The Malthusian Hypothesis

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Economic Growth and Comparative Development

Phases of Development: Standard of Living

- The Malthusian Epoch
- The Post-Malthusian Regime
- The Modern Growth Regime

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Phases of Development: Timeline of the Most Developed Economies

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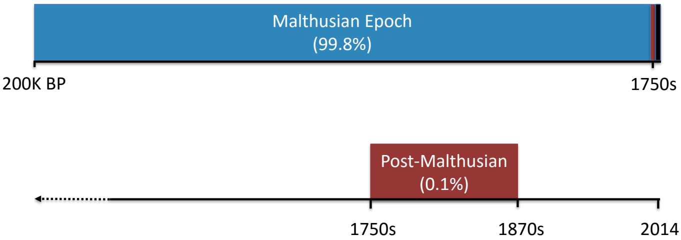

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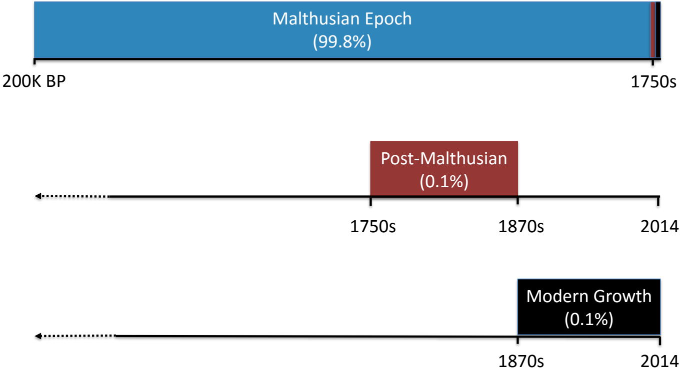

The Malthusian Epoch

- Characterized by Malthusian dynamics and the absence of economic growth
- Central characteristics of the period:
  - Positive effect of income on population growth
  - Diminishing returns to labor (reflecting the existence of fixed factor)
- Technological progress over this period
  - Increases income per capita in the short-run
  - Population adjust, as long as income remains above subsistence
  - Income per capita ultimately returns to its long-run level
- Technologically advanced & land-rich economies:
  - Higher population density
  - Similar levels of income per-capita in the long-run

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Malthusian Dynamics - Prominent Examples

- The dynamics of Irish economy (1650 - 1850)
    - Triggered by the cultivation of a new world crop – potato
- The dynamics of the Chinese Economy (1500 - 1800)
    - Triggered by superior agricultural technology
- The dynamics of the English economy (1348 - 1700)
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- The Colombian Exchange $\Longrightarrow$ massive cultivation of potato post-1650
  - 1650-1840s
    - Population increases from 2 to 6 million
    - Income per capita increases only very modestly
  - 1845-1852 Potato blight destroys crops $\Longrightarrow$ Great Famine
    - Population decreases by about 2 million
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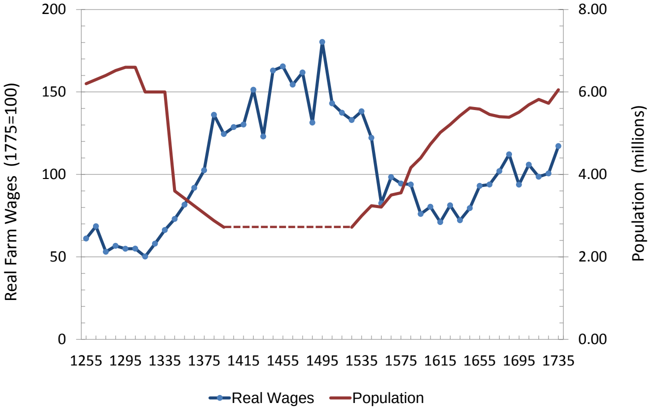
Malthusian Adjustments to the Black Death: England, 1348–1750



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- Positive effect of income on population
    - $y \uparrow \Longrightarrow L \uparrow$
- Fixed factor of production - Land
    - $L \uparrow \Longrightarrow APL \downarrow \Longrightarrow y \downarrow$

