Evolution of Culture: Selection and Drift

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Growth Breakfast

February 6, 2019

Research Objective

- The research explores the evolution of culture and its resulting dissimilarities between societies
- There are two fundamental forces that govern the evolution of culture:
  - Cultural Drift (result of random events and experiences over the group's history)
  - Selective pressure (imposed by an environment)

Literature Review

- There exists two strands of literature devoted to the evolution of culture and analysis of cultural differences across societies:
  - One links cultural distance to the spread of humanity across the Globe, genetic and linguistic divergence

    Spolaore and Wacziarg (2009, 2016, 2018), Desmet et al. (2011), Ashraf and Galor (2013)

  - Another focuses on the effect of environment (e.g., geography, climate, ecology) on culture

    Alesina et al. (2011, 2013), Talhelm et al. (2014), Galor and Ozak (2016), Galor and Savistkiy (2019), Cervellati et al. (2019), Giuliano and Nunn (2019)

Main Hypothesis

- Cultural Distance between societies is heterogeneous across different cultural traits
  - Traits affected by the drift – continuously diverge between groups

    (Cultural Distance grows with time since last common ancestry)
  - Traits subjected to selection – differ according to environment

    (Cultural Distance is stable and maps into environmental distance)

Theoretical Model

- A group is characterized by a set of *cultural traits*
- A trait varies between the groups and between members of a group
- Traits differ in their relation to the environment:
  - Some are orthogonal to environment and production
  - Others are selected to complement the environment
- Evolution of culture differs across these dimensions

Simple Set Up

- A group j with a constant population N in an environment E^j
- *Culture* of a group j in period t is composed of two traits:
  - x_t^j – trait orthogonal to the environment and production
  - z_t^j – trait is subjected to selection (the effect depends on the environment)
- Each trait can be represented as a real number
- Group level trait is an average other the individual level traits in a group

$$x_t^j = \sum_i x_{ti}^j / N \quad \text{and} \quad z_t^j = \sum_i z_{ti}^j / N$$

Evolution of x-Trait

- Trait x is passed between generations with random individual mutations

$$x_{ti}^j = x_{t-1,i}^j + \varepsilon_{ti}^j, \quad \forall i, t \quad \varepsilon_{ti}^j \sim \mathcal{N}(0, \sigma_\varepsilon^2)$$

- On the group level cultural trait x evolves as:

$$x_t^j = x_{t-1}^j + \varepsilon_t^j \quad \forall t \quad \varepsilon_t^j \sim \mathcal{N}(0, \sigma_\varepsilon^2 / N)$$

- $\{x_t^j\}_{t=0}^\infty$ is a random walk process with:

$$\mathbb{E}(x_t^j) = x_0^j$$

$$Var(x_t^j) = t\sigma_\varepsilon^2 / N \to_{t\to\infty} \infty$$

Evolution of z-Trait

- In an environment E^j trait z delivers maximal output at a level $z_j^* = z^*(E^j)$
- Passed trait is affected by the parents cultural trait, optimal level and random mutations:

$$z_{ti}^j = \lambda z_{t-1,i}^j + (1-\lambda) z_j^* + \eta_{ti}^j \quad \forall i, t \quad \eta_{ti}^j \sim \mathcal{N}(0, \sigma_\eta^2)$$

- Transition reflects heredity of the trait and adjustment due to:
  - Individual learning Micro Foundation
  - Social learning Micro Foundation
  - Natural selection Micro Foundation
- On the group level cultural trait z evolves as:

$$z_t^j = \lambda z_{t-1}^j + (1-\lambda) z_j^* + \eta_t^j \quad \forall t \quad \eta_t^j \sim \mathcal{N}(0, \sigma_\eta^2 / N)$$

- $\{z_t^j\}_{t=0}^\infty$ is an AR(1) process with: $\mathbb{E}(z_t^j) = z_j^*$ and $Var(z_t^j) = \sigma_\eta^2 / N(1-\lambda^2)$

Cultural Distance: x-Trait

- Groups A and B split from the common ancestral group at time 0
  The cultural distance in trait x between the groups at time t is:

$$dx_t^{A,B} = (x_t^A - x_t^B)^2$$

- In light of the nature of the x_t^j processes the distance is

$$dx_t^{A,B} = \left(x_0^A - x_0^B + \sum_{s=0}^{t} \varepsilon_s^A - \sum_{s=0}^{t} \varepsilon_s^B \right)^2$$

