction in mortality from infectious diseases (Galor and Moav, 2005, 2007)
  - An increase in the prevalence of autoimmune diseases (Franck-Galor-Özak, 2016)
- Variation in the timing of the Neolithic Revolution among the ancestral populations of each region contributed to the variation in life expectancy across regions

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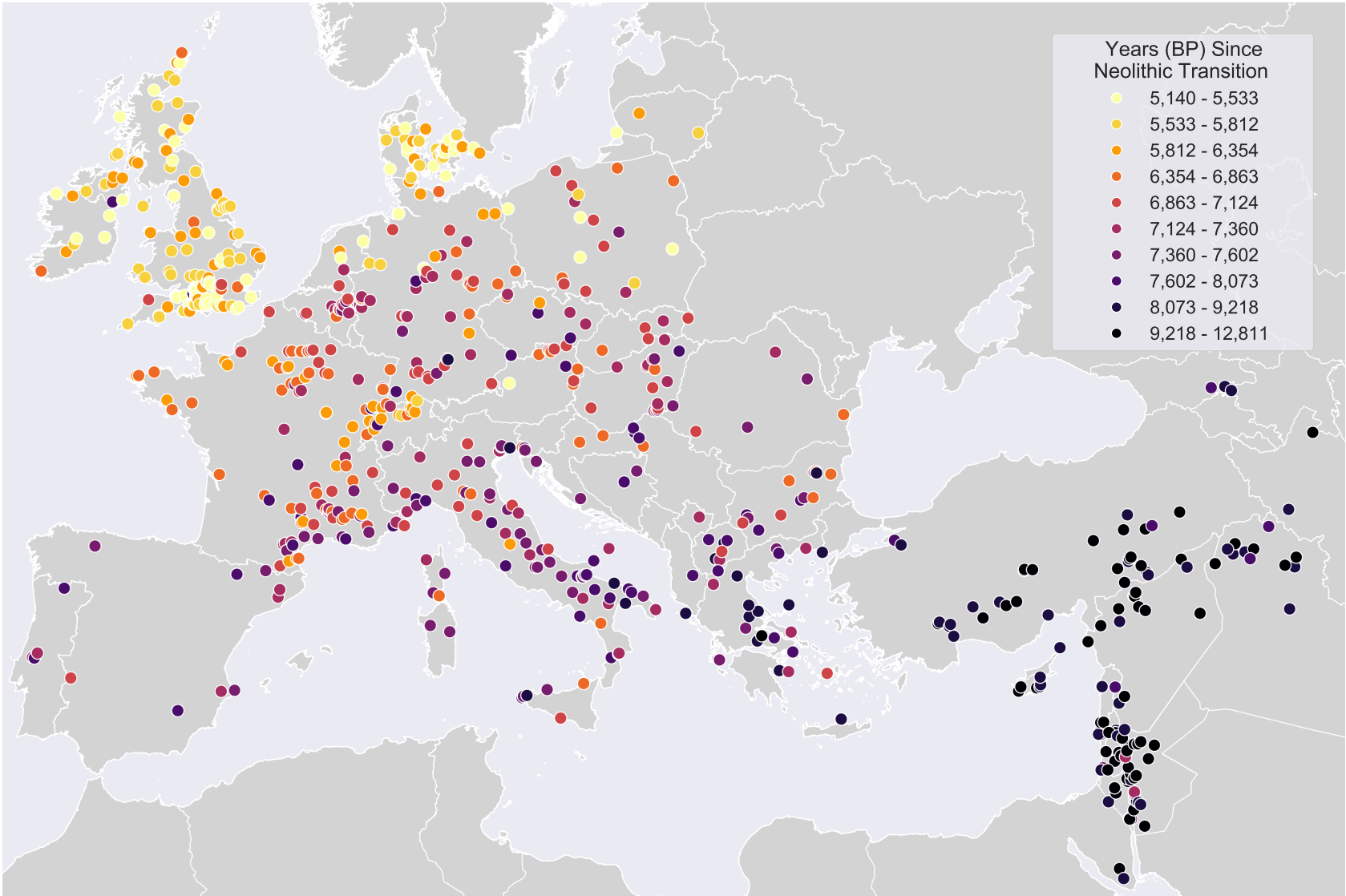
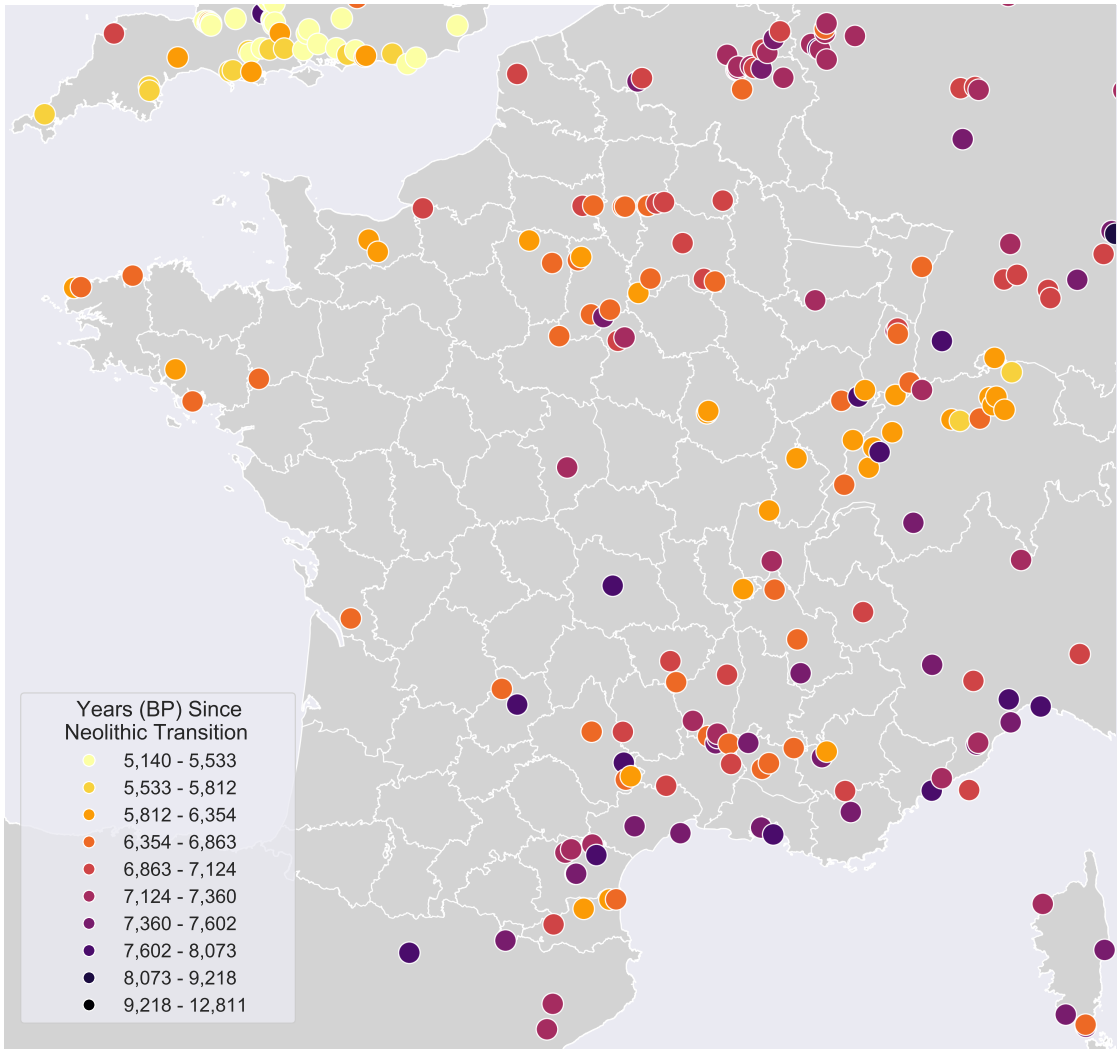
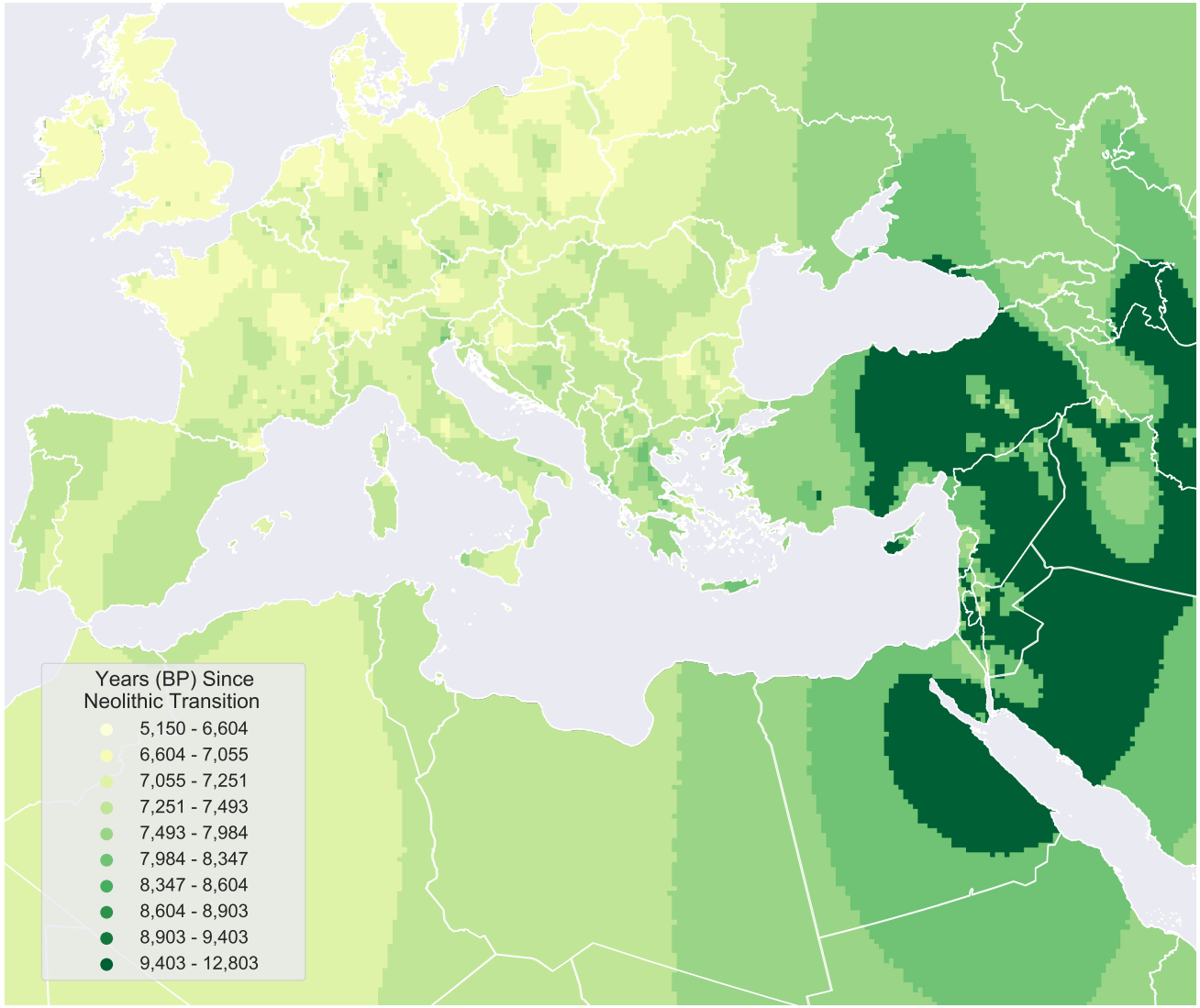
The Timing of the Neolithic Revolution in Europe and the Middle East



