Measuring intra-country cultural diversity

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Abstract

Cross-country comparative cultural analyses often utilize aggregations of national culture, where all individual attitudes, customs, and traits of a country are represented by a single point. Using data from the World Values Survey (1984-2022, in 7 separate waves, average wave duration: 5.43 years), **we explore various methods to quantify cultural diversity within each country.**

First, we apply principal component analysis on country averages (379 country-waves) then similarly transform individual respondents (approximately 800 respondents per country on average, after dropping rows with missing values), which better accounts for variance in the data while retaining individual-level information consistent with country-aggregate representation. On the resulting culture maps, we use standard deviational ellipses (SDEs) and contour maps (CMs) to measure cultural variation within countries. **While SDEs can generally provide area and eccentricity as descriptors for each country's distribution, we find that CMs can more precisely measure the area for a desired population percentage, with some decrease in accuracy for a higher population percentage.**

Abstract

Second, we treat each individual as a vector of cultural traits, as done in Axelrod models of cultural diffusion, and measure Euclidean distance and cosine distance between individuals within each country. We then compare cultural diversity rankings across these methods, and find that these have low correlation (Spearman correlation -0.04-0.31) with ethnic, linguistic, and religious fractionalization, indicating additional information accounted for in our diversity rankings.

The resulting diversity measures can easily be incorporated into predictive spatio-temporal cross-cultural analyses that use similar, if not the same culture vector representation, and will be useful when analyzing errors and uncertainty. Because individuals are represented as vectors of cultural traits, this can also be easily integrated into Axelrod models, which we also implement here, and other social network analyses of culture.

Keywords: sociophysics, econophysics, culture, data analytics

Measuring cultural values

The Integrated Values Survey (IVS)

- **What is culture?**
  - “the set of distinctive spiritual, material, intellectual, and emotional features of a society or a social group, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs” [1]
  - “a distinguishing amalgamation of characteristics, such as values, beliefs, attitudes, and behaviors, shared by members of a population, as well as all the indicators that may replace it to be useful in analyses” [2]
- **Survey on cultural values (Integrated Values Survey = World Values Survey + European Values Survey)** [1]
  - 1981-2022 in 7 waves (1981-1984, 1990-1994, … 2017-2022) + ongoing Wave 8
  - covers 120 countries in total across the 7 waves
- **Survey questions were designed to test the hypothesis that socioeconomic development brings systematic changes in basic cultural values, and vice versa** [2]

[1] F. Panebianco et al., Understanding Cultural Traits: A Multidisciplinary Perspective on Cultural Diversity (Springer, 2016).
[2] M. Minkov and G. Hofstede, Cross-Cultural Analysis: The Science and Art of Comparing the World’s Modern Societies and Their Cultures (SAGE Publications, Inc., 2013).
[3] “World Values Survey,” available online at: https://www. worldvaluessurvey.org/WVSContents.jsp
[4] R. Inglehart and C. Welzel, Modernization, Cultural change, and Democracy: The Human Development Sequence (Cambridge University Press, 2005)

Measuring cultural values

Extracting culture dimensions

SURVEY DATA
(rows with missing values dropped)

	x_1 Feeling of happiness	x_2 Trust in people	x_3 Respect for authority	...
person 1	1	1	4	
person 2	3	0	2	
person 5	1	1	1	
...				...

→ AGGREGATION (by country)

$$y'_k = \langle x_k \rangle_c$$

→ STANDARDIZATION

$$y'_k = (y_k - \mu_k)/\sigma_k$$

→ PCA WITH VARIMAX ROTATION

$$Q = A'Y^*$$
$$\Sigma A = A\Lambda$$

→ SELECT COMPONENTS CAPTURING MOST VARIANCE

Q

	PC_1 tradrat	PC_2 survself	...
country 1	2.10	1.86	
country 2	1.89	0.65	
...			

