Cultures as networks of cultural traits:

A unifying framework for measuring culture and cultural distances

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Culture and the Social Sciences

Culture is (now) recognised to have a major importance beyond the Humanities

- **Economics**: "cultural variables ... affect the speed of development and the wealth of nations" (Alesina & Giuliano, 2015)
- **Politics**: Political actions depend on culture (Lane & Ersson, 2016)
- **Sociology**: Culture shapes individual identity (Schwartz, 2008)
- **Management**: Organizations and local culture (Yeganeh & Su, 2006)
- **Anthropology**: Humans transmit through culture (Ruck et al., 2020)
- **Psychology**: Personality traits and culture (Kashima et al., 2019)
- **International Business**: Is about cultural differences (Taras et al., 2009)

Culture: Definition and Measurement

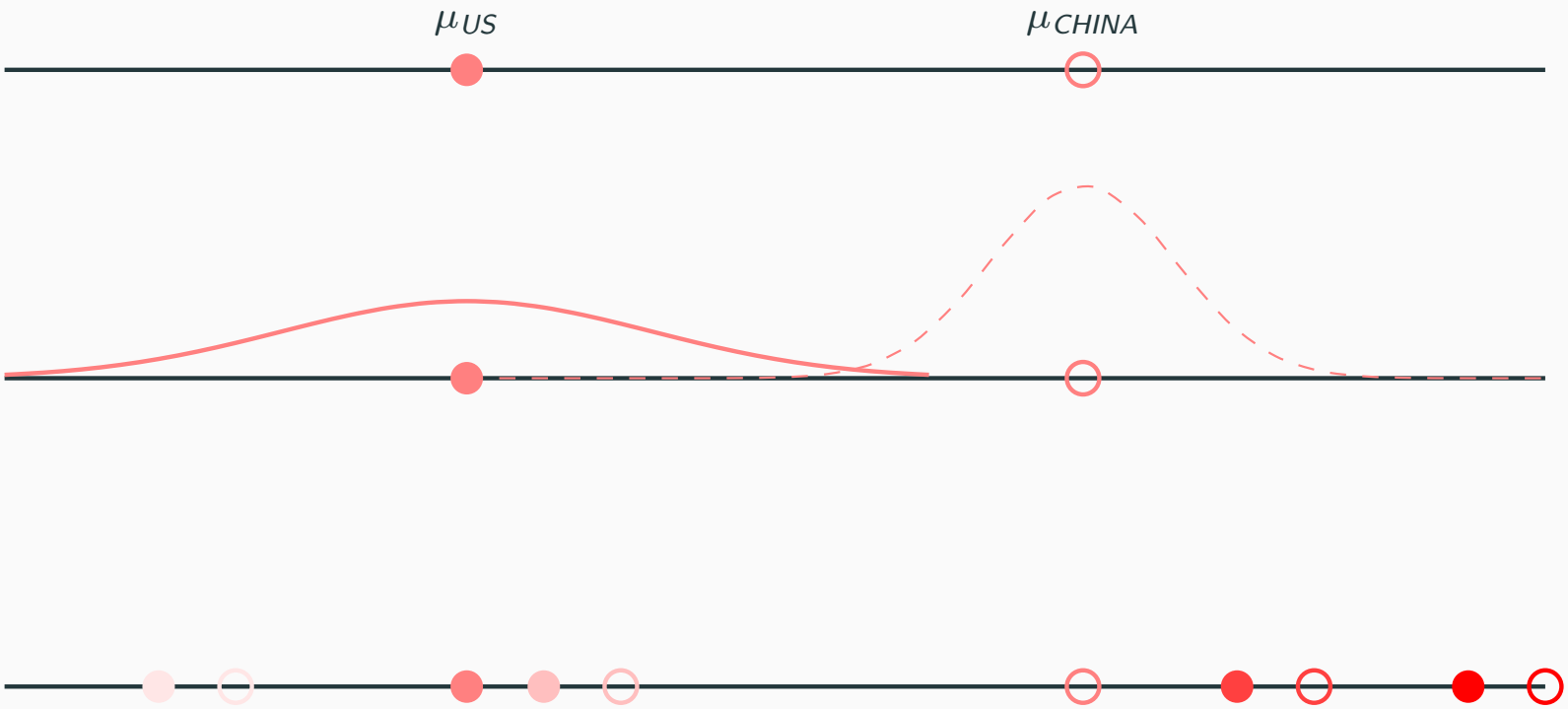
Defining culture

- From Taylor, 1871, to UNESCO, 2001, the definition of Culture is problematic.
- Up to 160 possible definitions of culture (Kroeber & Kluckhohn, 1952).
- Some authors conclude that the very notion of cultural diversity implies that cannot be any generally agreed definition of culture (Jahoda, 2012) $\rightsquigarrow$ ["emic" vs "etic" approaches].