The Timing of the Neolithic Revolution in France



Projected Timing of the Neolithic Revolution in Europe and the Middle East



Source: (Franck-Galor-Özak, 2016)

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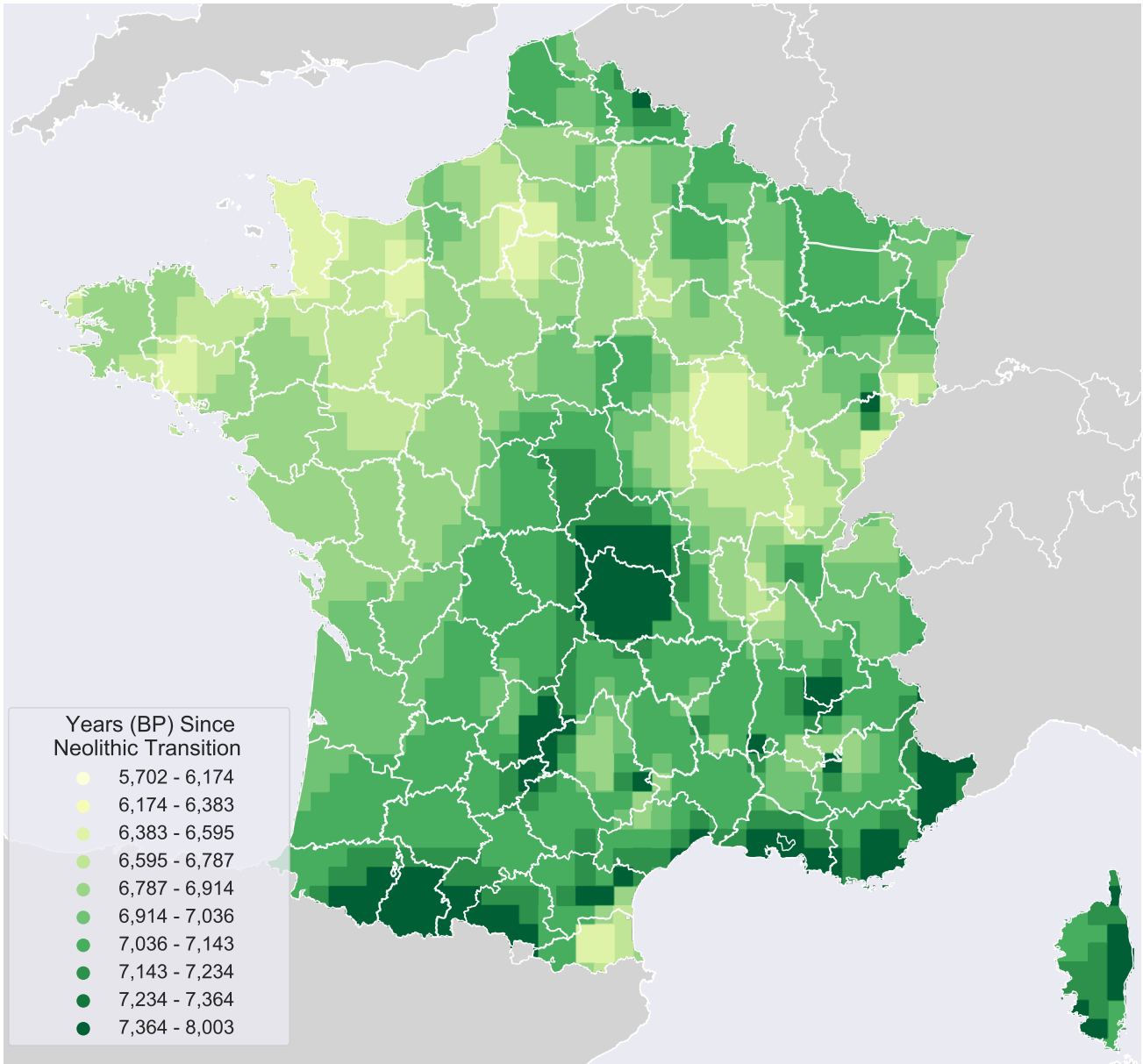
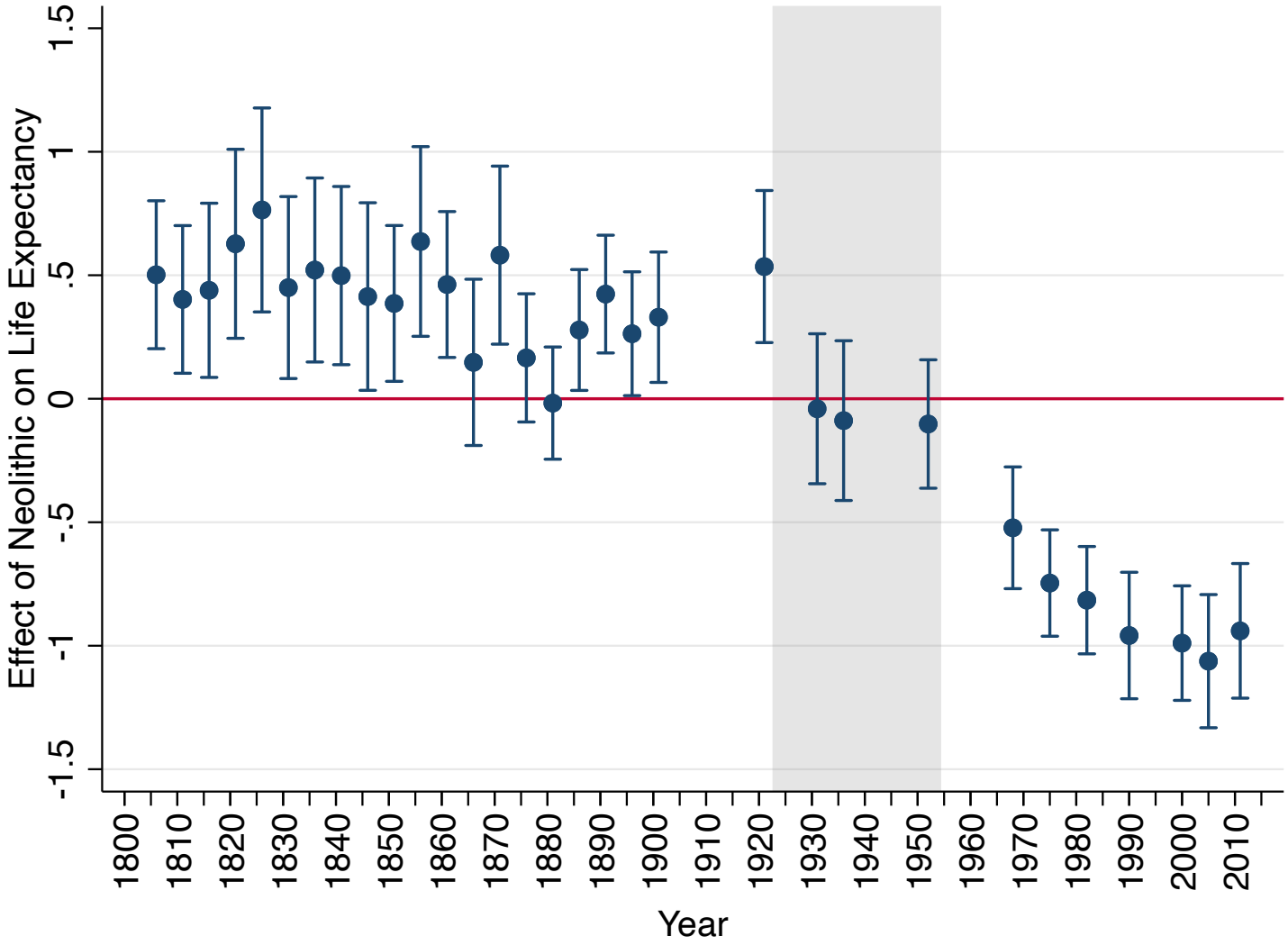