- aggregating by country results in greater variance explained
- varimax rotation rotates orthogonal basis vectors such that the squared variances of the loadings are maximized

[3] “World Values Survey,” available online at: https://www. worldvaluessurvey.org/WVSContents.jsp
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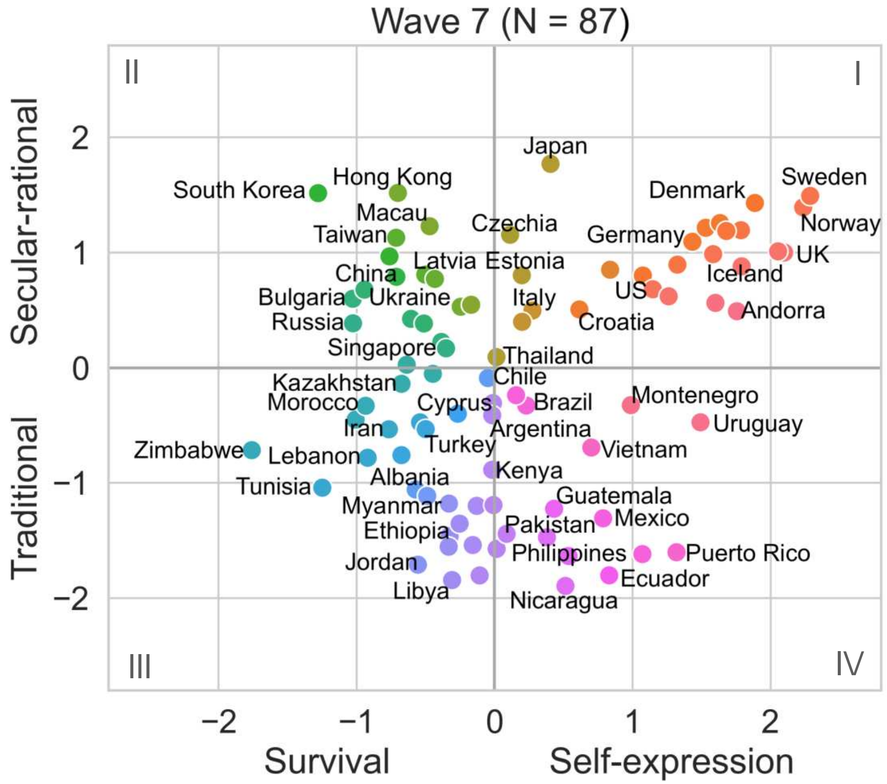


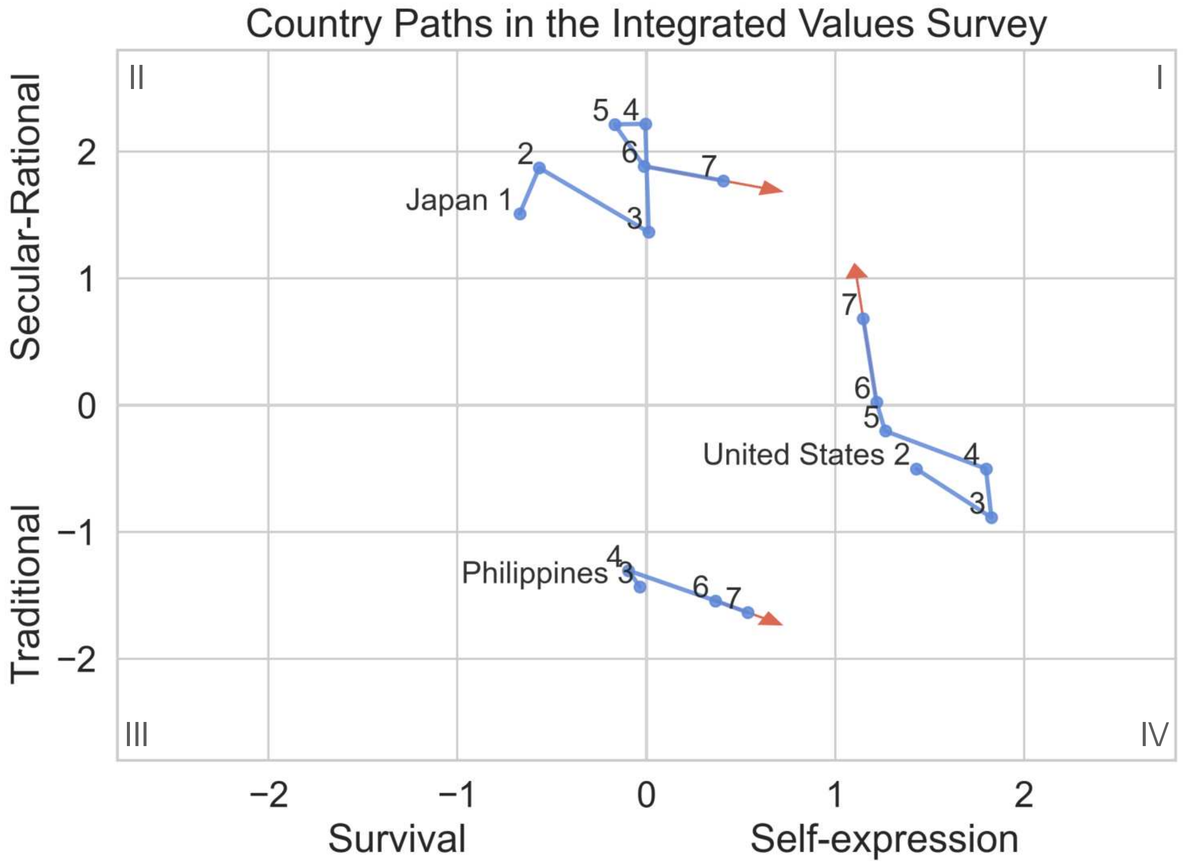
(PC1) traditional vs. secular-rational values: traditional societies prioritize religion, deference to authority, traditional family values