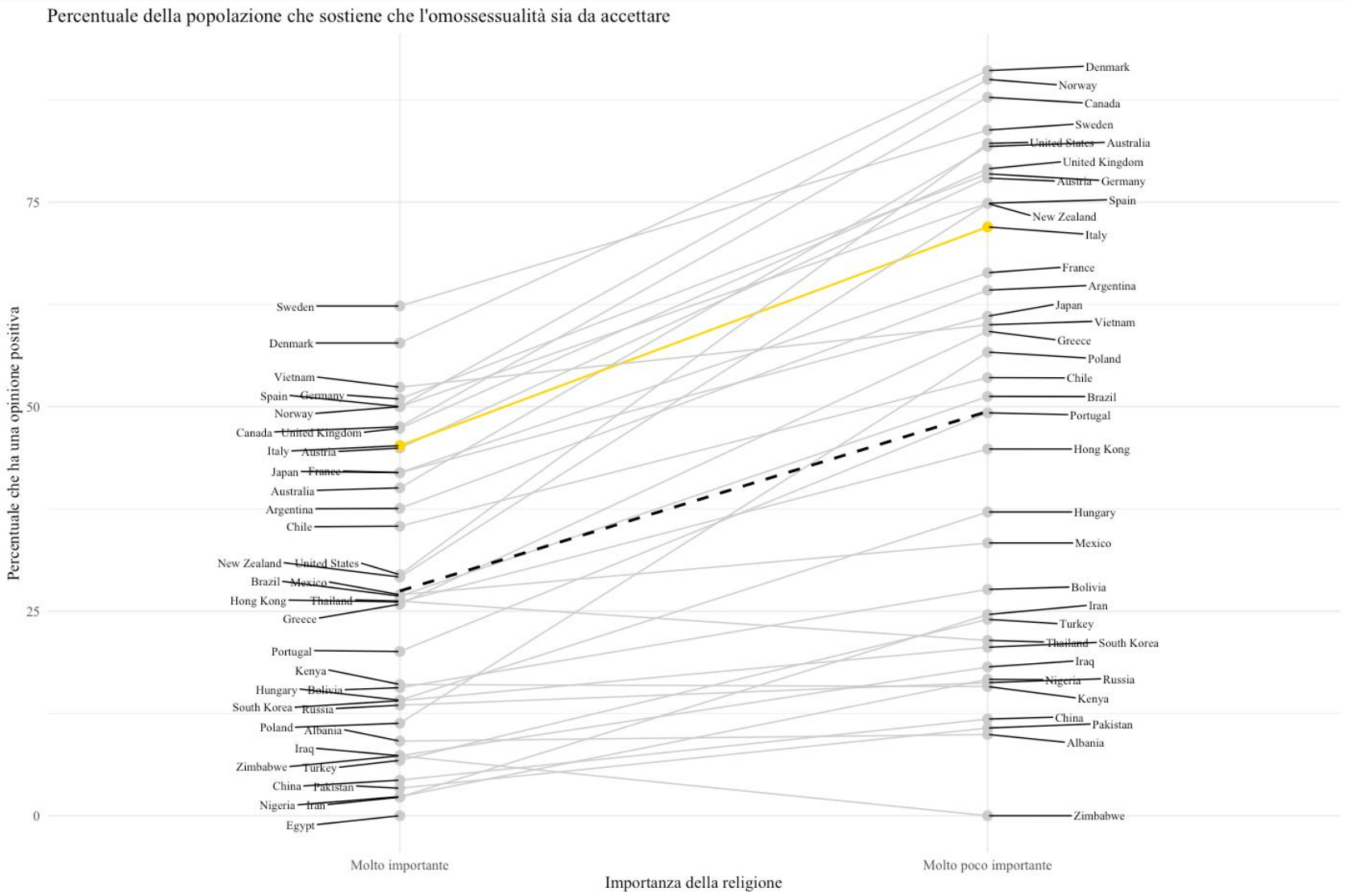
One (operationalisable) definition

- Culture is the/a set of local norms, customs, attitudes and values (Alesina & Giuliano, 2015).
- **Implication**: Latent dimensions of Culture

Illustrative example



More than one cultural trait



Culture: Definition and Measurement

A cross-country comparative cultural approach

- **Units of analysis**: Cultural traits.
- **Measurement of national culture**: as the network of interdependent cultural traits, at the country level.
- **Measurement of international cultural distance**: as the distance between national cultures.

Survey data

- Traditional methodologies - based on the comparison of means or on Principal Component Analysis - have been applied to different surveys (Hofstede, 1980; Inglehart & Welzel, 2005; Schwartz, 1994).
- We make use of the data from the **World Values Survey** (Waves 6/7).
- We take the work of Inglehart & Welzel (2005) as a benchmark: 60 (54) countries and 10 cultural traits.

Overview

Definition of culture
Culture is superadditive: it is more than the sum of its parts.

Culture as a network
Uncover the latent structure ($\mathbf{K}$) of Culture at the national level.

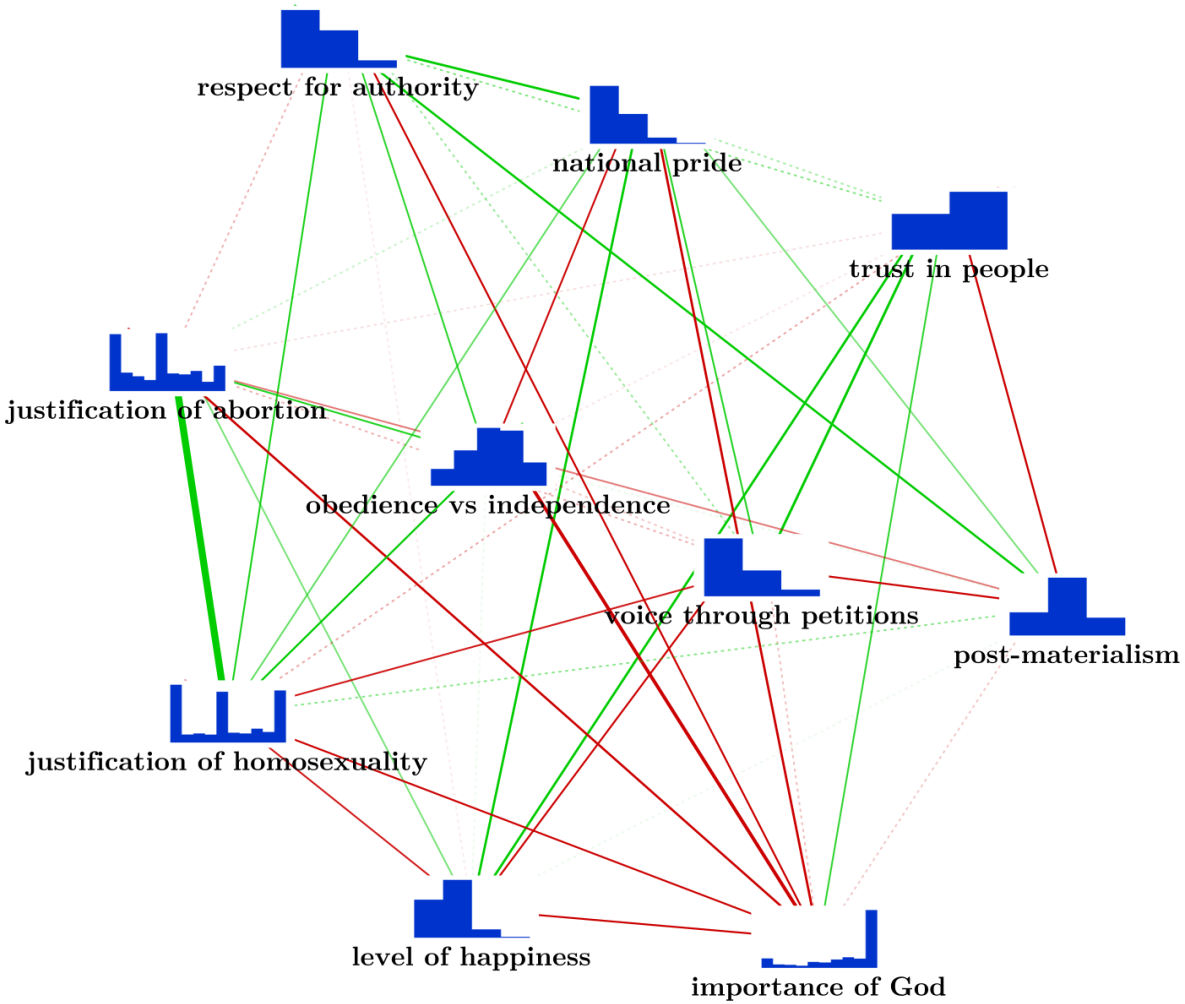
Methodology
Exploit the computational efficiency of Bayesian Copula Graphical Models, taking traditional methodologies as a benchmark (`IW Index`).

