Climatic Conditions, Somatic Capital, and the Timing of the Neolithic Transition

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Background

- Research on long-run growth attempts to identify deep-rooted determinants of comparative economic development.
  (Galor, 2005, 2011; Galor & Moav, 2002; Galor & Weil, 2000)
- Key episode in human history is the Neolithic Transition: shift from hunting and gathering to plant cultivation and animal husbandry.
- Early adoption of agriculture seems to have induced a development head-start that is still prevalent in current income levels.
  (Ashraf & Galor, 2011; Ashraf et al., 2010; Bleaney & Dimico, 2011; Galor & Moav, 2007; Hibbs & Olsson, 2004; Olsson & Hibbs, 2005; Putterman, 2008; Putterman & Weil, 2010)
- Hence, it is important to identify factors that influenced the timing of the transition to agriculture.

The Timing of the Neolithic Transition

Factors affecting the Neolithic Transition include:

- Biogeography: availability of domesticable plants and animals
  (Diamond, 1997; Hibbs & Olsson, 2004; Olsson & Hibbs, 2005)
- Climatic conditions
  (Ashraf & Michalopoulos, 2015; Dow et al., 2009)
- Distance to the Neolithic frontier
  (Baker, 2008)
- Excessive hunting and population growth
  (Locay, 1989; Smith, 1975)

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We propose a new explanatory factor:

- Climate-induced variation in human somatic capital.

Climatic Conditions & Somatic Capital

Somatic Capital:

- In a physical sense: embodied energy.
- In a functional sense: physical stature, but also factors like immune function, coordination, and skill, all of which affect the profitability of activities like resource acquisition (Kaplan et al., 1995).

Analysis in a Nutshell:

- We develop a growth model to analyse the effect of climatic conditions on somatic capital and the ultimate effect on the timing of the Neolithic Transition.
- We provide causal evidence for the main prediction of the theory using archaeological-site-level data.

Theory

The Model

Model Setup:

- Evolutionary economic growth model with overlapping generations.
- Individuals choose somatic investment in offspring such as to maximise reproductive fitness (quantity vs. quality) for a given skill intensity (harshness) of the environment.
- Somatic capital increases the innovation capability of individuals and ultimately leads to a higher rate of productivity growth.

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Theoretical Result (Hypothesis)

An increase in the skill intensity of the environment, i.e. harsher climatic conditions, has a positive effect on somatic investment per child, the growth rate of productivity, and ultimately (supports) an earlier transition to an agricultural society (Neolithic Transition).

Data & Empirical Strategy

Combined Data Sources

Key variables of interest (archaeological-site data):

- Neolithic Transition (NT) timing (832 sites)
  - Pinhasi et al., 2005
  - Fort et al., 2018
  - Isern et al., 2017
- Somatic capital (body mass, BM) for Pleistocene Homo Sapiens
  - Will et al., 2021
  - Stock et al., 2023

Other variables:

- Climatic and geographic controls
  - Galor and Özak, 2016, Harris et al., 2020, Kottek et al., 2006, Picard and Stepner, 2017
- Historical bioclimatic conditions (Instrument)
  - Beyer et al., 2020

Neolithic Transition & Somatic Capital

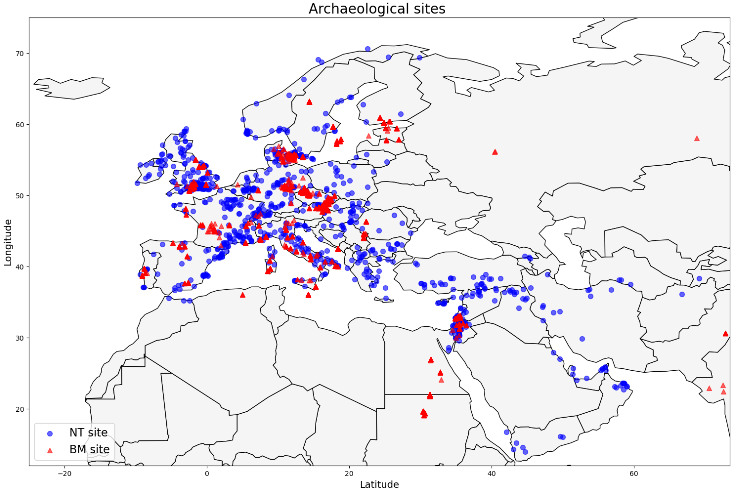


Figure 1: Spatial Distribution of Neolithic and Body Mass Sites.

