Geographical Roots of Comparative Development

Ömer Özak

Department of Economics
Southern Methodist University

Economic Growth and Comparative Development
The Origins of Inequality in Income per Capita across the Globe in 2010
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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- Emergence of non-food-producing class:
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- Technological head start and its persistent effect via:
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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
    - $\Rightarrow$ Onset of domestication

- Orientation of continents:
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Orientation of Continents

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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
    \[ \Rightarrow \text{Technological head start and its effect on development} \]

- 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
    \[ \Rightarrow \text{Guns, Germs and Steel} \]

- Variation in the timing of Neolithic Revolution:
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Variation in the timing of Neolithic Revolution:
- Comparative development in 1491
- Comparative development in the contemporary period
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

<table>
<thead>
<tr>
<th>Technology Level 1000BCE-1500CE</th>
<th>1000BCE</th>
<th>1CE</th>
<th>1500CE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Years Since Neolithic Revolution</td>
<td>0.72***</td>
<td>0.47***</td>
<td>0.56***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.12)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Continental FE</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Additional Geographical Controls</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Adjusted-$R^2$</td>
<td>0.51</td>
<td>0.60</td>
<td>0.31</td>
</tr>
<tr>
<td>Observations</td>
<td>112</td>
<td>111</td>
<td>134</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Technology Level 2000CE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) (2) (3) (4) (5) (6)</td>
</tr>
<tr>
<td>Years Since Neolithic Revolution</td>
<td>0.15* -0.09 -0.09</td>
</tr>
<tr>
<td></td>
<td>(0.09) (0.08) (0.11)</td>
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<tr>
<td>Years Since Neolithic Revolution (Ancestors)</td>
<td>0.32*** 0.09 0.09</td>
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<tr>
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<td>(0.07) (0.07) (0.10)</td>
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<td>Continental FE</td>
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<td>Additional Geographical Controls</td>
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<td>Adjusted-$R^2$</td>
<td>0.02 0.55 0.59 0.10 0.55 0.59</td>
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<td>132 131 131 132 131 131</td>
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</table>
### The Neolithic Revolution and Population Density 1-1500

<table>
<thead>
<tr>
<th>Log [Population Density]</th>
<th>1CE</th>
<th>500CE</th>
<th>1000CE</th>
<th>1500CE</th>
<th>1CE</th>
<th>500CE</th>
<th>1000CE</th>
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<tbody>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
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<td>(5)</td>
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<td>(7)</td>
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<td>(4)</td>
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<td></td>
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<td>(8)</td>
<td></td>
<td></td>
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<tr>
<td>Years Since Neolithic Revolution</td>
<td>0.73***</td>
<td>0.68***</td>
<td>0.58***</td>
<td>0.47***</td>
<td>0.67***</td>
<td>0.67***</td>
<td>0.61***</td>
<td>0.53***</td>
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<tr>
<td></td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td>(0.08)</td>
<td>(0.09)</td>
<td>(0.10)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Caloric Suitability (pre-1500CE)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.22***</td>
<td>0.28***</td>
<td>0.36***</td>
<td>0.45***</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>$R^2$</td>
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<td>0.21</td>
<td>0.61</td>
<td>0.54</td>
<td>0.45</td>
<td>0.39</td>
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<td>Observations</td>
<td>169</td>
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The Neolithic Revolution and Population Density 1-1500

The graph shows the effect of the Neolithic Revolution on population density from 1 to 1500 years. The x-axis represents the year, and the y-axis represents the effect of Neolithic on population density. The data points indicate a gradual decrease in population density over time.
## The Neolithic Revolution on Population Density in 1500

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<thead>
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<th>Log [Population Density 1500CE]</th>
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<tr>
<td></td>
<td>(1)</td>
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<tr>
<td>Years Since Neolithic Revolution</td>
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<td></td>
<td>(0.07)</td>
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<tr>
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<tr>
<td></td>
<td>0.45***</td>
</tr>
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<tr>
<td>Predicted Genetic Diversity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.42**</td>
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<td>(3.34)</td>
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<tr>
<td>Predicted Genetic Diversity Squared</td>
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<tr>
<td></td>
<td>-6.83**</td>
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</table>
The Neolithic Revolution on Population Density in 1500