A new `JD Index` of cultural distance
being the sum of two orthogonal components:

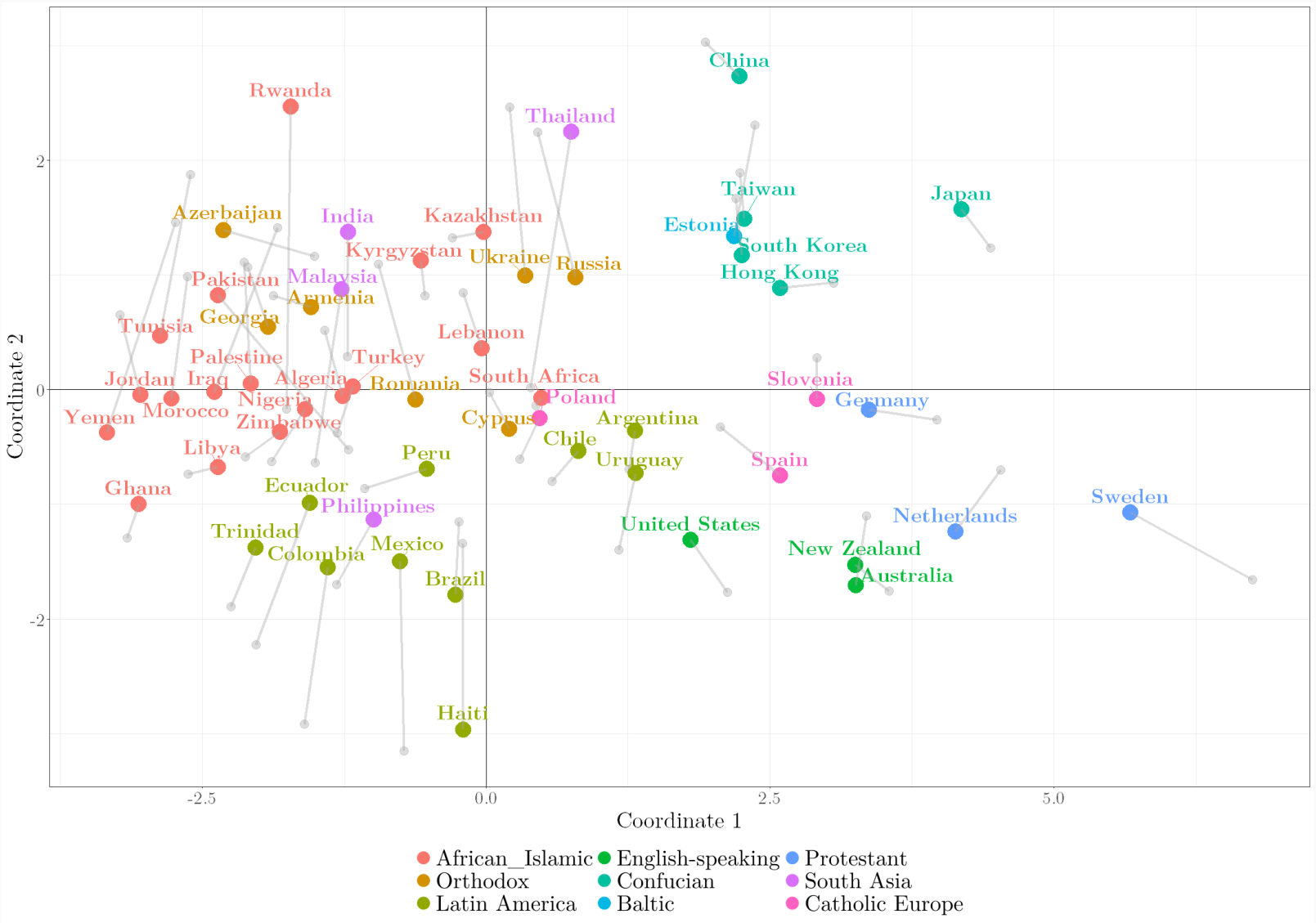
- `JD Marginals`: accounting for the distance in cultural traits.
- `JD Network`: accounting for the distance in the networks structure.

An analysis of the correlates of culture
Regression of the components of the `JD Index` on the characteristics of countries or the cultural configurations (sub-network structures) to evaluate what make countries culturally similar?

Overview: The US cultural network



Overview: Cultural distances projected on a Cultural Map

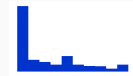


An account of the World Values Survey

Variables: all countries (1)

		Cultural traits			
id	**label**	**variable** (categories)	distribution	overall mean [min, max]	missing % [min, max]
V10	**H**	level of **happiness** (1:4)	 [low high]	1.855 [1.387, 2.256]	0.8 [0.0, 5.5]
V24	**T**	**trust** in people (1:2)	 [high low]	1.764 [1.326, 1.971]	2.7 [0.00, 10.8]
V69	**R**	**respect for authority** (1:3)	 [high low]	1.503 [1.062, 2.732]	4.5 [0.00, 18.7]
V85	**V**	**voice** through petitions (1:3)	 [high low]	2.314 [1.19, 2.857]	5.2 [0.00, 30.2]
V152	**G**	**importance of God** (1:10)	 [low high]	7.781 [3.482, 9.865]	2.5 [0.00, 16.3]

Variables (2)

Cultural traits					
id	**label**	**variable** (categories)	distribution	overall mean [min, max]	missing % [min, max]
V203	**O**	justification of **homosexuality** (1:10)	 [low high]	3.35 [1.127, 8.47]	5.6 [0.00, 34.6]
V204	**A**	justification of **abortion** (1:10)	 [low high]	3.24 [1.515, 7.997]	3.8 [0.00, 19.0]
V211	**P**	**national pride** (1:4)	 [high low]	1.523 [1.059, 2.176]	2.8 [0.00, 12.3]
Y002	**M**	**post-materialism** (1:3)	 [low high]	1.73 [1.281, 2.244]	4.2 [0.00, 31.9]
Y003	**B**	**obedience vs independence** (1:5)	 [high low]	3.059 [2.066, 4.261]	0.3 [0.00, 1.0]

Methodology

Bayesian Copula Graphical Models

Graphical models are popular models for inference of undirected graphs (Lauritzen, 1996). They consider variables as nodes and measure node-dependency (link) in terms of **partial correlations**, conditional on the interdependence with all other nodes.

- Cultural traits inter-dependencies are not observed and must be inferred $\rightsquigarrow$ **Gaussian graphical models** (Ggm)
- Cultural traits are ordinal variables $\rightsquigarrow$ **Copula** (Gcgm)
- **Bayesian procedure** allows to infer the posterior probability of a link.
- Advances in Bayesian computational procedure based on Birth-Death Markov Chain Monte Carlo (BDMCMC) methods allow to infer the Gcgm quite efficiently $\rightsquigarrow$ 2mil iterations in 8 days.

We use the R library `BDgraph` (Mohammadi & Wit, 2019) to infer the cultural network for each country in the dataset.

Bayesian Gaussian Copula Graphical Model

The Bayesian `GCGM` procedure applied to a $Y = (Y_1, \ldots, Y_p)$ vector of p cultural traits - given the joint distribution of Y:

$$P(Y_1 \leq y_1, \ldots, Y_p \leq y_p) = \underbrace{C(F_1(y_1), \ldots, F_p(y_p) \mid R)}_{Copula}.$$

where F_j is the marginal cumulative distribution function of the Y_j cultural trait, and R is the correlation matrix - produces:

- **Precision matrix ($K \equiv R^{-1}$)**: It is uniquely associated to the underlying network, as a conditionally independent graph. Precision matrix: US Example
- **Partial Correlation network**: it contains both the **intensity** and the **sign** of the relationships between cultural traits. Partial correlation matrix: US Example

$$\gamma_{ij} = \rho(Z_i, Z_j \mid Z_{-ij}) = -\frac{k_{ij}}{\sqrt{k_{ii}\, k_{jj}}}, \quad i \neq j.$$

- **Posterior Edge Inclusion Probabilities**: Posterior Edge Inclusion Probabilities: US Example

$$P(e \in E \mid Y) = \frac{\sum_{t=1}^{N} 1(e \in G^{(t)}) W(K^{(t)})}{\sum_{t=1}^{N} W(K^{(t)})},$$

where E is the set of edges, N is the number of MCMC iterations and $W(K^{(t)})$ is the waiting time for Graph $G^{(t)}$ with precision matrix $K^{(t)}$.

