The Terror of History: Solar Eclipses and the Origins of Critical Thinking and Complexity

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Motivation

- Human capital is crucial for economic growth.
  - Present time:
    - Barro (2001), Hanushek (2012).
  - Industrialisation:
    - Mokyr (2005), Gennaioli et al. (2013), Voitgländer and Squicciarini (2015), Madsen (2017).
  - Pre-industrialisation:
    - Valencia Caicedo (2018), Galor and Weil (2000)
- We focus on *critical thinking*:
  - A pre-cursor of human capital
- Unexplained phenomena $\rightarrow$ Curiosity $\rightarrow$ Research.

Research Question

Research question

Did societies that started to critically think earlier enjoy a comparative advantage?

- General idea: rare events induce curiosity.
  - Social groups often challenged
  - by unexplained phenomena
  - become better at thinking and solving problems.
  - **More development**.

This Paper

- Studies the causal effect of solar eclipses on economic growth.
  - Demand an explanation: $\rightarrow$ critical thinking.
    - Probably a wrong conclusion.
  - Are recurrent: $\rightarrow$ Demand for explanation remains over time.
- Uses pre-colonial data: Murdock's Ethnographic Atlas.
- Assesses the levels of:
  - Critical thinking: Gods complexity, strategy games.
  - Social complexity: Related to economic growth.

Contribution:

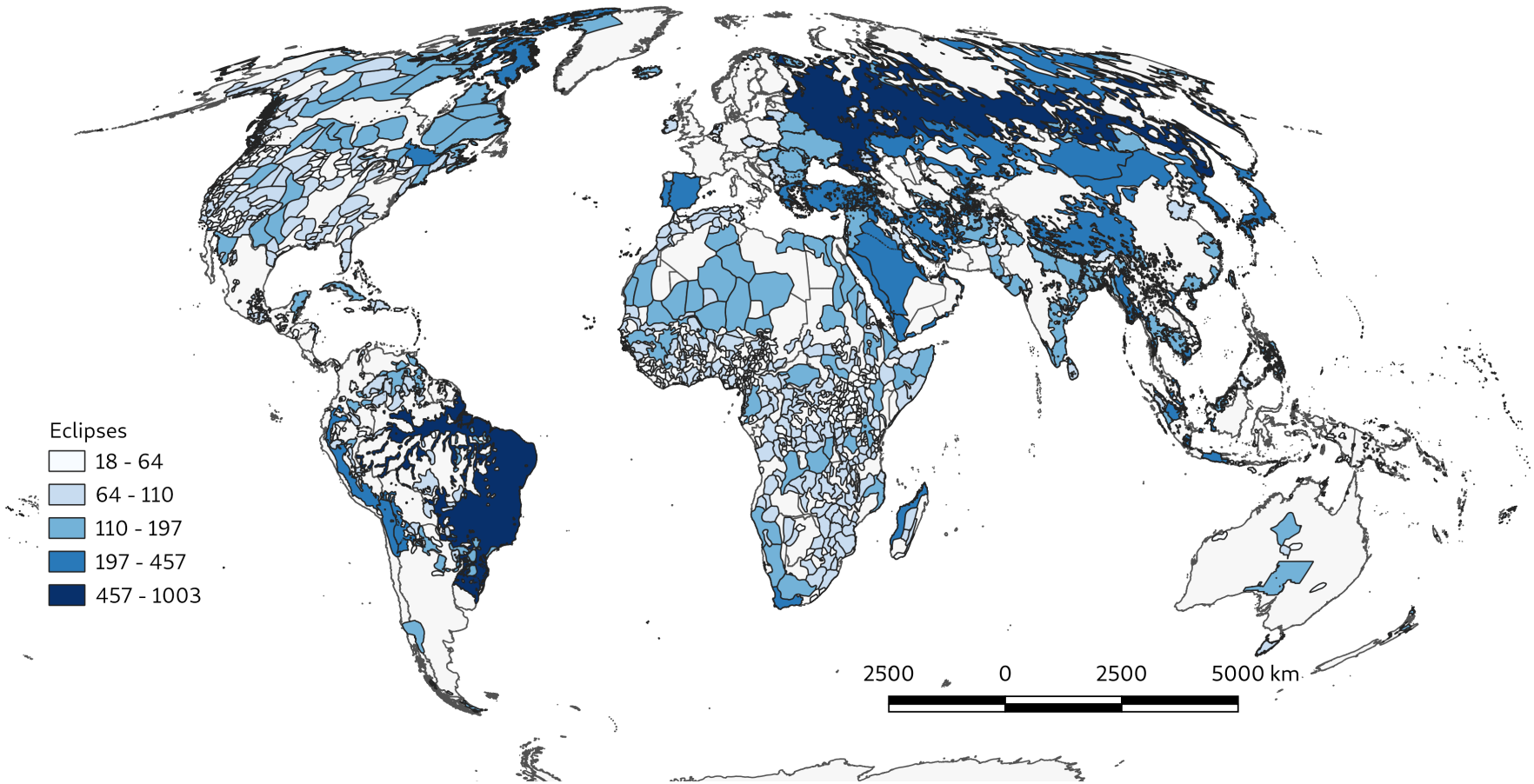
- The importance of thinking for economic growth.
- Pre-industrial set-up.