- Assuming that $x_0^A = x_0^B$ and mutations are independent:

$$\mathbb{E}(dx_t^{A,B}) = 2t\sigma_\varepsilon^2 / N \to_{t\to\infty} \infty$$

- The distance grows with time – *cultural drift*

Cultural Drift

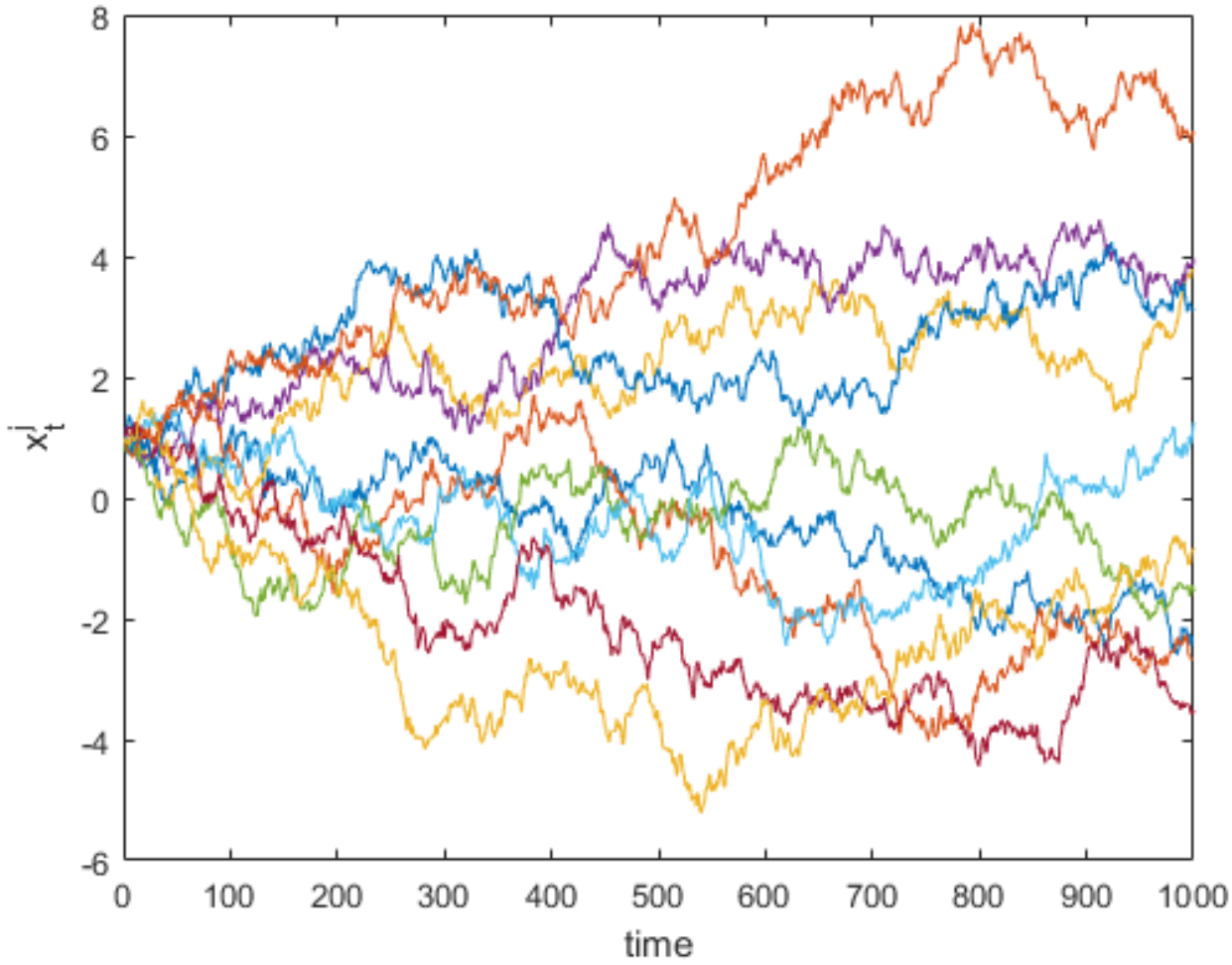


Figure 1: Evolution of x-trait

Cultural Distance: z-Trait

- For the same groups cultural distance in z is:

$$dz_t^{A,B} = \left[\lambda^t(z_0^A - z_0^B) + (1-\lambda)(z_A^* - z_B^*)\sum_{s=0}^{t-1}\lambda^s + \sum_{s=0}^{t-1}\lambda^s(\eta_{t-s}^A - \eta_{t-s}^B)\right]^2$$