The Effect of the NR on the Evolution of Life Expectancy: France 1806-2013



Source:

(Franck-Galor-Özak, 2016)

The Neolithic Origins and Mortality: French Towns 1901

	Mortality Rate across Towns (1900)									
	All Diseases		Infectious (Air)		Infectious (Water)		Suicides		Violent Deaths	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Years Since Neolithic Revolution	-0.40***	-0.69***	-0.34***	-0.59***	0.14	0.07	0.10	0.12	-0.07	0.04
	(0.12)	(0.23)	(0.10)	(0.18)	(0.16)	(0.30)	(0.12)	(0.19)	(0.09)	(0.17)
GDP per capita (1901)		0.05		0.12		0.01		0.09		-0.03
		(0.09)		(0.08)		(0.07)		(0.07)		(0.08)
Main Geographical Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
First-stage F-statistic	33.44	13.05	33.44	13.05	33.44	13.05	33.44	13.05	33.44	13.05
Adjusted-R^2	0.02	-0.03	0.08	0.08	0.15	0.18	-0.01	0.00	0.09	0.09
Observations	588	588	588	588	588	588	588	588	588	588

Source: (Franck-Galor-Özak, 2016)

The Neolithic Origins of Diseases: French Departments 2000-2013

	Incidence							Prevalence	
	Arterial ischemic events	Liver disease & cirrhosis	Diabetes	Respiratory failure	Alzheimer's disease & other dementias	Nephropathy	Ulcerative colitis & Crohn's disease	Coronary artery disease	Mechanical Heart Disease Heart Disease
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Years Since Neolithic Revolution	0.49***	0.57***	0.58***	0.42**	0.37**	0.50***	1.00***	0.42***	-0.01
	(0.18)	(0.13)	(0.11)	(0.18)	(0.15)	(0.17)	(0.15)	(0.16)	(0.17)
GDP per capita (2000-2010)	-0.41***	0.19**	-0.17*	-0.11	-0.08	0.19**	0.48***	-0.37***	-0.37***
	(0.10)	(0.10)	(0.09)	(0.10)	(0.13)	(0.09)	(0.14)	(0.12)	(0.11)
Main Geographical Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Population Density (1700)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
First-stage F-statistic	50.19	50.19	50.19	50.19	50.19	50.19	50.19	50.19	50.19
Adjusted-R^2	0.35	0.52	0.59	0.52	0.26	0.38	0.38	0.21	0.17
Observations	89	89	89	89	89	89	89	89	89

Source: (Franck-Galor-Özak, 2016)

The Neolithic Origins of Mortality: French Departments 2000-2013

	Non-Medical Death Rates per 100,000								
	Alcohol Abuse			Accidents			Falls		
	All	Female	Male	All	Female	Male	All	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Years Since Neolithic Revolution	-0.06	0.19	-0.12	-0.08	-0.04	-0.10	-0.24	-0.26	-0.20
	(0.12)	(0.14)	(0.12)	(0.15)	(0.16)	(0.14)	(0.17)	(0.19)	(0.15)
GDP per capita (2000-2010)	-0.53***	-0.36***	-0.55***	-0.66***	-0.61***	-0.67***	-0.55***	-0.52***	-0.53***
	(0.09)	(0.11)	(0.09)	(0.11)	(0.11)	(0.11)	(0.14)	(0.14)	(0.13)
Main Geographical Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Population Density (1700)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
First-stage F-statistic	50.19	50.19	50.19	50.19	50.19	50.19	49.97	49.97	49.97
Adjusted-R^2	0.53	0.46	0.52	0.58	0.48	0.61	0.47	0.32	0.53
Observations	89	89	89	89	89	89	88	88	88

Source: (Franck-Galor-Özak, 2016)

Persistence and Reversals in the Role of Geographical Factors

- Reversal in the role of
  - Land Productivity
  - Distance from the equator
- Persistence in the role of
  - Disease environment
  - Ecological diversity
  - Geographical Isolation
  - Range of land quality
  - Land suitable for large plantations