A unifying index of cultural distance

The **KL divergence** between two countries m and l is approximated by:

$$KL(m \quad || \quad l) \approx \underbrace{\sum_{i=1}^{p} KL(f_i^{(m)} || f_i^{(l)})}_{\texttt{KL Marginals}} + \underbrace{KL(c(\mathbf{F}^m; \mathbf{K}^{(m)}) || c(\mathbf{F}^l; \mathbf{K}^{(l)}))}_{\texttt{KL Network}} =$$

$$= \quad \sum_{i=1}^{p} \sum_{k=1}^{C_i} f_i^{(m)}(c_k) \log\left(\frac{f_i^{(m)}(c_k)}{f_i^{(l)}(c_k)}\right) + 0.5\left(\text{Trace}(\mathbf{K}^{(l)}(\mathbf{K}^{(m)})^{-1}) + \log\frac{|\mathbf{K}^{(m)}|}{|\mathbf{K}^{(l)}|} - p\right)$$

The symmetric KL divergence is a **Jeffreys' divergence**:

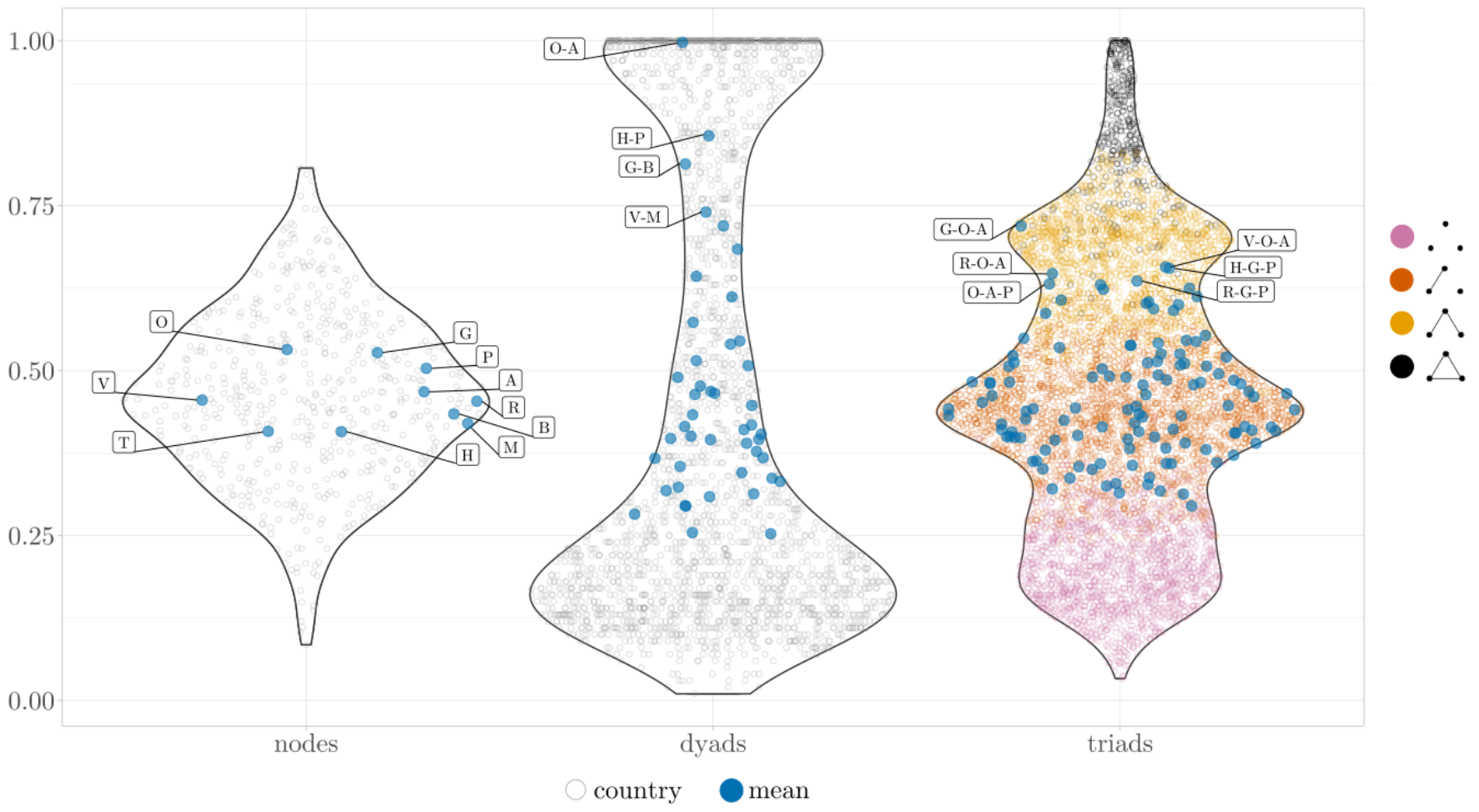
$$JD(m, l) \quad = \quad \underbrace{\sum_{i=1}^{p} \sum_{k=1}^{C_i} (f_i^{(m)}(c_k) - f_i^{(l)}(c_k)) \log\left(\frac{f_i^{(m)}(c_k)}{f_i^{(l)}(c_k)}\right)}_{\texttt{JD Marginals}} +$$

$$+ \underbrace{\frac{\text{Trace}(\mathbf{K}^{(l)}(\mathbf{K}^{(m)})^{-1}) + \text{Trace}(\mathbf{K}^{(m)}(\mathbf{K}^{(l)})^{-1})}{2} - p}_{\texttt{JD Network}}.$$

Description of the inferred networks of cultural values

Sinaplots (1): Topological properties of countries cultural networks

Sinaplots (2): Nodes centrality, edges probabilities and triads

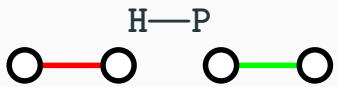
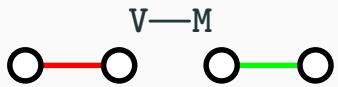
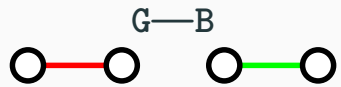
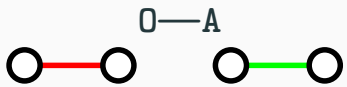
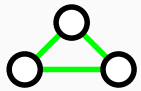
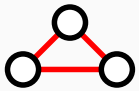
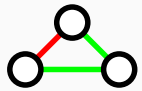
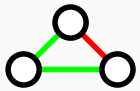
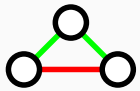
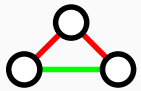
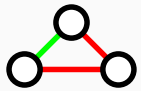
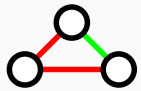
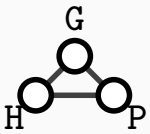
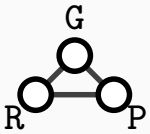
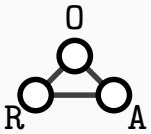
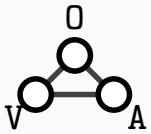
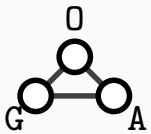
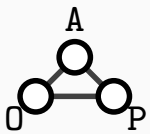