- Assuming that $z_0^A = z_0^B$ and mutations are independent:

$$\mathbb{E}_t(dz_t^{A,B}) = (z_A^* - z_B^*)^2\left[(1-\lambda)\sum_{s=0}^{t-1}\lambda^s\right]^2 + 2\sigma_\eta^2\sum_{s=0}^{t-1}\lambda^{2s}/N$$
$$\to (z_A^* - z_B^*)^2 + 2\sigma_\eta^2/N(1-\lambda^2)$$

- The distance is stationary and depends on the environmental distance $z^*(E^A) - z^*(E^B)$

Cultural Evolution under Selective Pressure

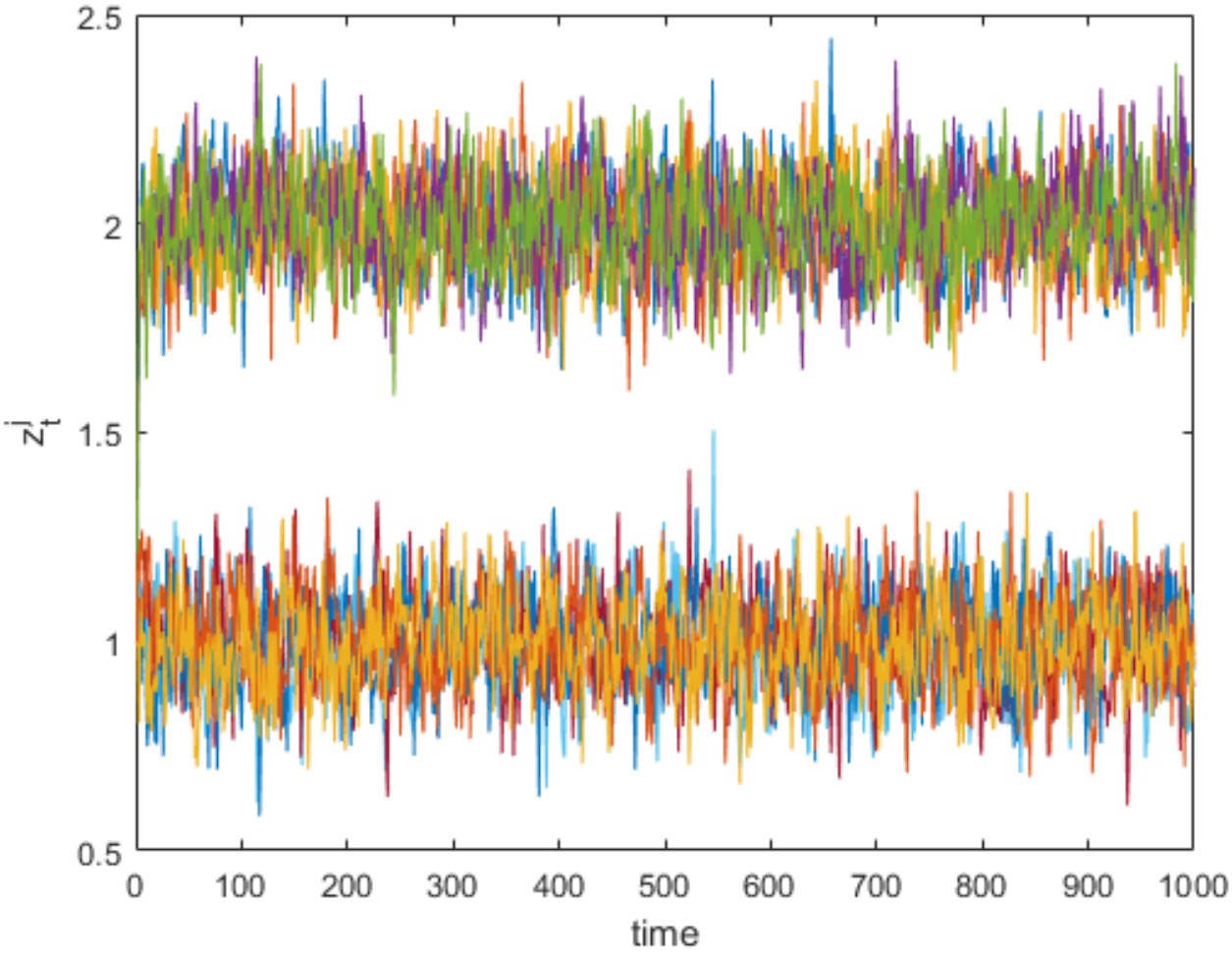


Figure 2: Evolution of z-trait

Theoretical Predictions

- Cultural distance over traits subjected to **drift** is a function of time since the last common ancestry:

$$\mathbb{E}(dx_t^{ij}) \sim t$$

- Cultural distance over traits subjected to **selection** is a function of environmental distance:

$$\mathbb{E}(dz_t^{ij}) \sim \left[z^*(E^i) - z^*(E^j)\right]^2$$

Data: Environmental Distance

- The environmental distance is calculated based on the geographic characteristics (over 50 characteristics in total):
  - Climate (e.g., temperature, precipitation, etc.) (World Climate database)
  - Agriculture (e.g., crop yields) (FAO GAEZ database)
  - Elevation and Ruggedness
- For a given location a mean value of each characteristic is calculated
- Principal component analysis is used to summarize environmental data
- Pair-wise environmental distance is calculated:
  - Naively – based on the mean euclidean distance across all variables