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The Basic Structure of the Model

- Overlapping-generations economy
- $t = 0, 1, 2, 3...$
- One homogeneous good
- 2 factors of production:
  - Labor
  - Land

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Production

- The output produced in period t

$$Y_t = (AX)^{\alpha} L_t^{1-\alpha} \qquad 0 < \alpha < 1$$

  - $L_t \equiv$ labor employed in period t
  - $X \equiv$ land
  - $A \equiv$ technological level
  - $AX \equiv$ effective resources

- Output per worker produced at time t

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  - Surface of planet earth
- Labor evolves endogenously
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Individuals

- Live for 2 period
  - Childhood: (1st Period):
    - Passive economic agents
    - Consume fixed amount of their parental resources
  - Adulthood (2nd Period):
    - Work
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Preferences and Budget Constraint

- Preferences of an adult at time t

$$u_t = (n_t)^{\gamma}(c_t)^{1-\gamma} \qquad 0 < \gamma < 1$$

  - $n_t \equiv$ number of children of individual t
  - $c_t \equiv$ consumption of individual t

- Budget constraint:

$$\rho n_t + c_t \leq y_t$$

  - $\rho \equiv$ cost of raising a child

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Optimization

- Optimal expenditure on consumption and children

$$c_t = (1-\gamma)y_t$$

$$\rho n_t = \gamma y_t$$

- Optimal number of children

$$n_t = \frac{\gamma}{\rho}y_t = \frac{\gamma}{\rho}\left[\frac{AX}{L_t}\right]^{\alpha}$$

  - Since $y_t = (AX/L_t)^{\alpha}$

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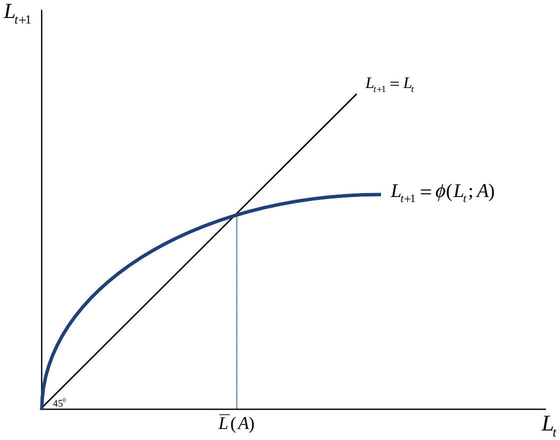

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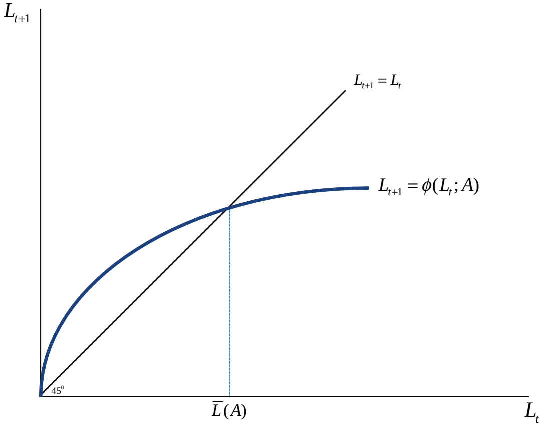
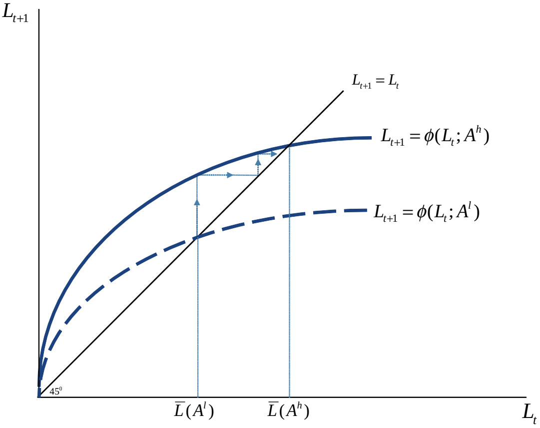