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Reversal in the Role of Land Productivity & Absolute Latitude

- Land productivity
  - 1-1500 CE
    - Positive association with population density
  - 2000s
    - Negative association with income per capita
- Absolute latitude
  - 1-1500 CE
    - Negative association with population density
  - 2000s
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Reversal in the Role of Land Productivity

	World sample (1)	Non-Colony sample (2)	Ex-Colony sample (3)	World sample (4)	Non-Colony sample (5)	Ex-Colony sample (6)
	Log Population Density			**Log Income per Capita**		
	1500			2005		
Log years since Neolithic	1.111***	0.769*	1.383***			
	(0.188)	(0.447)	(0.267)			
Log years since Neolithic (ancestry adjusted)				0.211	-0.100	0.083
				(0.322)	(0.559)	(0.382)
Log land productivity	0.568***	0.550***	0.585***	-0.494***	-0.518***	-0.456***
	(0.053)	(0.057)	(0.115)	(0.078)	0.087	0.141
Log absolute latitude	-0.330***	-0.491***	-0.302**	0.375***	0.891**	0.139
	(0.106)	(0.136)	(0.123)	(0.142)	(0.432)	(0.149)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	143	68	75	143	68	75
R^2	0.73	0.72	0.70	0.62	0.64	0.57

Additional Controls: mean distance to nearest coast & river and % land within 100 km of coast & river.
Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Land Productivity and Population Density in 1500

Conditional on years since Neolithic transition, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Land Productivity and Income per Capita in 2005

Conditional on years since Neolithic transition, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2013)

Origins of the Reversal in the Role of Land Productivity

- The effect is nearly identical in the:
  - World sample
  - Former colonies sample (Acemoglu-Johnson-Robinson, QJE 2002)
  - Non-former colonies sample
  - $\Longrightarrow$ Reversal in the role of land productivity is largely independent of the forces of colonialism
- Acquired comparative advantage in agriculture & delayed industrial transition (Galor-Mountford, RES, 2008)

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Reversal in the Role of Distance from the Equator