  - Based on the euclidean distance of several first principal components

Data: Time Since Last Common Ancestry

- We proxy for the effects of "drift" on cultural norms using the measures of genetic, linguistic, and geographic distance between populations
  - We use the weighted Fst genetic distance, based on the data from Spolaore and Wacziarg (2016)
  - Linguistic distance is a weighted measure from Fearon (2003) (based on a number of common linguistic nodes in the Ethnologue, for any given pair of countries)
  - As a measure of geographic distance, we use population weighted geodesic distance.

Data: Cultural Distance

- We use the cross-country (potentially, cross-regional) WVS survey data to measure cultural dissimilarities across the globe (based on Spolaore and Wacziarg (2016))
  - 98 questions for the whole sample, split into 5 clusters: (A) Perceptions of Life, (C) Work,(D) Family, (E) Politics and Society, and (F) Religion and Morale.
  - Analogously to genetics, questions correspond to gene loci, and answers correspond to alleles. For each question, Euclidean (or Manhattan, Fst, etc.) distance using the average answer shares is calculated. Standardize for each question.
  - Sum distances for all questions, and by each "cluster" of cultural norms.

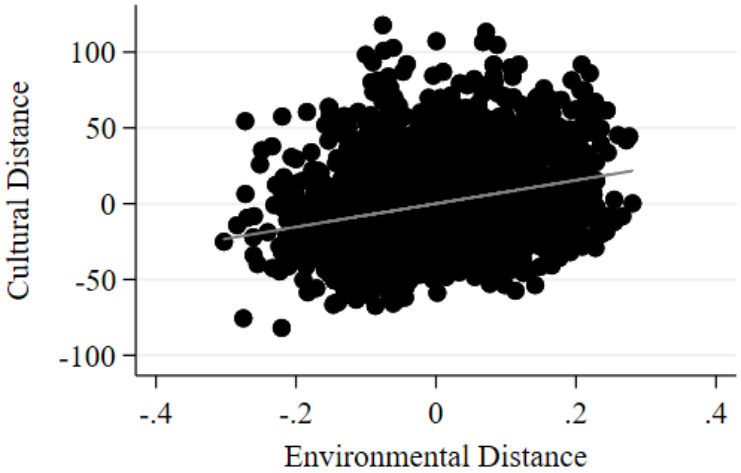
Preliminary results: overall cultural distance