Years Since Neolithic Transition

Log Population Density in 1500

(Control variables held at zero)
The Neolithic Revolution on Urbanization in 1-1500

<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>1CE</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Years Since Neolithic Revolution</td>
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<td>(0.23)</td>
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<tr>
<td>Caloric Suitability (pre-1500CE)</td>
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</table>

*Omer Ozak* Geography & Development Growth & Comparative Development 18 / 50
The Neolithic Revolution on Urbanization in 1500

<table>
<thead>
<tr>
<th></th>
<th>Log [Urbanization 1500CE]</th>
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<tbody>
<tr>
<td></td>
<td>(1)</td>
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<tr>
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<tr>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted Genetic Diversity Squared</td>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
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<tr>
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<tr>
<td>Adjusted-$R^2$</td>
<td>0.13</td>
</tr>
<tr>
<td>Observations</td>
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</table>
The Effect of the NR on Population Density and Urbanization in 1500

<table>
<thead>
<tr>
<th>Development in 1500CE</th>
<th>Log [PD]</th>
<th>Log [UR]</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Years Since Neolithic Revolution</td>
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<td>(0.12)</td>
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<tr>
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<td></td>
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<td>Predicted Genetic Diversity</td>
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<td>Predicted Genetic Diversity Squared</td>
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<td>Adjusted-$R^2$</td>
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# The Effect of the NR on Population Density and Urbanization in 1500

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<tr>
<th>Development in 1500CE</th>
<th>Semi-Partial $R^2$</th>
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<td>Years Since Neolithic Revolution</td>
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<tr>
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<td>Continental FE</td>
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<td>Additional Geographical Controls</td>
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<tr>
<td>Adjusted-$R^2$</td>
<td>0.66</td>
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<tr>
<td>Observations</td>
<td>84</td>
</tr>
</tbody>
</table>
Genetic Diversity and Urbanization in 1500

(Predicted) Genetic homogeneity vs. Log urbanization rate in 1500

(Control variables held at zero)
Interpretation

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

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<th>(2)</th>
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<th>(5)</th>
<th>(6)</th>
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<tr>
<td>Years Since Neolithic Revolution</td>
<td>0.40***</td>
<td>-0.07</td>
<td>0.01</td>
<td>-0.34**</td>
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<tr>
<td>Years Since Neolithic Revolution (Ancestors)</td>
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<td>0.08</td>
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<td>(0.09)</td>
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<tr>
<td>Caloric Suitability (pre-1500CE)</td>
<td>-0.26***</td>
<td>-0.18**</td>
<td>-0.26***</td>
<td>-0.16*</td>
<td>-0.13</td>
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<tr>
<td></td>
<td>(0.09)</td>
<td>(0.09)</td>
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<td>(0.09)</td>
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<td>Predicted Genetic Diversity (Ancestors)</td>
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<td>7.52***</td>
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<td>Predicted Genetic Diversity (Ancestors, Sq.)</td>
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<td>Additional Geographical Controls</td>
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<td>Yes</td>
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<td>Legal Origin FE</td>
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<td>$R^2$</td>
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<td>0.78</td>
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<td>0.78</td>
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<td>Adjusted-$R^2$</td>
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</tbody>
</table>
Genetic Diversity and Income per Capita in 2000

Log income per capita in 2000
(Predicted) Ancestry−adjusted genetic homogeneity

(Control variables held at zero)
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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Variation in the timing of the Neolithic Revolution among the ancestral populations of each region contributed to the variation in life expectancy across regions
The Timing of the Neolithic Revolution in Europe and the Middle East

Neolithic Sites

Years (BP) Since Neolithic Transition

6000 7000 8000 9000 10000 11000 12000
Projected Timing of the Neolithic Revolution in France

Source: (Franck-Galor-Özak, 2016)
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

<table>
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<tr>
<th></th>
<th>All Diseases</th>
<th>Infectious (Air)</th>
<th>Infectious (Water)</th>
<th>Suicides</th>
<th>Violent Deaths</th>
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<tr>
<td>Years Since Neolithic Revolution</td>
<td>-0.40***</td>
<td>-0.69***</td>
<td>-0.34***</td>
<td>-0.59***</td>
<td>0.14</td>
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<td>(0.23)</td>
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<td>(0.07)</td>
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<td>First-stage F-statistic</td>
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<td>13.05</td>
<td>33.44</td>
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Source: (Franck-Galor-Özak, 2016)
## The Neolithic Origins of Diseases: French Departments 2000-2013