	World sample (1)	Non-Colony sample (2)	Ex-Colony sample (3)	World sample (4)	Non-Colony sample (5)	Ex-Colony sample (6)
	Log Population Density			**Log Income per Capita**		
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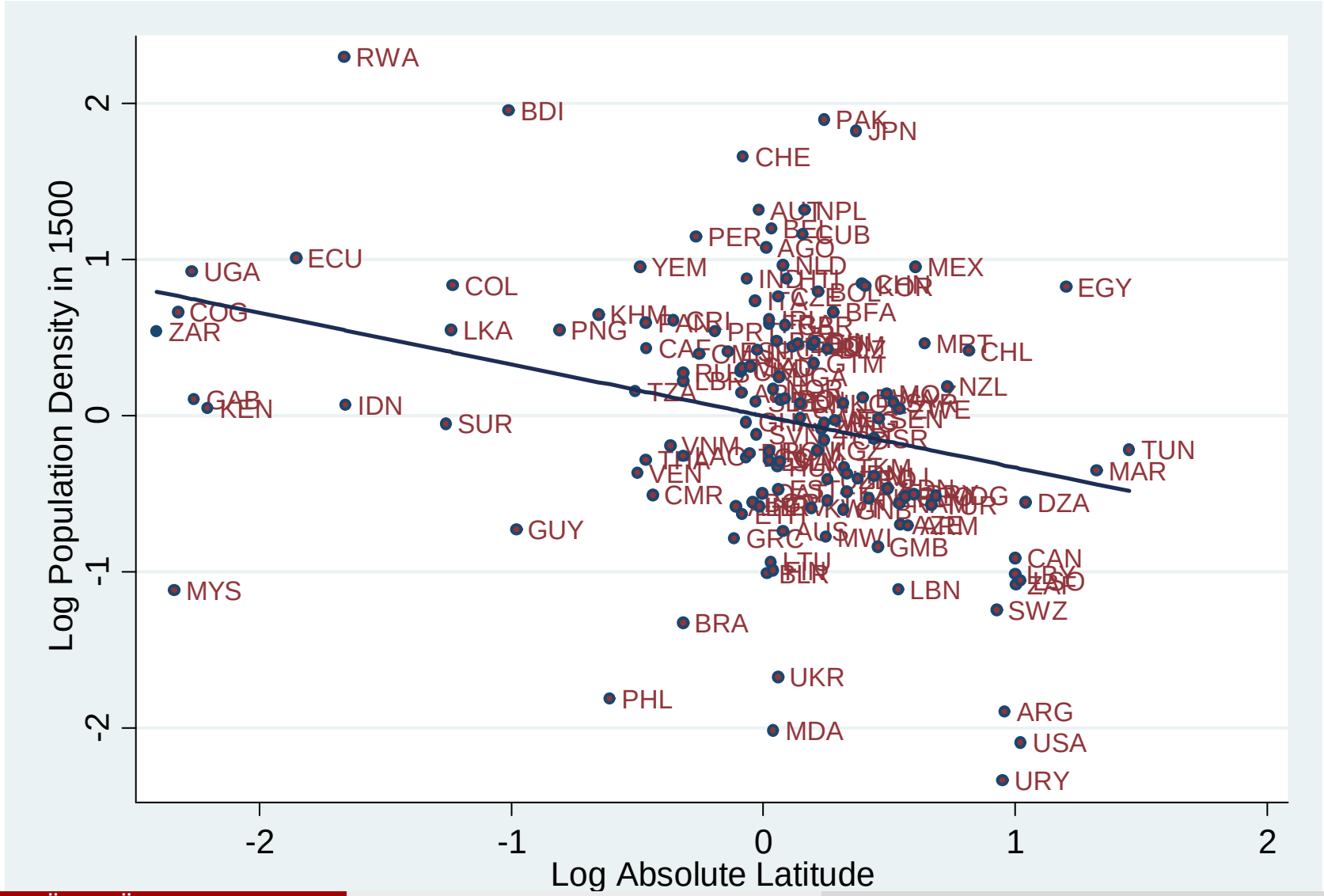
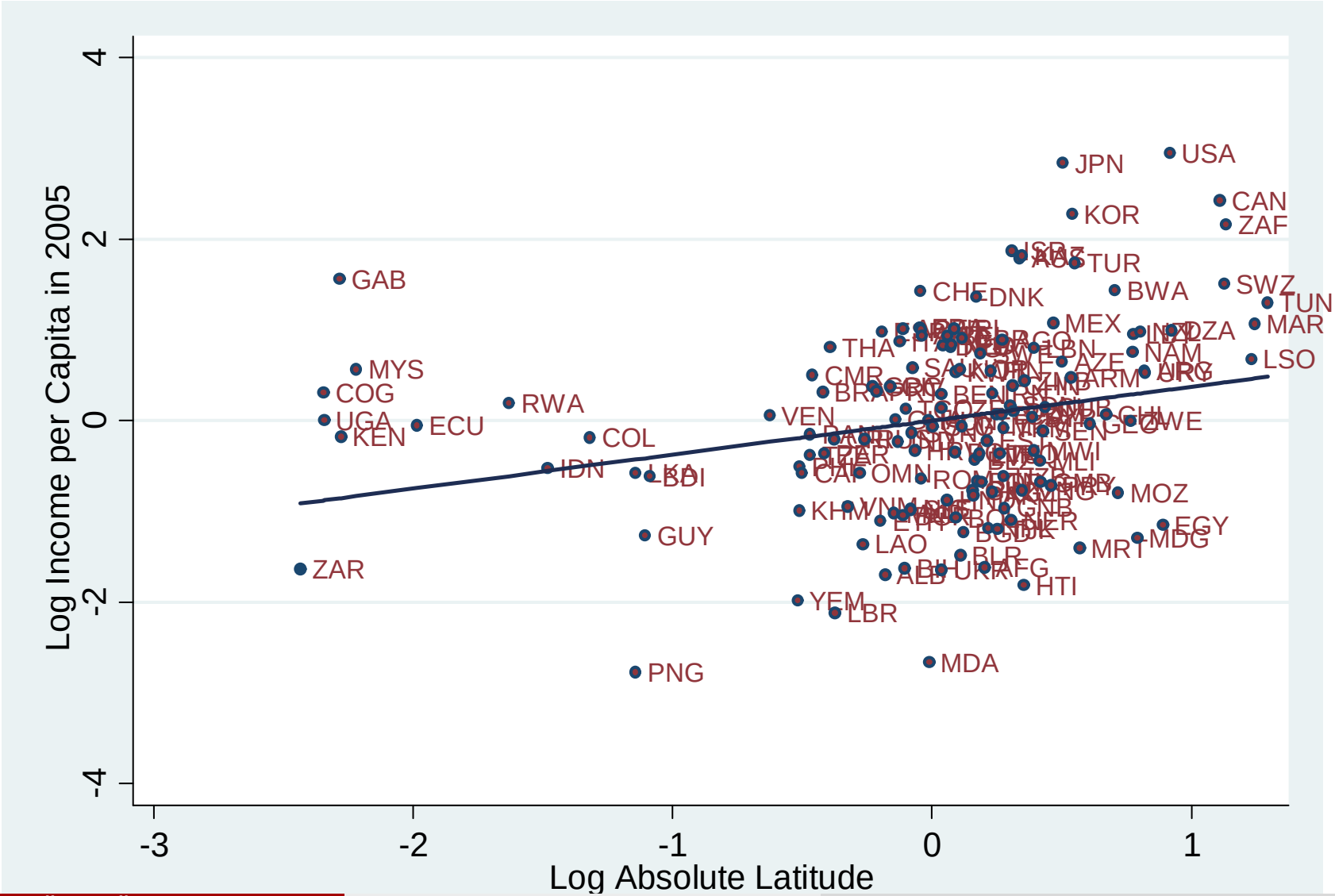
Log land productivity	0.568***	0.550***	0.585***	-0.494***	-0.518***	-0.456***
	(0.053)	(0.057)	(0.115)	(0.078)	0.087	0.141
Log absolute latitude	-0.330***	-0.491***	-0.302**	0.375***	0.891**	0.139
	(0.106)	(0.136)	(0.123)	(0.142)	(0.432)	(0.149)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	143	68	75	143	68	75
R^2	0.73	0.72	0.70	0.62	0.64	0.57

Additional Controls: mean distance to nearest coast & river and % land within 100 km of coast & river.
Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Distance from the Equator and Population Density in 1500



Distance from the Equator and Income per Capita in 2005



Origins of the Reversal in the Role of Distance from the Equator

- The effect is qualitatively similar in the:
  - World sample
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- Temperate drift hypothesis: Advanced technologies gradually complemented production in temperate zones