Table 1: Basic correlations

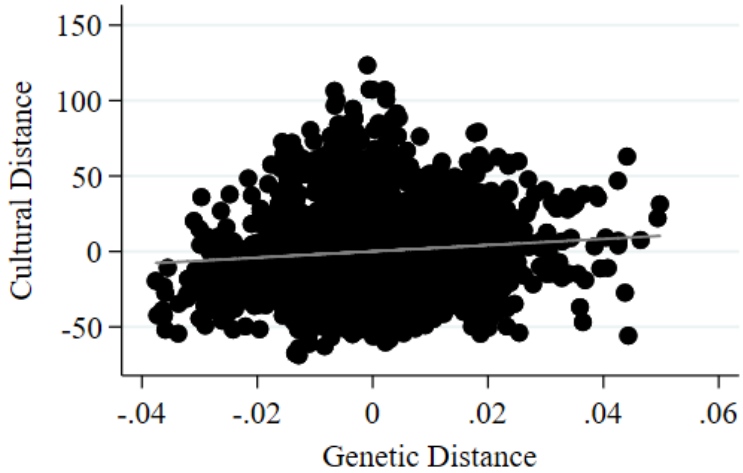
VARIABLES	(1) Cultural Distance	(2) Cultural Distance	(3) Cultural Distance	(4) Cultural Distance	(5) Cultural Distance	(6) Cultural Distance
Environmental Distance	0.362***	0.296***	0.272***	0.274***	0.205***	0.202***
	(7.612)	(5.406)	(4.939)	(5.081)	(4.041)	(5.691)
Genetic Distance		0.135**	0.0933	0.103	0.0527	0.107**
		(2.122)	(1.515)	(1.596)	(0.879)	(2.393)
Linguistic Proximity			-0.313***	-0.313***	-0.268***	-0.254***
			(-6.334)	(-6.420)	(-5.742)	(-5.911)
Geodesic Distance				-0.0199	-0.0224	-0.173***
				(-0.515)	(-0.626)	(-3.929)
Observations	2,628	2,346	2,080	2,080	2,016	2,016
R-squared	0.131	0.143	0.231	0.232	0.312	0.419
Other Bilateral	No	No	No	No	Yes	Yes
Continent FE (levels)	No	No	No	No	No	Yes

Two-way cluster-robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

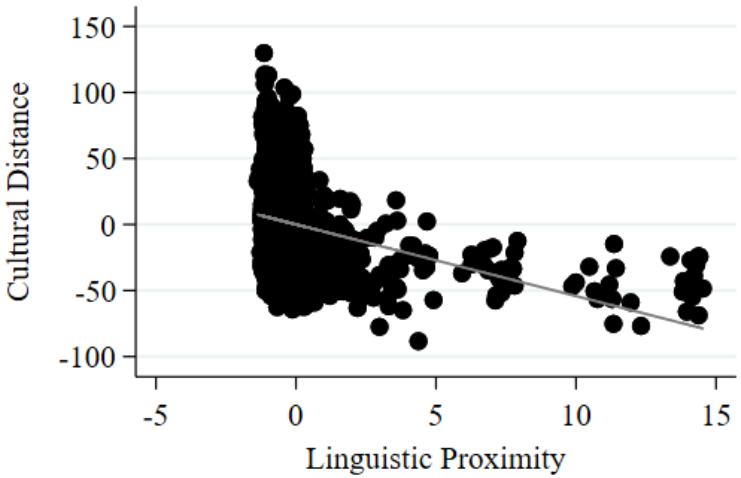
Preliminary results: overall cultural distance



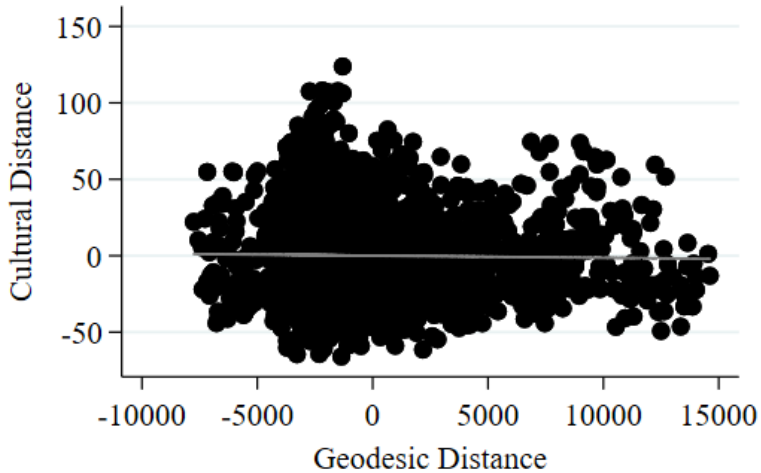
coef = 77.119754, (robust) se = 13.222123, t = 5.83