Most frequent configuration: dyads and triads

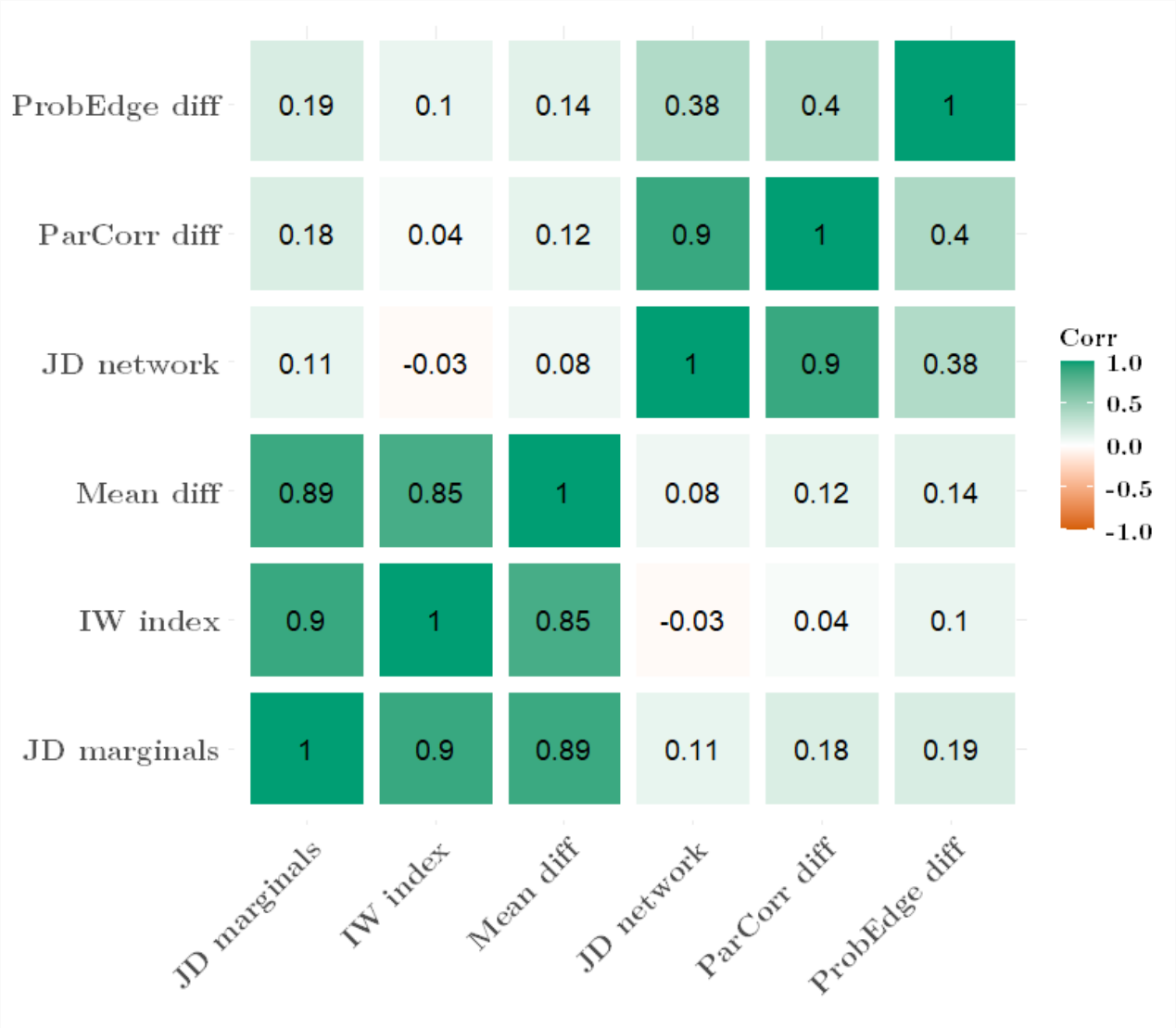
	H—P		V—M		G—B		O—A	
dyads	1.85	**98.15**	**90.74**	9.26	**98.15**	1.85	0.00	**100.00**

triads								
G H P	7.41	1.85	1.85	33.33	0.00	**55.56**	0.00	0.00
G R P	3.70	11.11	5.56	16.67	0.00	**61.11**	1.85	0.00
O R A	**59.26**	0.00	11.11	0.00	24.07	0.00	0.00	5.56
O V A	5.56	0.00	29.63	0.00	18.52	0.00	0.00	**46.30**
O G A	3.70	0.00	20.37	0.00	16.67	0.00	0.00	**59.26**
A O P	**59.26**	0.00	0.00	12.96	24.07	0.00	3.70	0.00

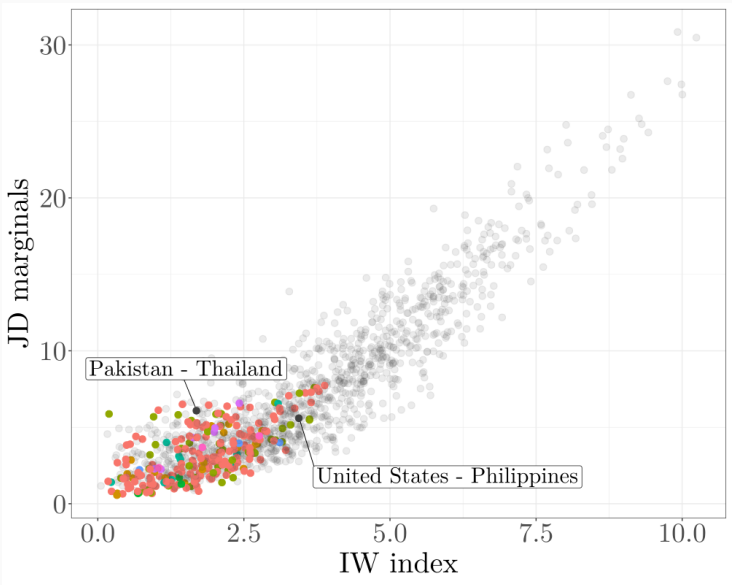
Most frequent configuration: dyads and triads

								
dyads	H—P		V—M		G—B		O—A	
	1.85	**98.15**	**90.74**	9.26	**98.15**	1.85	0.00	**100.00**
triads								
	7.41	1.85	1.85	33.33	0.00	**55.56**	0.00	0.00
	3.70	11.11	5.56	16.67	0.00	**61.11**	1.85	0.00
	**59.26**	0.00	11.11	0.00	24.07	0.00	0.00	5.56
	5.56	0.00	29.63	0.00	18.52	0.00	0.00	**46.30**
	3.70	0.00	20.37	0.00	16.67	0.00	0.00	**59.26**
	**59.26**	0.00	0.00	12.96	24.07	0.00	3.70	0.00