Adjustment of Population to Advancements in Technology



The Evolution of Income per Worker

- The time path of income per worker

$$y_{t+1} = \left[\frac{AX}{L_{t+1}}\right]^{\alpha} = \left[\frac{AX}{n_t L_t}\right]^{\alpha} = \frac{y_t}{n_t^{\alpha}}$$

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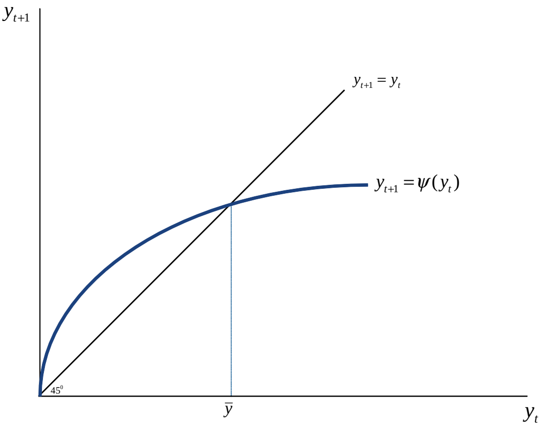

The Steady-State Level of Income per Worker

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$$\bar{y} = \left[\frac{\rho}{\gamma}\right]$$

The Steady-State Level of Income per Worker

- The time path of income per worker

$$y_{t+1} = \left[\frac{\rho}{\gamma}\right]^{\alpha} y_t^{1-\alpha}$$

- Steady-State $y_{t+1} = y_t = \bar{y}$

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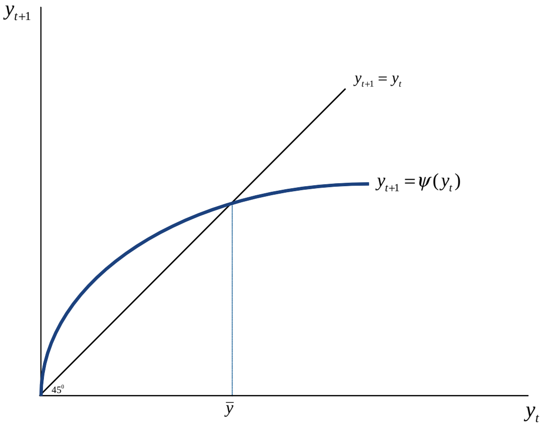
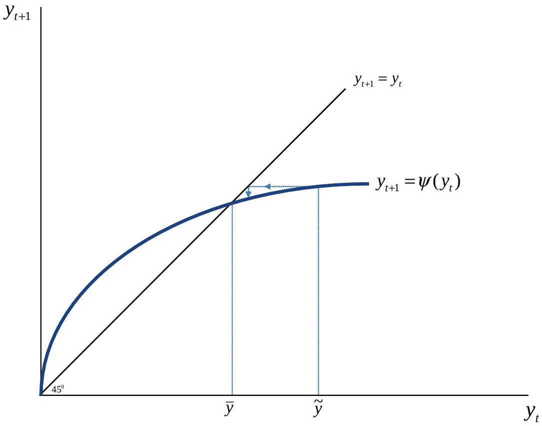
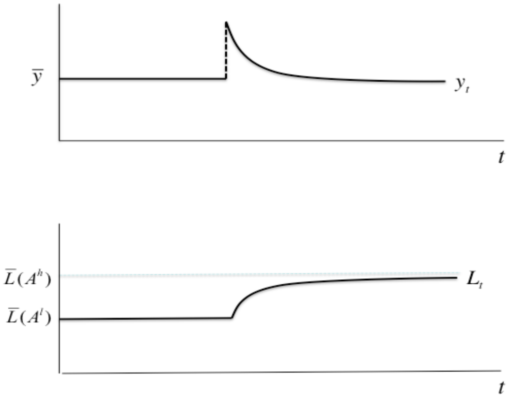
The Evolution of Income per Worker



The Effect of Technological Advancement on income per Worker



The Effect of Technological Advancement on the Time Path of Population and Income per Worker