coef = 206.80109, (robust) se = 93.815037, t = 2.2

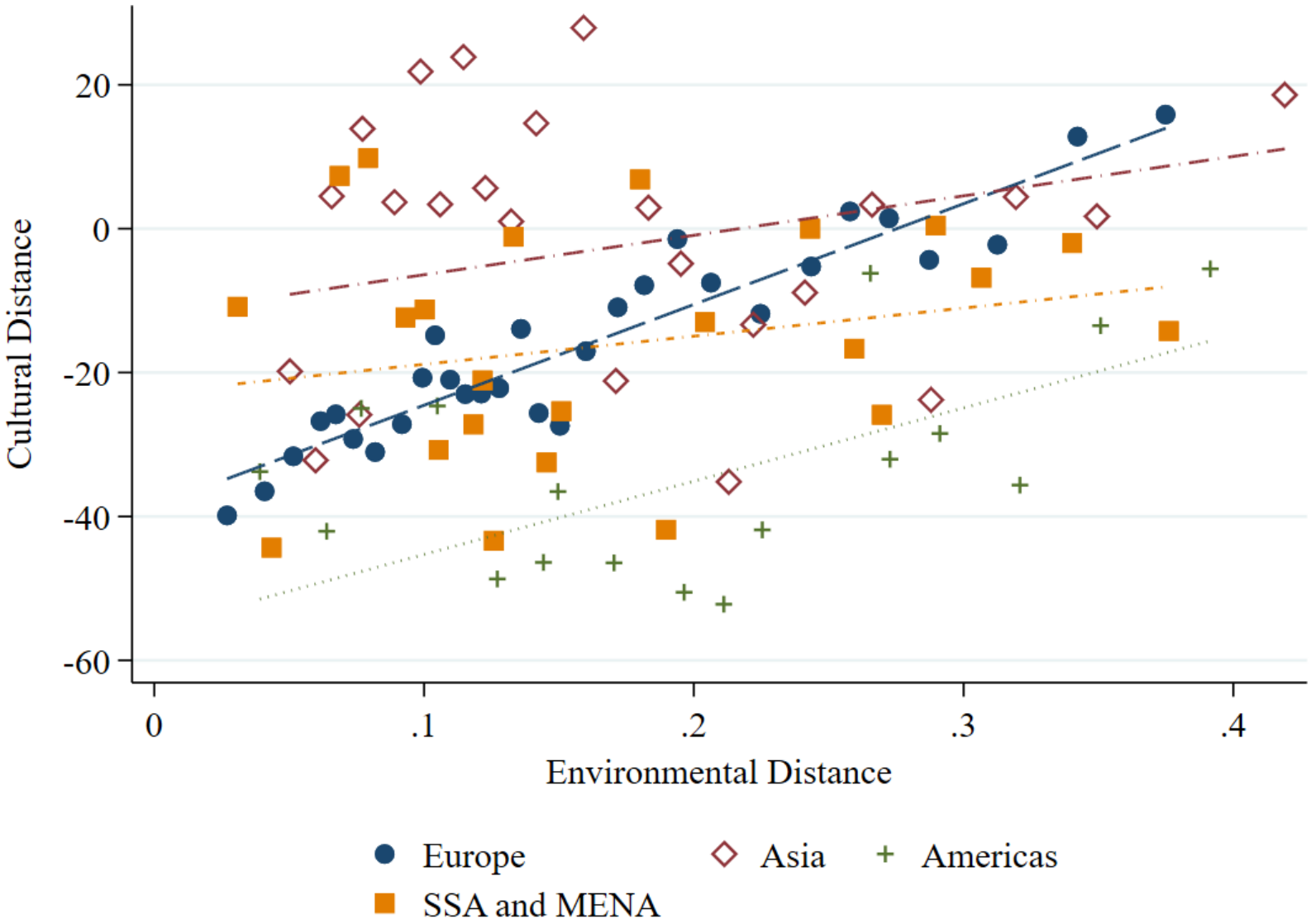


coef = -5.4189179, (robust) se = .5677044, t = -9.55



coef = -.00013935, (robust) se = .00023493, t = -.59

Preliminary results: overall cultural distance



Preliminary results: overall cultural distance

Table 2: Types of environmental characteristics

VARIABLES	(1) Cultural Difference	(2) Cultural Difference	(3) Cultural Difference	(4) Cultural Difference
Environmental Distance	0.274***		0.202***	
	(5.081)		(5.691)	
Agricultural Distance		0.0129		-0.00292
		(0.485)		(-0.106)
Climatic Distance		0.354***		0.255***
		(5.914)		(6.576)
Geographic Distance		-0.0205		0.0101
		(-0.618)		(0.265)
Genetic Distance	0.103	0.0847	0.107**	0.0729
	(1.596)	(1.387)	(2.393)	(1.615)
Linguistic Proximity	-0.313***	-0.296***	-0.254***	-0.245***
	(-6.420)	(-6.206)	(-5.911)	(-5.582)
Geodesic Distance	-0.0199	-0.0525	-0.173***	-0.198***
	(-0.515)	(-1.402)	(-3.929)	(-4.458)
Observations	2,080	2,080	2,016	2,016
Adjusted R-squared	0.230	0.263	0.410	0.428
Other Bilateral	No	No	Yes	Yes
Continent FE	No	No	Yes	Yes

Two-way cluster-robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Preliminary results: cultural clusters (WVS)

Table 3: Cultural clusters: drift vs. selection

Partial R-squared values	Overall	Perceptions of Life	Work	Family	Politics and Society	Religion and Morale
Environmental Distance	0.07	0.036	<0.01	0.03	0.063	0.055
Genetic Distance	<0.01	<0.01	<0.01	0.016	0.01	0.017
Linguistic Distance	0.11	0.1	0.023	0.078	0.075	0.032
Geodesic Distance	<0.001	<0.001	<0.001	0.01	<0.01	<0.01

Further steps: extensive margin

- Finer data on regions and groups for which culture and environment are calculated
  - GADM subnational regions (contemporary polygons)
  - Ethnographic Atlas (historical polygons for ethnic groups)
  - Afrobarometer (contemporary points (PSUs))
- More exquisite clustering into "drift - intensive" and "selection-intensive" traits (Machine Learning)