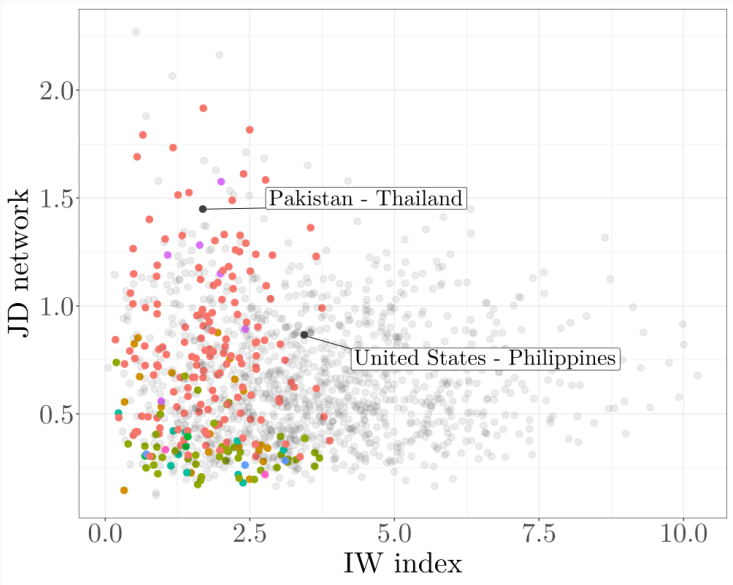
Correlation between different cultural distances



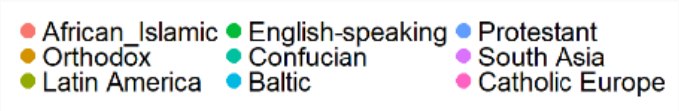
Comparison: IW index, JD marginals and JD network