The Effect of Advancement in Technology or Land Productivity

- Increases the short-run and the steady-state level of the working population

$$\frac{\partial L_t}{\partial A} > 0 \quad \text{and} \quad \frac{\partial \bar{L}}{\partial A} > 0$$

- Increases the level of income per capita in the short-run but does not affect the steady-state levels of income per worker

$$\frac{\partial y_t}{\partial A} > 0 \quad \text{and} \quad \frac{\partial \bar{y}}{\partial A} = 0$$

Testable Implications

- Variations in technology and land quality across countries will be reflected primarily in variation in population density:
  - Technological superiority will result primarily in higher population density without any sizable effect on income per-capita in the long-run
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Empirical Hurdles

- Objective:
  - Establish the causal effect of
    - Technology on Population in 1500
- Hurdles
  - Reverse Causality: Correlation between technology and population
    - Technology $\Longrightarrow$ Population (Malthusian forces)
    - Population $\Longrightarrow$ Technology (Scale effects [illegible])
  - Omitted Variables Bias:
    - 3rd factor (e.g., ability) affected Population & Technology

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- Exploit exogenous sources of cross-country variation in technological level
  - Historical origins (thousands of years earlier):
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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 :
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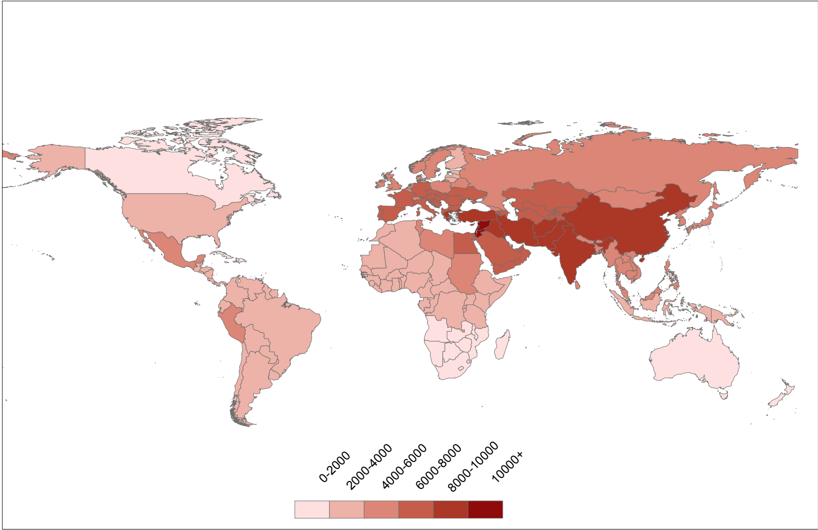
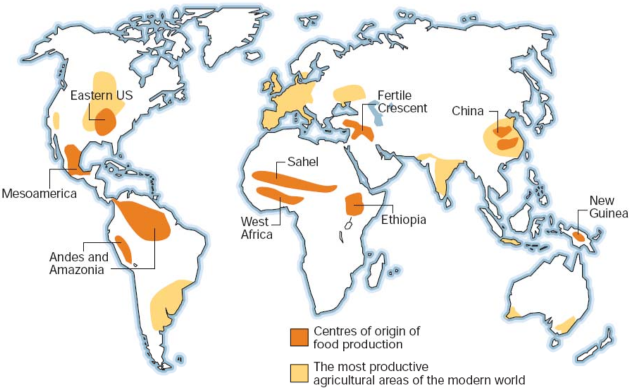
Variation in the Onset of the Neolithic Revolution



Independent Origins



Source: Diamond (Nature 2002)

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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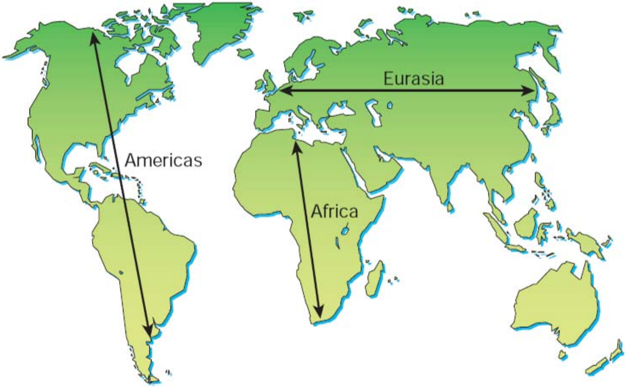

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The Diamond Hypothesis

- The domination of Euro-Asia in the pre-colonial era reflects:
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Identification Strategy

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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.