Further steps: identification

- 2nd-generation migrants analysis
  - Within a given country, looking at cultural differences of children of immigrants from various countries
  - Is that true that children of immigrants from countries that are close geographically but far apart environmentally (like Niger and Nigeria) are more distant culturally than children of immigrants from countries that are geographically distant but similar environmentally?
- Analyzing societies that are sufficiently far apart

Further steps: linkages to development

- What kinds of cultural differences, "drift-intensive" or "selection-intensive", are the major barriers for
  - trade
  - migration
  - spread of knowledge
- The effects of environmental (dis)similarity on the location choices of migrants and the subsequent cultural adaptations

Individual Learning: Individual

- Individual i of generation t has a utility function:

$$u_{it} = \gamma \log n_{it} + (1-\gamma) \log c_{it} - \alpha \log(x_{it}^a - x_{it})^2 - \beta \log(z_{it}^a - z_{it})^2$$

- Individual chooses:
  - Fertility – n_{it}
  - Consumption – c_{it}
  - Action x – x_{it}^a
  - Action z – z_{it}^a
- Action along x and z dimension are influenced by a corresponding cultural traits: x_{it} and z_{it}

Individual Learning: Production

- The output of an individual is:

$$y_{it}(z_{it}^a) = y_t \exp\{-\delta(z_{it}^a - z^*)^2\}$$

- The output depends on z but not on x:
  - Output is maximized under z^* (effect of the environment)
  - Output is orthogonal to x (no selective pressure on x)

- The budget constraint of an individual is:

$$c_{it} + \tau n_{it} \leq y_{it}(z_{it}^a)$$

Individual Learning: Individual Choice

- When choosing z action individual is influenced by:
  - Cultural trait – z_{it}
  - The environment – z^* (learning component)
- As a result individual chooses:

$$z_{it}^a = \lambda z_{it} + (1-\lambda) z^*, \quad \lambda \equiv \beta / (\beta + \delta)$$