<table>
<thead>
<tr>
<th>Incidence</th>
<th>Prevalence</th>
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<tbody>
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<td>Arterialischemic events</td>
<td>Liver disease &amp; cirrhosis</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Years Since Neolithic Revolution</td>
<td>0.49***</td>
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<tr>
<td>GDP per capita (2000-2010)</td>
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<td>First-stage F-statistic</td>
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The Neolithic Origins of Mortality: French Departments 2000-2013

<table>
<thead>
<tr>
<th>Non-Medical Death Rates per 100,000</th>
<th>Alcohol Abuse</th>
<th>Accidents</th>
<th>Falls</th>
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<tr>
<td></td>
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<td>Male</td>
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<tr>
<td>Years Since Neolithic Revolution</td>
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<td>0.19</td>
<td>-0.12</td>
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<td>(0.12)</td>
<td>(0.14)</td>
<td>(0.12)</td>
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<tr>
<td>GDP per capita (2000-2010)</td>
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<td>-0.36***</td>
<td>-0.55***</td>
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<td>(0.11)</td>
<td>(0.09)</td>
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<td>Yes</td>
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<td>Yes</td>
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<td>50.19</td>
<td>50.19</td>
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<tr>
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<td>0.46</td>
<td>0.52</td>
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<td>89</td>
<td>89</td>
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</tbody>
</table>

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
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    - Negative association with population density
  - 2000s
    - Positive association with income per capita
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<td>Log Population Density</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Log years since Neolithic</td>
<td>1.111*** (0.188)</td>
<td>0.769* (0.474)</td>
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<td></td>
<td></td>
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<tr>
<td>2005</td>
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<td></td>
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</tr>
<tr>
<td>Log years since Neolithic (ancestry adjusted)</td>
<td>0.211 (0.322)</td>
<td>-0.100 (0.559)</td>
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<tr>
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<td>68</td>
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</tr>
<tr>
<td>R²</td>
<td>0.73</td>
<td>0.72</td>
<td>0.70</td>
<td>0.62</td>
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Reversal in the Role of Land Productivity

Land Productivity and Population Density in 1500

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

Source: Ashraf-Galor (AER 2011)
Geographical Factors
Reversal in the Role of Land Productivity

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 \((\text{Acemoglu-Johnson-Robinson, QJE 2002})\)
  - Non-former colonies sample

  \(\implies\) Reversal in the role of land productivity is largely independent of the forces of colonialism

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

Source: Ashraf-Galor (AER 2011)
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- The effect is qualitatively similar in the:
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Geographical Factors

Persistent: Institutions & Human Diversity

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

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

Log Income per Capita in 2005

Log Population Density in 1500

coefficient = 0.04305199, robust standard error = 0.11347758, t-statistic = 0.38
Population Density in 1500 & Income per Capita in 2005 – Ex-Colonies Sample

Log Population Density in 1500

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

- This reversal in the relative performance of countries is:
  - Absent in the world sample
  - Present in the former colonies sample

  \[ \implies \text{Reversal of Fortune is largely triggered by colonialism} \]

  (Engerman-Sokoloff, 1997; Acemoglu et al., AER 2001, QJE 2002)
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  - Exclusive (growth retarding) institutions imposed in densely populated areas
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Population Density in 1500 & Subsequent Changes in Genetic Diversity

![Graph showing relationship between log population density in 1500 CE and change in genetic diversity from 1500-2000 CE. The graph includes data points for countries in Oceania and the Americas, with a trend line indicating a negative correlation. Coefficient (coef) = -0.021, robust standard error (se) = 0.003, t-statistic (t) = -6.09, and sample size (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**
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- **Range of soil quality**
  - Emergence of geographical specific human capital $\implies$ reduced mobility
    
    $\implies$ ethnic fractionalization
    
    (Michalopoulos, AER 2012)
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  - Concentration of landownership:
    - Suboptimal investment in public education (Galor-Moav-Vollrath, RES 2009)

- Soil quality conducive for agriculture
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