Empirical Model I

$$\ln P_{i,t} = \alpha_{0,t} + \alpha_{1,t} \ln T_{i,t} + \alpha_{2,t} \ln X_i + \alpha'_{3,t} \Gamma_i + \alpha'_{4,t} D_i + \delta_{i,t}$$

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- $P_{i,t} \equiv$ population density of country i in year t
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- $T_i \equiv$ years elapsed since the onset of agriculture in country i
- $X_i \equiv$ measure of land productivity for country i
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Determinants of Population Density in 1500 CE

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
	Dependent Variable:			**Log population density in 1500 CE**		
Log years since Neolithic	**0.833*****		**1.025)*****	**1.087*****	**1.389*****	**2.077*****
	(0.298)		**(0.223**	**(0.184)**	**(0.224)**	**(0.391)**
Log land productivity		**0.587*****	**0.641*****	**0.576*****	**0.573*****	**0.571*****
		(0.071)	**(0.059)**	**(0.052)**	**(0.095)**	**(0.082)**
Log absolute latitude		-0.425***	-0.353***	-0.314***	-0.278**	-0.248**
		(0.124)	(0.104)	(0.103)	(0.131)	(0.117)
Distance to nearest coast or river				-0.392***	0.220	0.250
				(0.142)	(0.346)	(0.333)
% land within 100 km of coast or river				0.899***	1.185***	1.350***
				(0.282)	(0.377)	(0.380)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	147	147	147	147	96	96
R^2	0.40	0.60	0.66	0.73	0.73	0.70
First-stage F-statistic						14.65
Overident. p-value						0.44

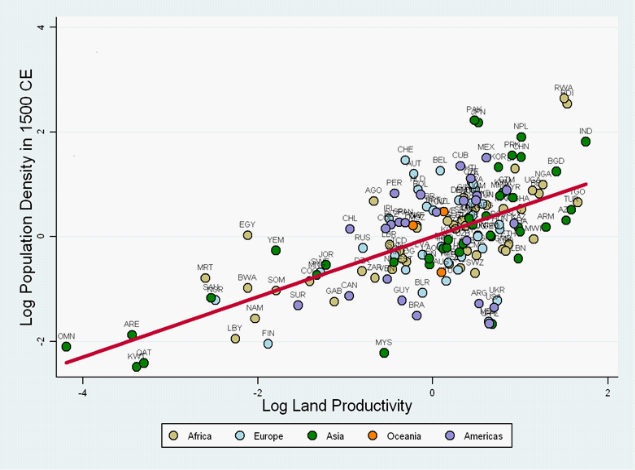
Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Effects on Income per Capita versus Population Density

	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
	Log Income Per Capita in			Log Population Density in		
	1500 CE	1000 CE	1 CE	1500 CE	1000 CE	1 CE
Log years since Neolithic	**0.159**	**0.073**	**0.109**	**1.337****	**0.832****	**1.006****
	(0.136)	(0.045)	(0.072)	(0.594)	(0.363)	(0.483)
Log land productivity	**0.041**	**-0.021**	**-0.001**	**0.584*****	**0.364*****	**0.681****
	(0.025)	(0.025)	(0.027)	(0.159)	(0.110)	(0.255)
Log absolute latitude	-0.041	0.060	-0.175	0.050	-2.140**	-2.163**
	(0.073)	(0.147)	(0.175)	(0.463)	(0.801)	(0.979)
Distance to nearest coast or river	0.215	-0.111	0.043	-0.429	-0.237	0.118
	(0.198)	(0.138)	(0.159)	(1.237)	(0.751)	(0.883)
% land within 100 km of coast or river	0.124	-0.150	0.042	1.855**	1.326**	0.228
	(0.145)	(0.121)	(0.127)	(0.820)	(0.615)	(0.919)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	31	26	29	31	26	29
R^2	0.66	0.68	0.33	0.88	0.95	0.89