- Choice of x action is affected only by cultural trait:

$$x_{it}^a = x_{it}$$

Individual Learning: Evolution

- Children of an individual i in generation $t+1$ adopt the action of parent as their cultural trait with a mutation:

$$x_{it+1} = x_{it}^a + \varepsilon_{it+1} = x_{it} + \varepsilon_{it+1}$$
$$z_{it+1} = z_{it}^a + \eta_{it+1} = \lambda z_{it} + (1-\lambda)z^* + \eta_{it+1}$$

Back

Social Learning: Individual

- Individual i of generation t has a utility function:

$$u_{it} = \gamma \log n_{it} + (1 - \gamma) \log c_{it}$$

- Individual chooses:
  - Fertility – n_{it}
  - Consumption – c_{it}
  - Action x – x_{it}^a
  - Action z – z_{it}^a

- Action along x and z dimension are chosen to exactly match corresponding cultural traits x_{it} and z_{it}:

$$x_{it}^a = x_{it}$$

$$z_{it}^a = z_{it}$$

Social Learning: Production

- The output of an individual is:

$$y_{it}(z_{it}^a) = y_t \exp\{-\delta(z_{it}^a - z^*)^2\}$$

- The output depends on z but not on x:
  - Output is maximized under z^* (effect of the environment)
  - Output is orthogonal to x (no selective pressure on x)

- The budget constraint of an individual is:

$$c_{it} + \tau n_{it} \leq y_{it}(z_{it}^a)$$

- Even though z_{it}^a affects the output, individual does not internalize this when making a choice (no individual learning)

Social Learning: Evolution

- Children of an individual i in generation $t+1$ observe the action of parent but also learn from other **successful** individuals:

$$z_{it+1} = \phi(z_{it}^a, z_{st}^a) + \eta_{it+1} = \lambda z_{it} + (1-\lambda) z_{st} + \eta_{it+1}$$

- Where s is the most successful individual (prestige bias)

$$s = \arg\max_i \{u_{it}\} = \arg\max_i \{y_{it}(z_{it}^a)\}$$

- Thus $z_{st} = z^*$ (assuming that such individual exists)

$$z_{it+1} = \lambda z_{it} + (1-\lambda) z^* + \eta_{it+1}$$

Back

Natural Selection: Individual

- Individual i of generation t has a utility function:

$$u_{it} = \gamma \log n_{it} + (1 - \gamma) \log c_{it}$$

- Individual chooses:
  - Fertility – n_{it}
  - Consumption – c_{it}
  - Action x – x_{it}^a
  - Action z – z_{it}^a

- Action along x and z dimension are chosen to exactly match corresponding cultural traits x_{it} and z_{it}:

$$x_{it}^a = x_{it}$$

$$z_{it}^a = z_{it}$$

Natural Selection: Production

- The output of an individual is:

$$y_{it}(z_{it}^a) = y_t \exp\{-\delta(z_{it}^a - z^*)^2\}$$

- The output depends on z but not on x:
  - Output is maximized under z^j (effect of the environment)
  - Output is orthogonal to x (no selective pressure on x)

- The budget constraint of an individual is:

$$c_{it} + \tau n_{it} \leq y_{it}(z_{it}^a)$$

- Even though z_{it}^a affects the output, individual does not internalize this when making a choice (no individual learning)

Natural Selection: Evolution

- Reproductive success of an individual i in period t depends on the trait z but not on x:

$$n_{it}(z_{it}) = \gamma/\tau y_{it}(z_{it}) = \gamma/\tau y_t \exp\{-\delta(z_{it} - z^*)^2\}$$

- Children of an individual i in generation $t+1$ inherit the traits of the parent with mutations:

$$x_{it+1} = x_{it} + \varepsilon_{it}$$
$$z_{it+1} = z_{it} + \eta_{it}$$

- The evolution of a cultural trait on a group level is:

$$z_{t+1} = \sum_i n_{it}(z_{it}) z_{it} / \sum_i n_{it}(z_{it}) + \eta_t$$
$$x_{t+1} = \sum_i n_{it}(z_{it}) x_{it} / \sum_i n_{it}(z_{it}) + \varepsilon_t$$

Natural Selection: Evolution

- The $\{z_t\}_{t=0}^{\infty}$ process is no longer AR(1), but it can be shown that:
  - $\mathbb{E}(z_t) = z^*$
  - $Var(z_t)$ – is stationary
- Natural selection introduces alternative/additional force to make $\{z_t\}_{t=0}^{\infty}$ stationary

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