Neolithic Transition & Somatic Capital

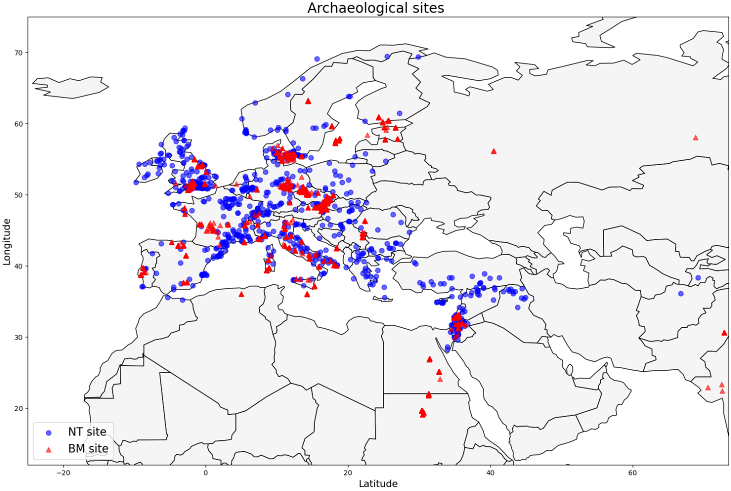
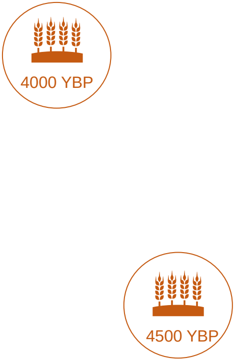
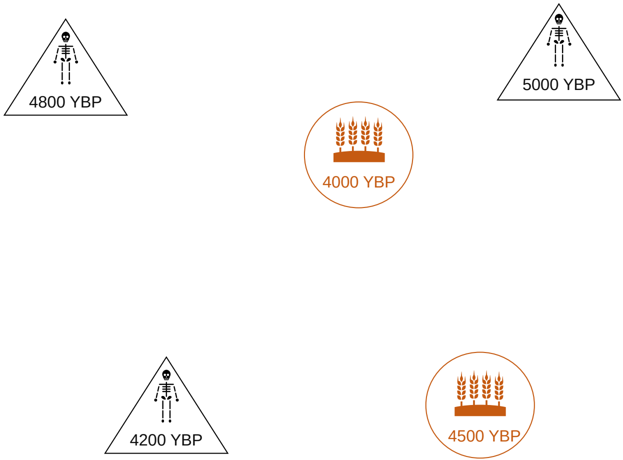


Figure 1: Spatial Distribution of Neolithic and Body Mass Sites.

Combining NT & BM Data: IDW Method



Combining NT & BM Data: IDW Method



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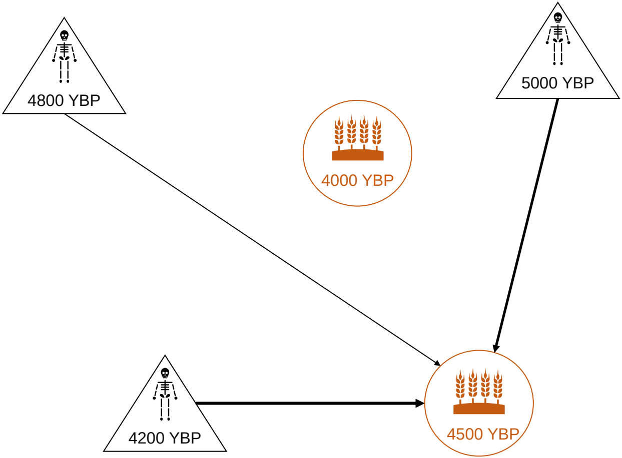