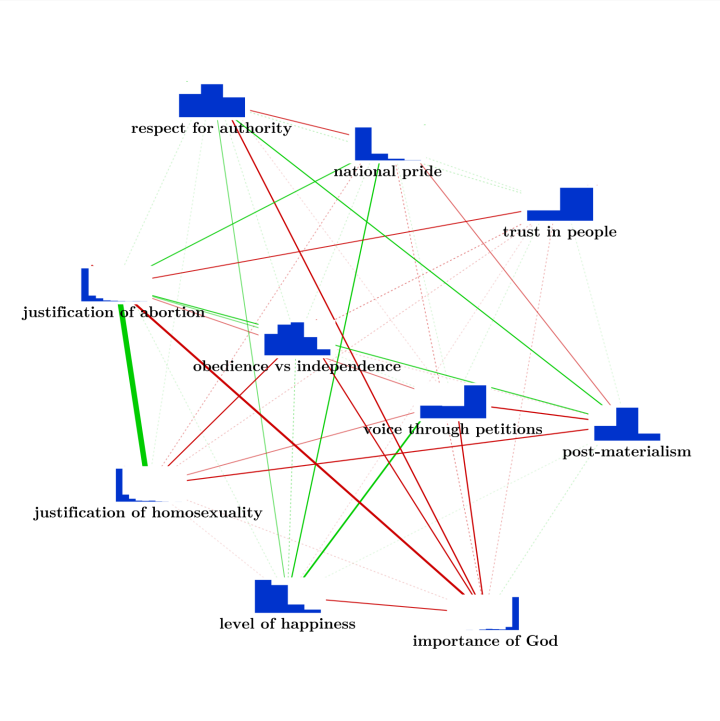
(a) IW index vs JD marginals



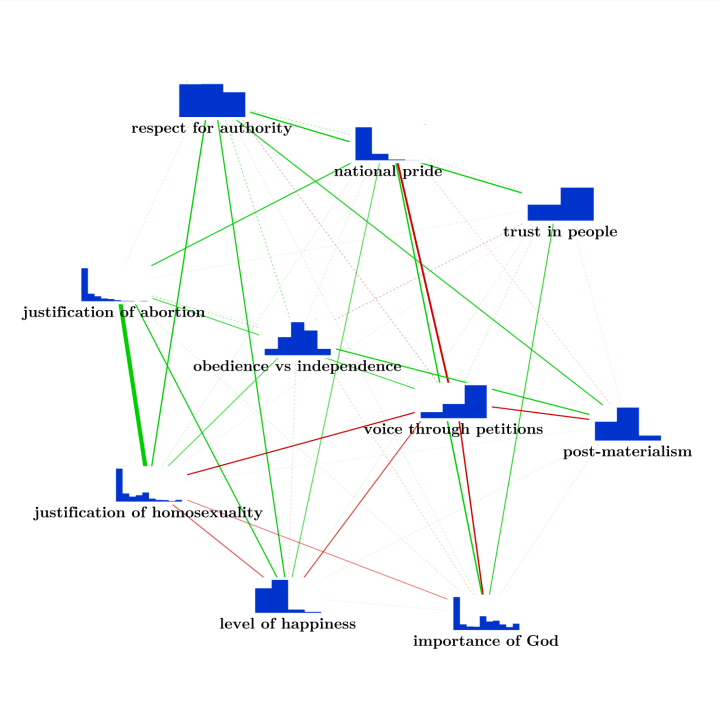
(b) IW index vs JD network



The Network Structure of National Cultures: Pakistan and Thailand

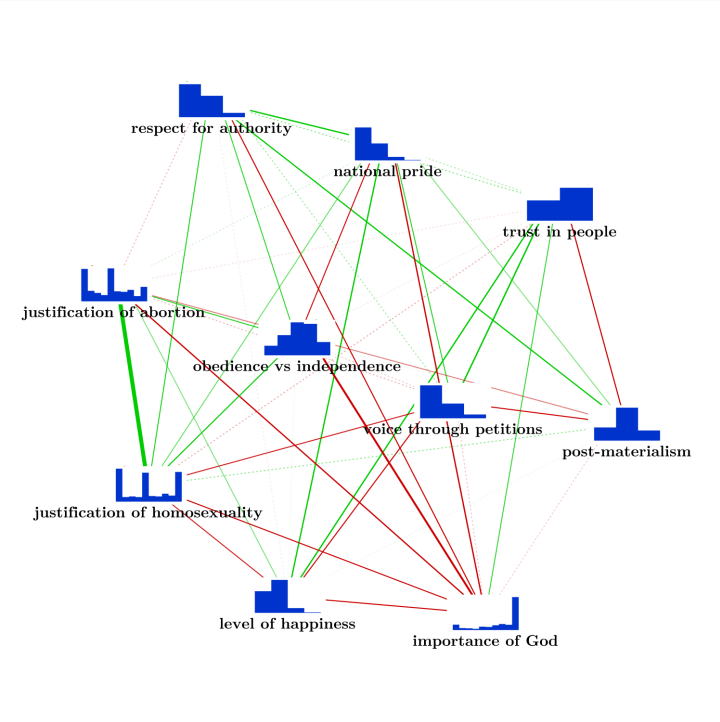


(a) *Pakistan's Cultural Network*

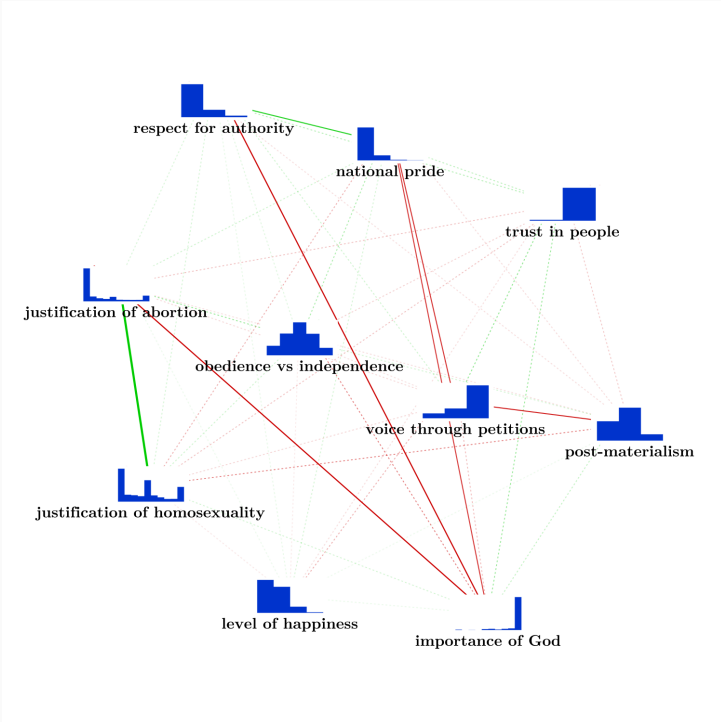


(b) *Thailand's Cultural Network*

The Network Structure of National Cultures: USA and Philippines

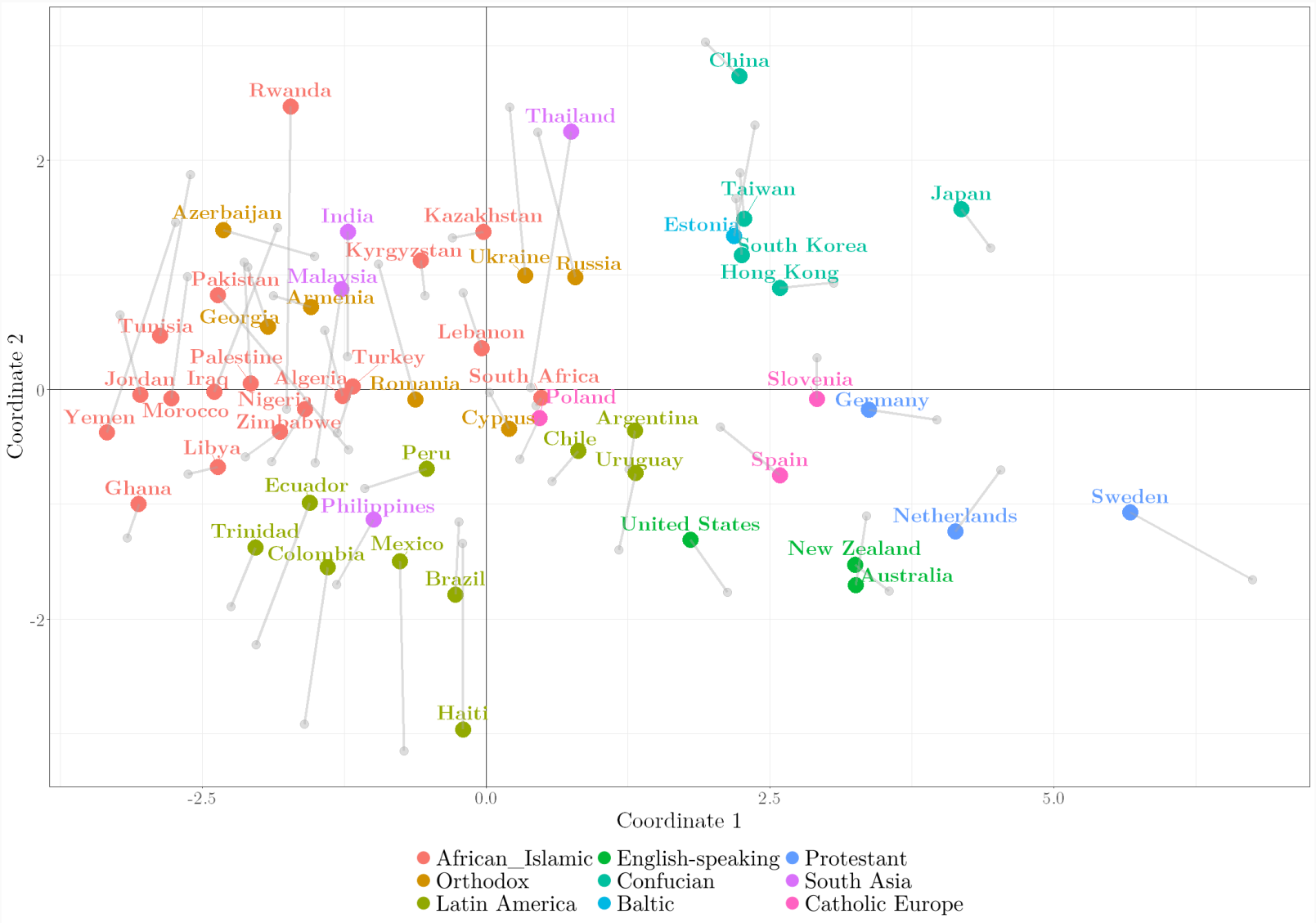


(a) *United States' Cultural Network*



(b) *Philippines' Cultural Network*

A new Cultural Map



Cultural distance's correlates

Dyadic regression on the JD index components: model

$$y_{i,j}^{\texttt{JD component}} = \beta^T x_{i,j} + a_i + b_j + \epsilon_{i,j}$$

$y_{i,j}^{\texttt{JD component}}$ is either `JD Marginals` or `JD Network`. a_i and b_j capture country i and j heterogeneity. ϵ allows $\epsilon_{i,j}$ and $\epsilon_{j,i}$, to be cross-correlated.

$$Var\left[\begin{pmatrix} a_i \\ b_i \end{pmatrix}\right] = \Sigma = \begin{pmatrix} \sigma_a^2 & \sigma_{ab} \\ \sigma_{ab} & \sigma_b^2 \end{pmatrix} \quad ; \quad Var\left[\begin{pmatrix} \epsilon_{i,j} \\ \epsilon_{j,i} \end{pmatrix}\right] = \sigma^2 \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}$$

$$\begin{aligned} y_{i,j}^{\texttt{JD component}} = \; & \beta_0 + \beta_1 \textit{geographical distance}_{i,j} + \beta_2 \textit{spatial contiguity}_{i,j} + \\ & + \beta_3 \textit{gdppc similarity}_{i,j} + \beta_4 \textit{polity similarity}_{i,j} + \\ & + \beta_5 \textit{common empire}_{i,j} + \beta_6 \textit{common language}_{i,j} + \\ & + \beta_7 \textit{density}_{i,j} + \beta_8 \textit{centralization}_{i,j} + \beta_9 \textit{clustering}_{i,j} + \\ & + \beta_{10} \textit{IW groups}_{i,j} + a_i + b_j + \epsilon_{i,j} \end{aligned}$$