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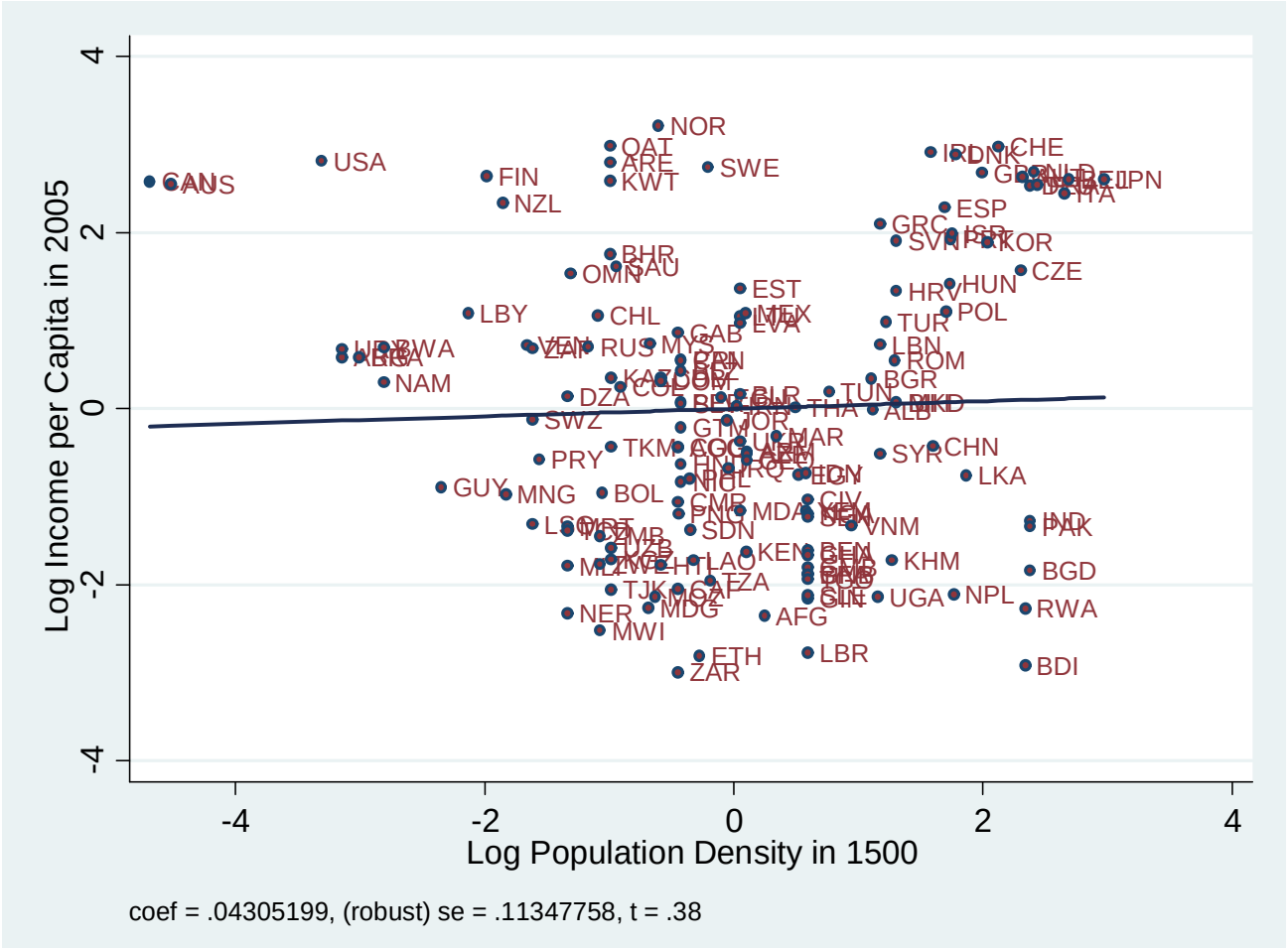
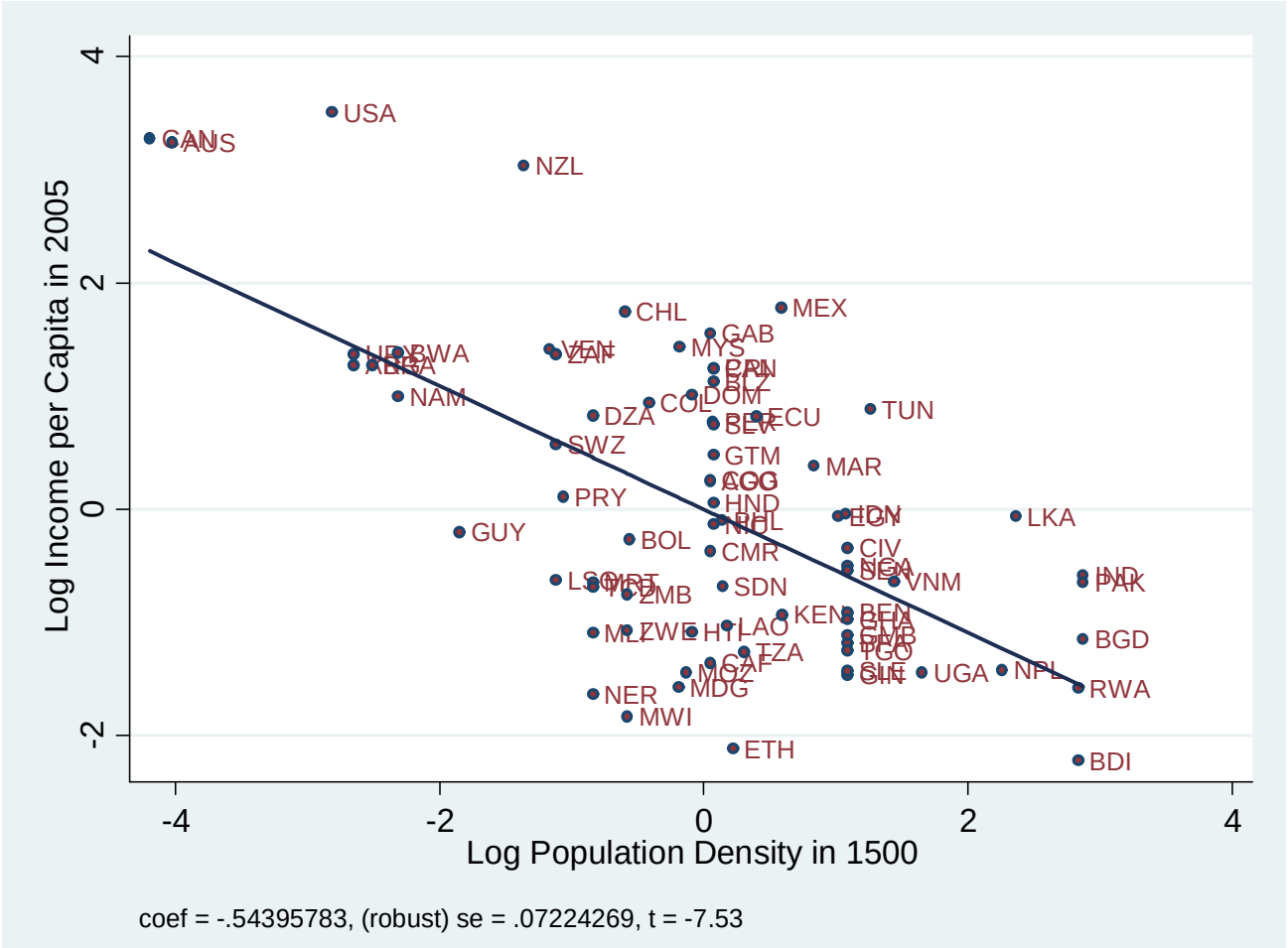
Population Density in 1500 and Income per Capita in 2005 – World Sample