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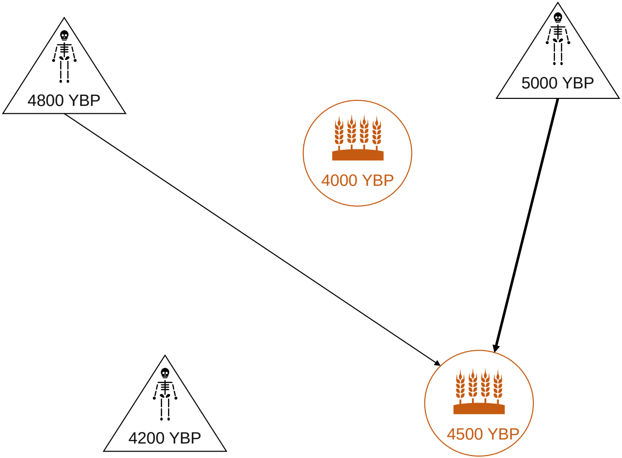

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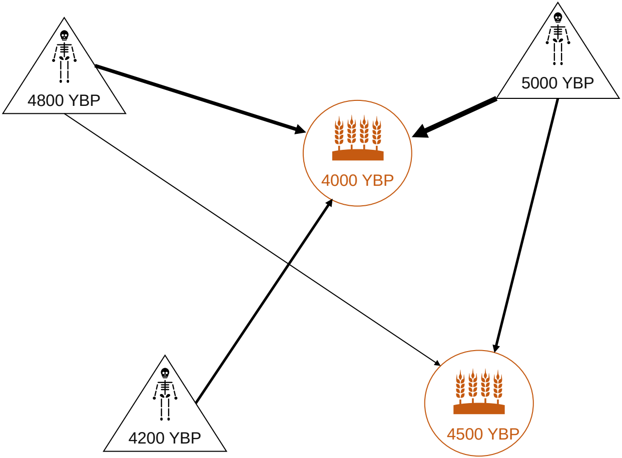


Combining NT & BM Data: IDW Method

The predicted body mass for NT site j, $\hat{y}_j$, is equal to the weighted average of N observations i from different body mass sites, y_i:

$$\hat{y}_j = \sum_{i=1}^{N} \lambda_{ij} y_i. \tag{1}$$

Weights of observation i for site j, λ_{ij}, are set according to:

$$\lambda_{ij} = \begin{cases} \frac{\left(d_{ij}^{time}+\epsilon\right)^{-\alpha^{time}} + \left(d_{ij}^{geo}+\epsilon\right)^{-\alpha^{geo}}}{\sum_{k=1}^{N}\left(d_{kj}^{time}+\epsilon\right)^{-\alpha^{time}} + \left(d_{kj}^{geo}+\epsilon\right)^{-\alpha^{geo}}} & \text{if} \quad d_{ij}^{time} \geq 0, \ \forall \ k : d_{kj}^{time} \geq 0; \\ 0 & \text{if} \quad d_{ij}^{time} < 0. \end{cases} \tag{2}$$

- d_{ij}^{geo}: distance between NT site j and the site of BM observation i.
- d_{ij}^{time}: difference in the timing between NT site j and BM observation i.
- $\alpha^{geo}, \alpha^{time}$: chosen to minimise the mean squared prediction error on BM dataset.
- We add a small ϵ to distances to avoid discontinuities in the weights.

Identification Strategy

Instrumental variable approach:

- Instruments based on empirical evidence from anthropology.
- Will et al. (2021) analyse the effect of environmental conditions on Homo sapiens body mass and brain size.
- Main finding: Interannual volatility of precipitation and net primary productivity (NPP) are the best predictors of body mass and, in particular, brain size:
  - Larger brain and body sizes reduce extinction risk in the presence of environmental variability and habitat instability.
  - Increased behavioural flexibility (brain) or physiological ability (body) is a buffer against variability and unpredictability.