Dyadic regression on the JD index components: results

	JD Marginals		JD Network	
intercept	**11.445**	[9.61 13.45]	**2.630**	[2.33 2.95]
geographical distance	**0.517**	[0.33 0.72]	0.006	[-0.01 0.02]
spatial contiguity	-0.475	[-1.02 0.21]	**-0.049**	[-0.08 -0.02]
gdppc similarity	**-10.689**	[-11.63 -9.79]	**-0.268**	[-0.31 -0.22]
polity similarity	**-11.229**	[-13.41 -9.12]	**-0.262**	[-0.38 -0.15]
common empire	**-2.757**	[-3.33 -2.32]	-0.022	[-0.05 0.01]
common language	0.085	[-0.30 0.45]	**-0.034**	[-0.06 -0.02]
IW groups	**-2.060**	[-2.39 -1.79]	**0.000**	[-0.02 0.02]
density			**-11.058**	[-12.55 -9.69]
centralization			-0.102	[-0.42 0.23]
clustering			**6.849**	[5.73 8.05]
...	...		...	
O-A-V			**0.543**	[0.42 0.65]
O-A-G			**0.787**	[0.72 0.86]
countries	51		51	

Conclusion

Concluding Remarks

Main contributions

- **National Cultures** are more than the sum of their cultural trait.
- **Graphical models** provide a way of inferring the inter-connectedness among cultural traits of individual countries.
- The **Network structure** is informative on national cultures beyond and above cultural traits.
- We made use of a **Jeffreys' divergence** as a the new measure of **cultural distance**.
- The components of the `JD Index` correlates with different measures of economic, political, historical, spatial distance, and with networks' topologies.

Work in progress

- Sensitivity analysis to more or less cultural traits,
- Move from nations to regions and explore local cultures,
- Focus on cultural heterogeneity: gender, age, education
- Temporal evolution of culture of a country.

Paper link

- https://doi.org/10.48550/arXiv.2007.02359

Thank you!

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US GCGM Precision matrix

```
$`United States`
          [,1]     [,2]    [,3]   [,4]   [,5]   [,6]    [,7]   [,8]     [,9]    [,10]
 [1,]  1.12650 -0.23084  0.0003  0.128  0.136  0.111 -0.0495 -0.228 -0.00044 -0.00025
 [2,] -0.23084  1.13830 -0.0399 -0.251 -0.082  0.026  0.0042 -0.026  0.15590  0.00089
 [3,]  0.00030 -0.03987  1.1708 -0.029  0.157 -0.105  0.0249 -0.236 -0.19741 -0.07702
 [4,]  0.12756 -0.25105 -0.0290  1.105  0.018  0.115  0.0255 -0.089  0.12023  0.01192
 [5,]  0.13603 -0.08159  0.1571  0.018  1.540  0.180  0.3157  0.270  0.01327  0.45106
 [6,]  0.11110  0.02628 -0.1047  0.115  0.180  1.858 -1.0396 -0.058 -0.04629 -0.19061
 [7,] -0.04952  0.00423  0.0249  0.025  0.316 -1.040  1.8410 -0.012  0.05240 -0.10077
 [8,] -0.22796 -0.02602 -0.2360 -0.089  0.270 -0.058 -0.0124  1.205 -0.03859  0.11416
 [9,] -0.00044  0.15590 -0.1974  0.120  0.013 -0.046  0.0524 -0.039  1.08787 -0.00084
[10,] -0.00025  0.00089 -0.0770  0.012  0.451 -0.191 -0.1008  0.114 -0.00084  1.29643
```

back to GCGM

US GCGM Partial Correlation matrix

```
$`United States`
          [,1]     [,2]     [,3]   [,4]   [,5]   [,6]    [,7]    [,8]     [,9]    [,10]
 [1,]  1.00000  0.20385 -0.00026 -0.114 -0.103 -0.077  0.0344  0.1956  0.00040  0.00021
 [2,]  0.20385  1.00000  0.03454  0.224  0.062 -0.018 -0.0029  0.0222 -0.14010 -0.00074
 [3,] -0.00026  0.03454  1.00000  0.026 -0.117  0.071 -0.0170  0.1987  0.17492  0.06251
 [4,] -0.11432  0.22384  0.02552  1.000 -0.014 -0.080 -0.0179  0.0769 -0.10965 -0.00996
 [5,] -0.10329  0.06163 -0.11698 -0.014  1.000 -0.107 -0.1875 -0.1980 -0.01025 -0.31926
 [6,] -0.07680 -0.01807  0.07100 -0.080 -0.107  1.000  0.5621  0.0388  0.03256  0.12282
 [7,]  0.03439 -0.00292 -0.01695 -0.018 -0.188  0.562  1.0000  0.0083 -0.03702  0.06523
 [8,]  0.19563  0.02222  0.19867  0.077 -0.198  0.039  0.0083  1.0000  0.03370 -0.09132
 [9,]  0.00040 -0.14010  0.17492 -0.110 -0.010  0.033 -0.0370  0.0337  1.00000  0.00071
[10,]  0.00021 -0.00074  0.06251 -0.010 -0.319  0.123  0.0652 -0.0913  0.00071  1.00000
```

back to GCGM

US GCGM Posterior Edge Inclusion Probabilities matrix

$`United States`

	V10	V24	V69	V85	V152	V203	V204	V211	Y002	Y003
V10	0.00	1.00	0.08	0.99	1.00	0.89	0.52	1.00	0.07	0.07
V24	1.00	0.00	0.49	1.00	0.80	0.35	0.12	0.34	1.00	0.09
V69	0.08	0.49	0.00	0.40	1.00	0.89	0.30	1.00	1.00	0.82
V85	0.99	1.00	0.40	0.00	0.25	0.89	0.30	0.85	0.99	0.22
V152	1.00	0.80	1.00	0.25	0.00	0.99	1.00	1.00	0.22	1.00
V203	0.89	0.35	0.89	0.89	0.99	0.00	1.00	0.61	0.46	1.00
V204	0.52	0.12	0.30	0.30	1.00	1.00	0.00	0.20	0.52	0.87
V211	1.00	0.34	1.00	0.85	1.00	0.61	0.20	0.00	0.52	0.96
Y002	0.07	1.00	1.00	0.99	0.22	0.46	0.52	0.52	0.00	0.08
Y003	0.07	0.09	0.82	0.22	1.00	1.00	0.87	0.96	0.08	0.00

back to GCGM

US GCGM Adjacency matrix

```
$`United States`
     V10 V24 V69 V85 V152 V203 V204 V211 Y002 Y003
V10    0   1   0   1    1    1    1    1    0    0
V24    0   0   0   1    1    0    0    0    1    0
V69    0   0   0   0    1    1    0    1    1    1
V85    0   0   0   0    0    1    0    1    1    0
V152   0   0   0   0    0    1    1    1    0    1
V203   0   0   0   0    0    0    1    1    0    1
V204   0   0   0   0    0    0    0    0    1    1
V211   0   0   0   0    0    0    0    0    1    1
Y002   0   0   0   0    0    0    0    0    0    0
Y003   0   0   0   0    0    0    0    0    0    0
```

back to GCGM