Notes: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

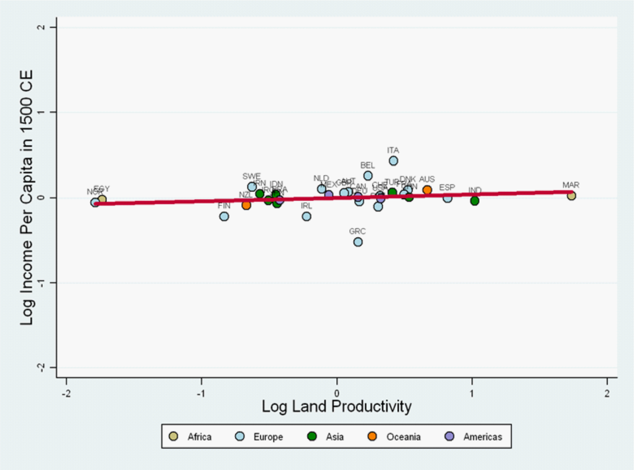
Land Productivity and Population Density in 1500



Conditional on transition timing, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Land Productivity and Income per Capita in 1500



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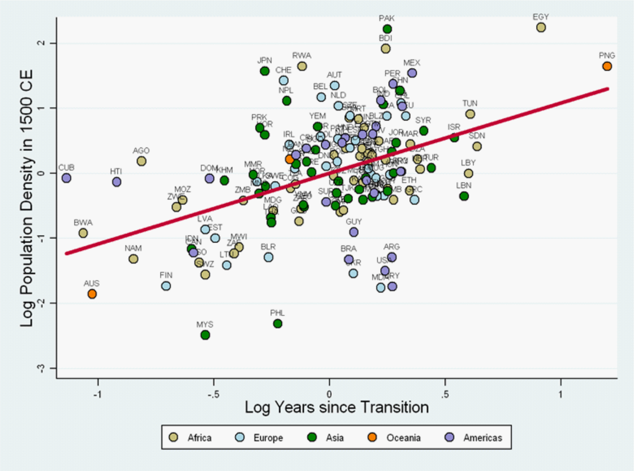
Source: Ashraf-Galor (AER 2011)

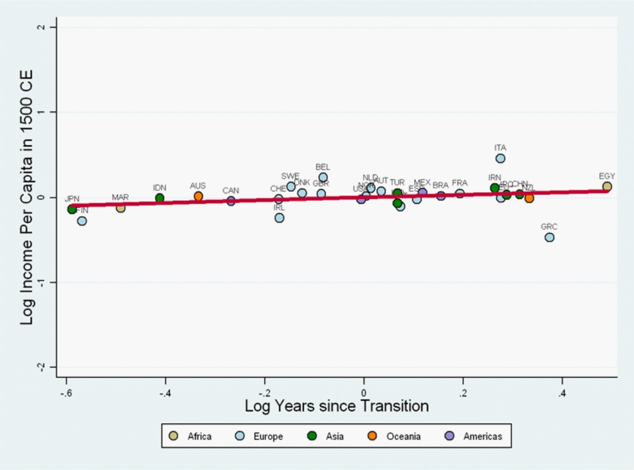
Technology and Population Density in 1500



Years elapsed since the Neolithic Transition reflects the technological level in 1500.

Conditional on land productivity, geographical factors, and continental fixed effects.