Identification Strategy

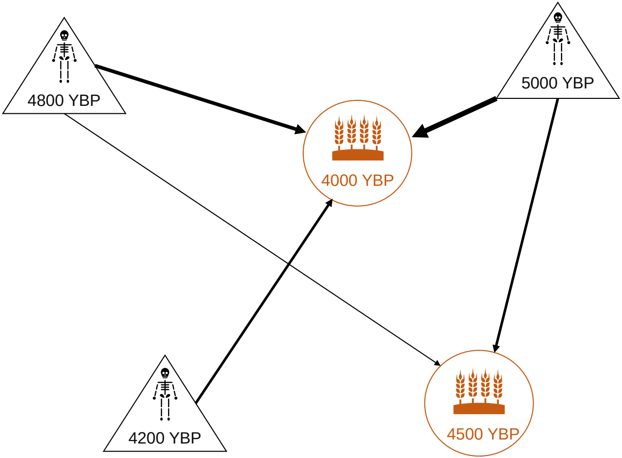
Two instruments:

- Interannual volatility of precipitation/NPP long before the timing of the NT as instrumental variable for body mass.
- Environmental variability $\uparrow \rightarrow$ body & brain mass $\uparrow \rightarrow$ earlier NT

Instrument validity:

- Relevance: The instruments are correlated with body mass (similar effect to Will et al. (2021), see first stage results).
- Exclusion restriction:
  - We use bioclimatic conditions between 21k YBP (at least 10k before earliest NT) and 40k (end of second Out-of-Africa migration wave).
  - No direct effect of these conditions on probability of NT.
  - Effect on NT only via persistent variation in somatic capital.

Adding Information on Historical Bioclimatic Conditions



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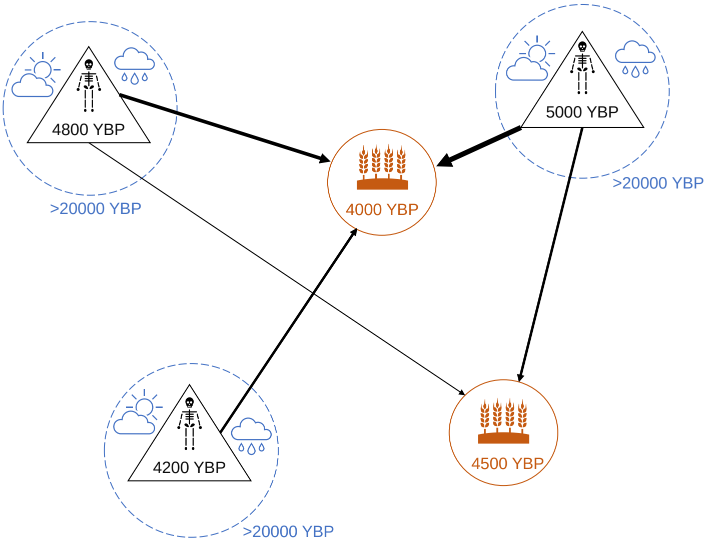

Estimation Equation and Controls

First stage (IV):

$$SomCap_k = \delta_0 + \delta_1 HistEnv_k + \boldsymbol{\delta_2 \mathrm{Geo}_k} + \boldsymbol{\delta_3 \mathrm{Clim}_k} + \boldsymbol{\delta_4}\mu_k + \eta_k \qquad (3)$$

Second stage (IV) and OLS:

$$YNT_k = \beta_0 + \beta_1 \widehat{SomCap}_k + \boldsymbol{\beta_2 \mathrm{Geo}_k} + \boldsymbol{\beta_3 \mathrm{Clim}_k} + \boldsymbol{\beta_4}\mu_k + \epsilon_k \qquad (4)$$

- YNT_k: years since the Neolithic Transition at site k.
- $HistEnv_k$: $PrecVol_k$ and $NPPVol_k$ are the precipitation volatility and net primary productivity of the environment.
- $SomCap_k$: somatic capital (body mass) before NT.
- Geo_k and $Clim_k$: vectors of geographical and climatic controls.
- μ_k are fixed effects, ϵ_k and η_k are idiosyncratic error terms.