Solar Eclipses

- Characteristics:
  - Alignment between the Sun, the Moon and the Earth.
  - The Moon obscures the Sun.
    - Completely exogenous.
  - A solar eclipse can be seen from a narrow path on Earth.
    - Random occurrence.
    - 100 km wide, stretching long distances east-west.
    - Affect several locations simultaneously.
  - At a given location, one solar eclipse every 410 years.
  - We focus at the ethnic level:
    - An eclipse is seen from within ethnic boundaries on average every 65 years.
  - Possible to back-predict eclipse visibility.

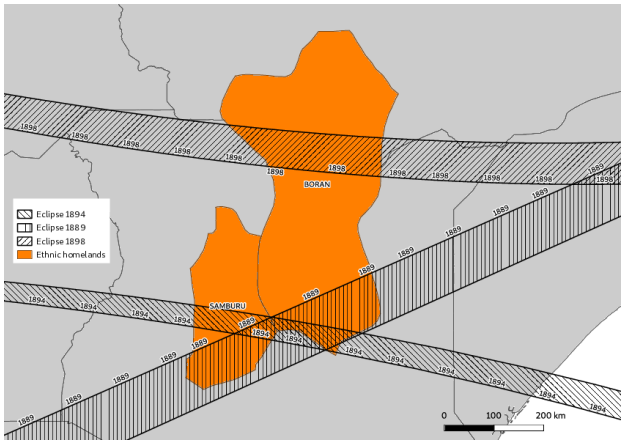
Solar Eclipses

- Other terrifying phenomena:
  - Volcano eruptions,
  - earthquakes,
  - thunder and lightning,
  - supernovae.
- Why eclipses?
  - Not common (as lightning) but not too rare.
  - Do not destroy physical nor human capital.
  - Narrow area of effect: provides variation.
    - Lunar eclipses can be seen from half of the world,
    - Supernovae can be seen from all the world.


Eclipses
18 - 64
64 - 110
110 - 197
197 - 457
457 - 1003
2500
0
2500
5000 km

Construction of the main variable

- We intersect eclipse paths with ethnic homelands.
- We consider all total solar eclipses between -2000 and 2000.
  - Partial eclipses covering less than 90% of the Sun are unnoticeable in terms of darkening.
- We count the number of total solar eclipses visible from within an ethnic homeland.



Outcomes of Interest

- Factors related with development in the Ethnographic Atlas:
  - Social complexity: Diamond (1997), Michalopoulos et al. (2013).
    - Jurisdictional Hierarchy Beyond Local Community.
      No levels; . . .; four levels.
    - Political Integration
      Absence; Local com.; Peace groups; Min. states; Little states; States
    - Class Stratification
      Absence; Wealth; Elite; Dual; Complex.
  - Religion: Campante et al. (2015), Andersen et al. (2017).

    No high gods; Not active in human affairs; Active, not supportive of morality; Supportive of morality.
  - General cognitive ability: playing strategy games.

Results: Social Complexity

	Jurisdictional Hierarchy			Political Integration			Class Stratification		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total number of eclipses	0.014*** (0.003)	0.015*** (0.002)	0.015*** (0.002)	0.011*** (0.003)	0.013*** (0.003)	0.016*** (0.003)	0.008*** (0.003)	0.011*** (0.003)	0.011*** (0.003)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Ethnic	No	No	Yes	No	No	Yes	No	No	Yes
R^2	0.148	0.219	0.229	0.093	0.192	0.228	0.082	0.157	0.162
Observations	906	906	906	251	251	251	821	821	821

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Results: Critical Thinking

	Higher Gods			Strategy Games		
	(1)	(2)	(3)	(4)	(5)	(6)
Total number of eclipses	0.009*** (0.003)	0.006*** (0.002)	0.006*** (0.002)	0.002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Geography	No	Yes	Yes	No	Yes	Yes
Ethnic	No	No	Yes	No	No	Yes
R^2	0.140	0.238	0.247	0.540	0.617	0.655
Observations	584	584	584	334	334	334

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Area

- Eclipses are exogenous.
- However, a bigger ethnic-homeland mechanically experiences more eclipses.
  - It is more likely that a solar eclipse can be seen from an inside location.
- We tackle this by:
  - Control for area.
    - Possible "bad control" if more developed societies capture neighbour's land.
  - Control for neighbour's total number of eclipses.
  - Redefine the main variable:
    Total number of eclipses in a 100-km radius circle around ethnic homelands' centroids.