Technology and Income per Capita in 1500



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Robustness of Identification Strategy

- Robustness to the inclusion of direct measures of technology
  - Exploit variation in a direct measure of the technology level
  - Variation in prehistoric biogeographic endowments – IV for this direct measure of technology
- Robustness to the distance from the technological frontier
- Robustness to the exclusion of unobserved time-invariant country fixed effects
  - First-difference estimation strategy (with a lagged explanatory variable)
  - The effect of changes in the level of technology in 1000 BCE-1 CE on population density and income per capita in 1-1000CE

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Robustness to Direct Measures of Technological Level

	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable:					
	Log Population Density in:		Log Income Per Capita in:		Log Population Density in:	
	1000 CE	1 CE	1000 CE	1 CE	1000 CE	1 CE
Log Technology Index in Relevant Period	4.315***	4.216***	0.064	0.678	12.762***	7.461**
	(0.850)	(0.745)	(0.230)	(0.432)	(0.918)	(3.181)
Log land productivity	0.449***	0.379***	-0.016	0.004	0.429**	0.725**
	(0.056)	(0.082)	(0.030)	(0.033)	(0.182)	(0.303)
Log absolute latitude	-0.283**	-0.051	0.036	-0.198	-1.919***	-2.350***
	(0.120)	(0.127)	(0.161)	(0.176)	(0.576)	(0.784)
Distance to nearest coast or river	-0.638***	-0.782***	-0.092	0.114	0.609	0.886
	(0.188)	(0.198)	(0.144)	(0.164)	(0.469)	(0.904)
% land within 100 km of coast or river	0.385	0.237	-0.156	0.092	1.265**	0.788
	(0.313)	(0.329)	(0.139)	(0.136)	(0.555)	(0.934)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	140	129	26	29	26	29
R^2	0.61	0.62	0.64	0.30	0.97	0.88

Notes: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The Causal Effect of Technological Level on Population Density

	OLS	OLS	IV	OLS	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Population Density in:					
	1000CE			1CE		
Log Technology Index in Relevant Period	4.315***	4.198***	14.530***	4.216***	3.947***	10.798***
	(0.850)	(1.164)	(4.437)	(0.745)	(0.983)	(2.857)
Log land productivity	0.449***	0.498***	0.572***	0.379***	0.350**	0.464**
	(0.056)	(0.139)	(0.148)	(0.082)	(0.172)	(0.182)
Log absolute latitude	-0.283**	-0.185	-0.209	-0.051	0.083	-0.052
	(0.120)	(0.151)	(0.209)	(0.127)	(0.170)	(0.214)
Distance to nearest coast or river	-0.638***	-0.363	-1.155*	-0.782***	-0.625	-0.616
	(0.188)	(0.426)	(0.640)	(0.198)	(0.434)	(0.834)
% land within 100 km of coast or river	0.385	0.442	0.153	0.237	0.146	-0.172
	(0.313)	(0.422)	(0.606)	(0.329)	(0.424)	(0.642)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	140	92	92	129	83	83
R^2	0.61	0.55	0.13	0.62	0.58	0.32
First-stage F-statistic			12.52			12.00
Overid. p-value			0.941			0.160

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Robustness to Technology Diffusion and other Geographic Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Population Density in 1500		Log Income Per Capita in 1500		Log Population Density in 1500	
Log Technology Index in Relevant Period	0.828***	0.877***	0.117	0.103	1.498**	1.478**
	(0.208)	(0.214)	(0.221)	(0.214)	(0.546)	(0.556)
Log land productivity	0.559***	0.545***	0.036	0.047	0.596***	0.691***
	(0.048)	(0.063)	(0.032)	(0.037)	(0.123)	(0.122)
Log Distance to Frontier	-0.186***	-0.191***	-0.005	-0.001	-0.130*	-0.108*
	(0.035)	(0.036)	(0.011)	(0.013)	(0.066)	(0.055)
Small Island Dummy	0.067	0.086	-0.118	-0.046	1.962**	2.720***
	(0.582)	(0.626)	(0.216)	(0.198)	(0.709)	(0.699)
Landlocked Dummy	0.131	0.119	0.056	0.024	1.490***	1.269***
	(0.209)	(0.203)	(0.084)	(0.101)	(0.293)	(0.282)
% Land in Temperate Climate Zones		-0.196		-0.192		-1.624*
		(0.513)		(0.180)		(0.917)
Continental dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	147	147	31	31	31	31
R^2	0.76	0.76	0.67	0.67	0.94	0.96

Conclusions

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