coef = .04305199, (robust) se = .11347758, t = .38

Population Density in 1500 & Income per Capita in 2005 – Ex-Colonies Sample



coef = -.54395783, (robust) se = .07224269, t = -7.53

Reversal of Fortune

- This reversal in the relative performance of countries is:
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(Engerman-Sokoloff, 1997; Acemoglu et al., AER 2001, QJE 2002)

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Origins of Reversal of Fortune among Ex-Colonies

- Persistent effect of institutions implemented by colonial powers (Engerman-Sokoloff, 1997; Acemoglu et al., AER 2001, QJE 2002)
  - Exclusive (growth retarding) institutions imposed in densely populated areas
  - Inclusive (growth enhancing) institutions implemented in sparsely populated areas
- Persistent effect of the human capital and diversity brought by the colonists
  - Larger effect of colonizers in sparsely populated areas (Glaeser et al., JEG 2004; Easterly-Levine, 2016; Ashraf-Galor, 2014)

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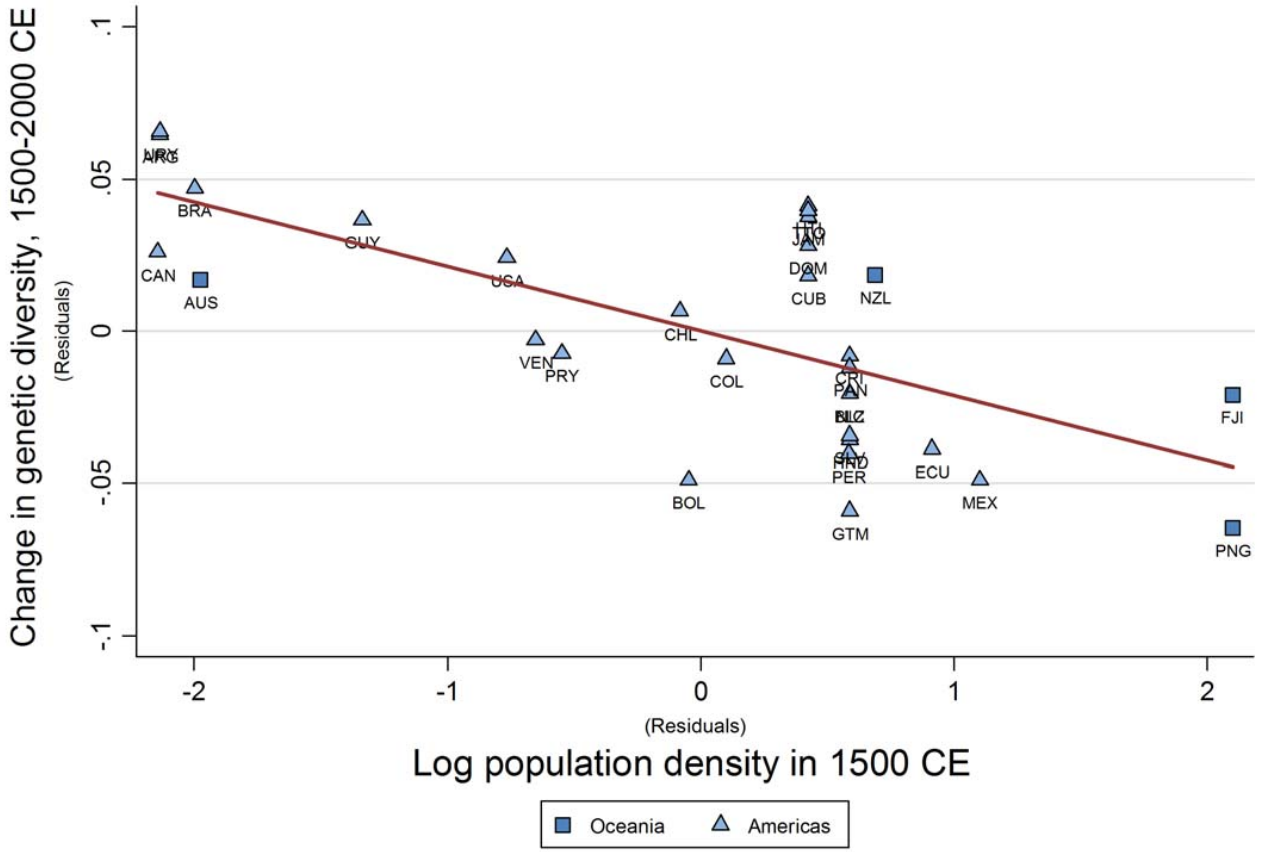
Population Density in 1500 & Subsequent Changes in Genetic Diversity



coef = -0.021; (robust) se = 0.003; t = -6.09; n = 30

Persistent Effects of Some Geographical Factors

- Disease environment
  - Persistent effect on labor productivity & investment in human capital (Gallup-Sachs, 2001; Andersen-Dalgaard-Selaya, RES 2016)
- Geographical isolation
  - Reduced trade and technological diffusion (Gallup-Mellinger-Sachs, 1999)
  - Persistence of culture conducive for innovations (Ashraf-Galor-Özak, JEEA 2010; Özak, 2011)
- Range of soil quality
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