Area: Results

	Jurisdictional Hierarchy	Political Integration	Class Stratification	Higher Gods	Strategy Games
	(1)	(2)	(3)	(4)	(5)
	Panel A: Area				
Total number of eclipses	0.016***	0.011***	0.012***	0.006***	0.001***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.000)
Area	−0.002	0.007	−0.003	0.001	0.000
	(0.005)	(0.006)	(0.004)	(0.008)	(0.001)
R^2	0.229	0.213	0.162	0.247	0.655
Observations	906	267	821	584	334
	Panel B: Nearest neighbour				
Total number of eclipses	0.016***	0.013***	0.013***	0.007***	0.001***
	(0.002)	(0.003)	(0.004)	(0.002)	(0.000)
Total number of eclipses, neighbour	−0.002	0.001	−0.004***	0.003	0.000
	(0.002)	(0.002)	(0.001)	(0.003)	(0.000)
R^2	0.226	0.209	0.158	0.269	0.653
Observations	861	247	779	552	311
	Panel C: Buffer				
Total number of eclipses (buffer)	0.017*	0.035**	0.004	0.039**	0.000
	(0.010)	(0.015)	(0.008)	(0.016)	(0.002)
R^2	0.187	0.168	0.137	0.245	0.626
Observations	906	267	821	584	334
Controls (common to all regressions)					
Fixed effects	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes
Ethnic	Yes	Yes	Yes	Yes	Yes

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Robustness

- Other rare events Rare events
  - Lunar eclipses,
  - Distance to volcanoes,
  - Distance to tectonic plates.
- Controlling for:
  - Population density,
  - Ecological diversity (Fenske, 2014). Controls 1
  - Other measures of eclipses: Controls 2
    - Average time between eclipses,
    - Maximum time between eclipses,
    - Minimum time between eclipses.
- Different clustering. Clusters
- Other time frames: -2000 to -1500, -1500 to -1000, etc.

Concluding Remarks

- We contribute to the understanding of the relationship between human capital and growth.
- We find that higher exposure to total solar eclipses is related with:
  - More complex thinking,
  - More complex societies.
- Our results suggests that higher exposition to terrifying events encourages thinking.
  $\rightarrow$ Development of more complex Gods and strategy games.
- This represents an advantage in the human capital accumulation process.
  $\rightarrow$ Economic advantage manifested by more complex social structures.

Robustness: Rare Events

Back

	Jurisdictional Hierarchy	Political Integration	Class Stratification	Higher Gods	Strategy Games
	(1)	(2)	(3)	(4)	(5)
	Panel A: Volcanoes				
Total number of eclipses	0.015***	0.013***	0.012***	0.006***	0.001***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.000)
Dist. Volcano	0.014	0.004	−0.055**	−0.009	0.001
	(0.021)	(0.020)	(0.026)	(0.035)	(0.004)
R^2	0.229	0.211	0.167	0.248	0.655
Observations	906	267	821	584	334
	Panel B: Tectonic plates				
Total number of eclipses	0.015***	0.013***	0.011***	0.006***	0.001***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.000)
Dist. Tec. Plate	−0.018	−0.011	−0.024	0.011	−0.002
	(0.016)	(0.020)	(0.025)	(0.027)	(0.002)
R^2	0.229	0.212	0.163	0.248	0.656
Observations	906	267	821	584	334
	Panel C: Lunar Eclipses				
Total number of eclipses	0.016***	0.013***	0.012***	0.007**	0.002***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)
Total number of lunar eclipses	−0.001	−0.000	−0.001	−0.001	−0.000
	(0.002)	(0.002)	(0.001)	(0.002)	(0.000)
R^2	0.229	0.211	0.162	0.248	0.656
Observations	906	267	821	584	334
Controls (common to all regressions)					
Fixed effects	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes
Ethnic	Yes	Yes	Yes	Yes	Yes