Results

OLS Results

Table 1: The Effect of Somatic Capital on NT Timing: OLS Estimates

	(1)	(2)	(3)	(4)	(5)
Pre-NT Body Mass	169.9***	134.3***	79.02***	76.59***	80.74***
	(15.45)	(14.06)	(13.43)	(13.11)	(12.94)
Log Distance to Neolithic Frontier		-1351.0***	-607.2***	-603.1***	-462.7***
		(132.2)	(115.7)	(118.7)	(131.4)
Absolute Latitude			-101.9***	-103.3***	-93.53***
			(7.002)	(6.735)	(13.20)
Elevation			0.146	0.142	0.222
			(0.110)	(0.111)	(0.136)
Climate Suitability				182.4**	174.6**
				(76.89)	(77.36)
Annual Mean Temperature					68.11**
					(28.54)
Annual Temperature Volatility					3225.5**
					(1284.1)
Annual Temperature Volatility SQ					-778.0*
					(424.8)
Continent & Island Fixed Effects	YES	YES	YES	YES	YES
Observations	832	832	832	832	832
R^2	0.577	0.639	0.759	0.763	0.771

The dependent variable is *Years since Neolithic Transition*. Robust standard errors are reported in parentheses.
* $p < .1$, ** $p < .05$, *** $p < .01$.

Instrumental Variable Results

Table 2: The Effect of Somatic Capital on NT Timing: IV Estimates

	Instrument: Precipitation Volatility			Instrument: NPP Volatility		
	(1)	(2)	(3)	(4)	(5)	(6)
	A. Second Stage Results					
Pre-NT Body Mass	130.1***	124.6***	139.6***	209.6***	206.9***	228.8***
	(42.81)	(43.11)	(43.89)	(69.30)	(69.77)	(71.27)
	A. First Stage Results					
Log Historical Precipitation Volatility	1.136***	1.129***	1.113***			
	(0.137)	(0.137)	(0.139)			
Log Historical NPP Volatility				0.802***	0.799***	0.779***
				(0.160)	(0.160)	(0.163)
Geographical Controls	YES	YES	YES	YES	YES	YES
Biogeographic Controls	NO	YES	YES	NO	YES	YES
Climatic Controls	NO	NO	YES	NO	NO	YES
Continent & Island Fixed Effects	YES	YES	YES	YES	YES	YES
Montiel-Pflueger F Statistic	69.08	67.61	63.92	25.11	24.87	22.91
Observations	832	832	832	832	832	832

Robust standard errors are reported in parentheses.
* $p < .1$, ** $p < .05$, *** $p < .01$.

Overview & Additional Results

- Spatial variation in somatic capital due to climatic conditions explains a difference in the timing of the Neolithic Transition (range of 11,000 years) of:
  - 229 years per kg body mass,
  - 3,400 years over the range of body mass in our dataset.
- First stage of the IV estimation is consistent with previous empirical findings (e.g., Will et al., 2021).
- Results remain consistent across different specifications, i.a.:
  - Inclusion of NT sites with minimum distance to BM site $> 1000km$.
  - Alternative IDW power parameters, e.g. based on Olsson and Paik (2016).

Conclusion

Conclusion

- We propose a new explanatory factor for the timing of the Neolithic Transition: Climate induced variation in somatic capital.
- Our theory predicts that harsher climatic conditions lead to higher investment in somatic capital and ultimately an earlier transition to agriculture.
- We empirically test this main prediction using data from neolithic and body mass sites.
- IV approach: Using historical bioclimatic conditions as an instrument, we find evidence for a causal effect of somatic capital on the transition to agriculture.

Thank you for your attention!

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