(PC2) survival vs. self-expression values: survival-oriented societies prioritize economic and physical security over environmental protection, gender equality, activism

[3] “World Values Survey,” available online at: https://www. worldvaluessurvey.org/WVSContents.jsp
[4] R. Inglehart and C. Welzel, Modernization, Cultural change, and Democracy: The Human Development Sequence (Cambridge University Press,2005)

Motivation

Predicting the temporal trajectory of cultural values from Wave 1 to Wave 7



Start of Wave 1: 1981

End of Wave 7: 2022

Average wave duration: 5.43 years

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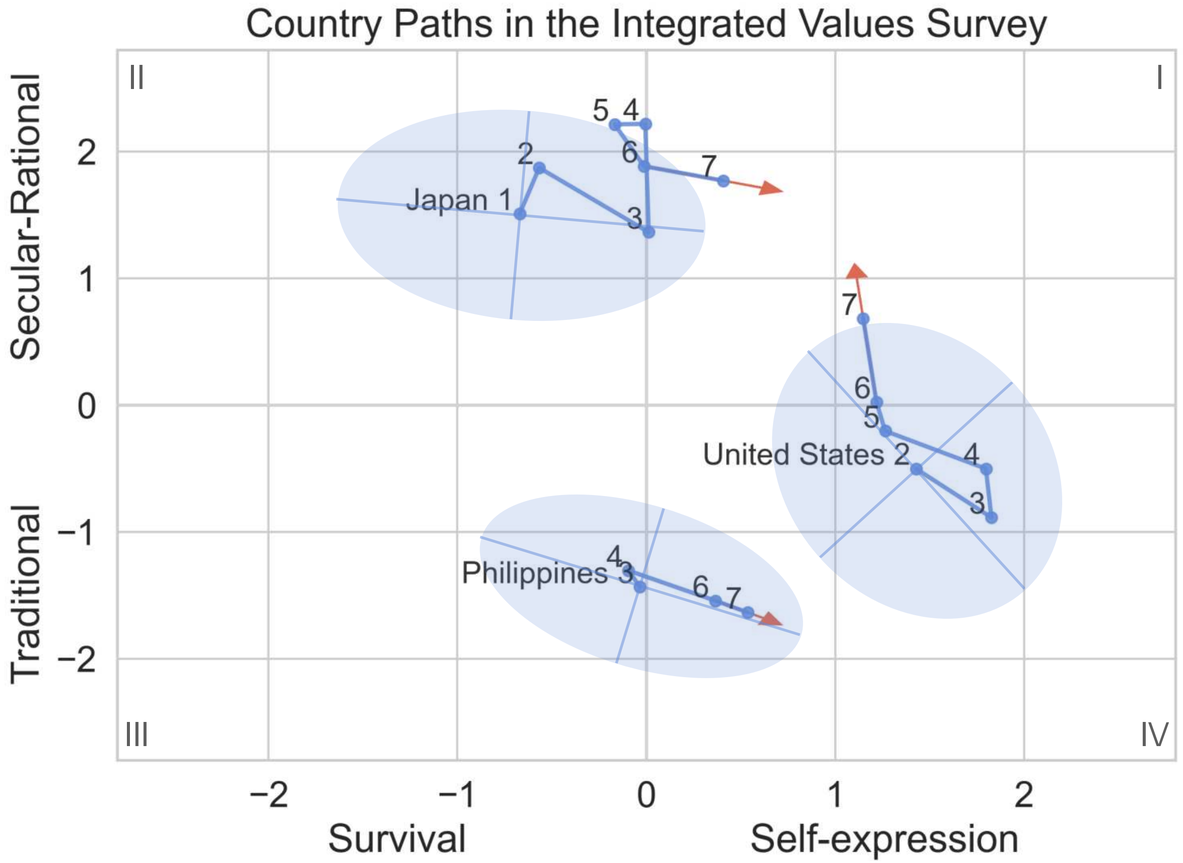