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Robustness: Controls 1

Back

	Panel A: Population density				
Total number	0.017***	0.020***	0.018***	−0.002	0.001
of eclipses	(0.003)	(0.008)	(0.005)	(0.005)	(0.001)
Population density					
< 1 p. / 1-5 sq. mile	Ref.	Ref.	Ref.	Ref.	Ref.
1 p. / 1-5 sq. mile	−0.203	−1.763	2.969***	0.677	−0.021
	(0.821)	(1.730)	(0.968)	(0.539)	(0.182)
1-5 p. / sq. mile	2.227	1.151	−0.085	−0.502	0.312**
	(1.673)	(1.772)	(1.109)	(1.194)	(0.135)
1-25 p. / sq. mile	3.517**	1.087	0.757	0.169	0.275
	(1.752)	(1.168)	(0.952)	(1.182)	(0.233)
26-100 p. / sq. mile	2.503	2.842**	1.131	0.007	0.007
	(1.786)	(1.325)	(0.793)	(0.657)	(0.156)
101-500 p. / sq. mile	3.187*	2.353	1.313	0.827	0.164
	(1.837)	(2.387)	(1.019)	(0.959)	(0.388)
> 500 p. / sq. mile	3.962**	3.939***	1.333	−0.552	0.403
	(1.965)	(1.358)	(1.464)	(1.170)	(0.343)
R^2	0.411	0.439	0.408	0.337	0.799
Observations	113	86	114	103	76
	Panel B: Ecological Diversity				
Total number	0.015***	0.012***	0.011***	0.006***	0.001***
of eclipses	(0.002)	(0.002)	(0.003)	(0.002)	(0.000)
Eco. divesity	1.379***	1.443**	1.458***	−0.205	−0.040
	(0.335)	(0.625)	(0.322)	(0.431)	(0.086)
R^2	0.236	0.218	0.171	0.248	0.656
Observations	906	267	821	584	334
Controls (common to all regressions)					
Fixed effects	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes
Ethnic	Yes	Yes	Yes	Yes	Yes

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Robustness: Controls 2

Back

	Jurisdictional Hierarchy	Political Integration	Class Stratification	Higher Gods	Strategy Games
	(1)	(2)	(3)	(4)	(5)
	Panel A: Maximum time between eclipses				
Total number of eclipses	0.012***	0.017***	0.008***	0.005	0.001***
	(0.002)	(0.004)	(0.003)	(0.003)	(0.000)
Max. time between eclipses	−0.258*	0.089	−0.211	−0.115	−0.015
	(0.140)	(0.224)	(0.154)	(0.144)	(0.024)
R^2	0.233	0.229	0.165	0.248	0.656
Observations	906	251	821	584	334
	Panel B: Minimum time between eclipses				
Total number of eclipses	0.014***	0.017***	0.011***	0.006**	0.002***
	(0.002)	(0.003)	(0.003)	(0.002)	(0.000)
Min. time between eclipses	−7.932	8.792*	0.506	−2.041	1.608***
	(6.208)	(4.835)	(4.366)	(5.253)	(0.333)
R^2	0.230	0.231	0.162	0.248	0.661
Observations	906	251	821	584	334
	Panel C: Avg. time between eclipses				
Total number of eclipses	0.008***	0.012***	0.007***	0.003	0.002***
	(0.002)	(0.004)	(0.002)	(0.003)	(0.000)
Avg. time between eclipses	−1.986***	−0.931	−1.109*	−0.915	0.108
	(0.706)	(1.014)	(0.663)	(0.578)	(0.095)
R^2	0.236	0.230	0.165	0.250	0.657
Observations	906	251	821	584	334
Controls (common to all regressions)					
Fixed effects	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes
Ethnic	Yes	Yes	Yes	Yes	Yes

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Robustness: Clustering

Back

	Jurisdictional Hierarchy	Political Integration	Class Stratification	Higher Gods	Strategy Games
	(1)	(2)	(3)	(4)	(5)
	Panel A: Clustering at linguistic families				
Total number of eclipses	0.016***	0.013***	0.013***	0.007***	0.001***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.000)
R^2	0.226	0.209	0.158	0.269	0.653
Observations	861	247	779	552	311
	Panel B: Clustering at ecoregions				
Total number of eclipses	0.016***	0.013***	0.013***	0.007***	0.001**
	(0.002)	(0.003)	(0.003)	(0.002)	(0.000)
R^2	0.226	0.209	0.158	0.269	0.653
Observations	861	247	779	552	311
Controls (common to all regressions)					
Fixed effects	Yes	Yes	Yes	Yes	Yes
Geography	Yes	Yes	Yes	Yes	Yes
Ethnic	Yes	Yes	Yes	Yes	Yes

[1] Geography: avg. temp., temp. seasonality, precipitation, precipitation seasonality, dist. to the coast, to rivers and to Addis Ababa, ruggedness, elevation, malaria, caloric yield, absolute latitude, south dummy, major habitat type dummies. Ethnic: major crop type (Fenske, 2014).

[2] * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.