Standard deviational ellipse (SDE) as possible measure of intra-country diversity.

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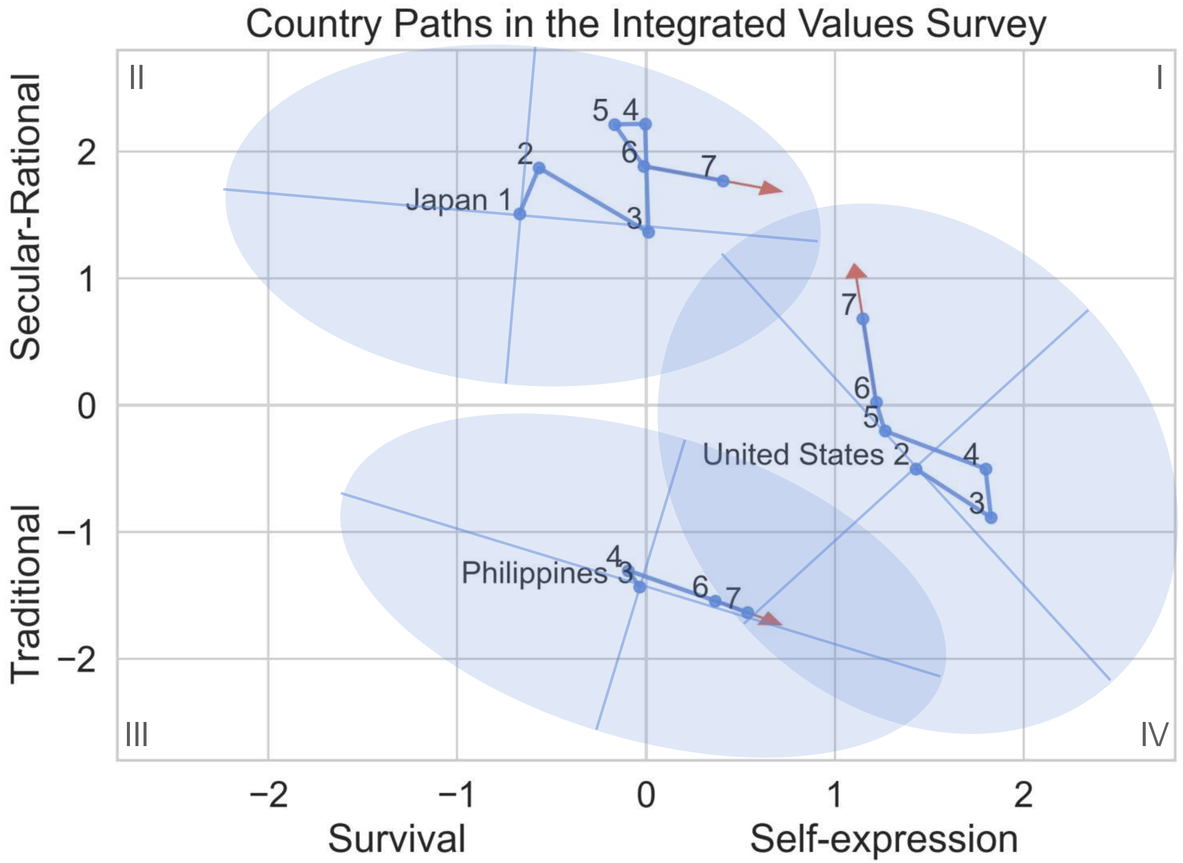

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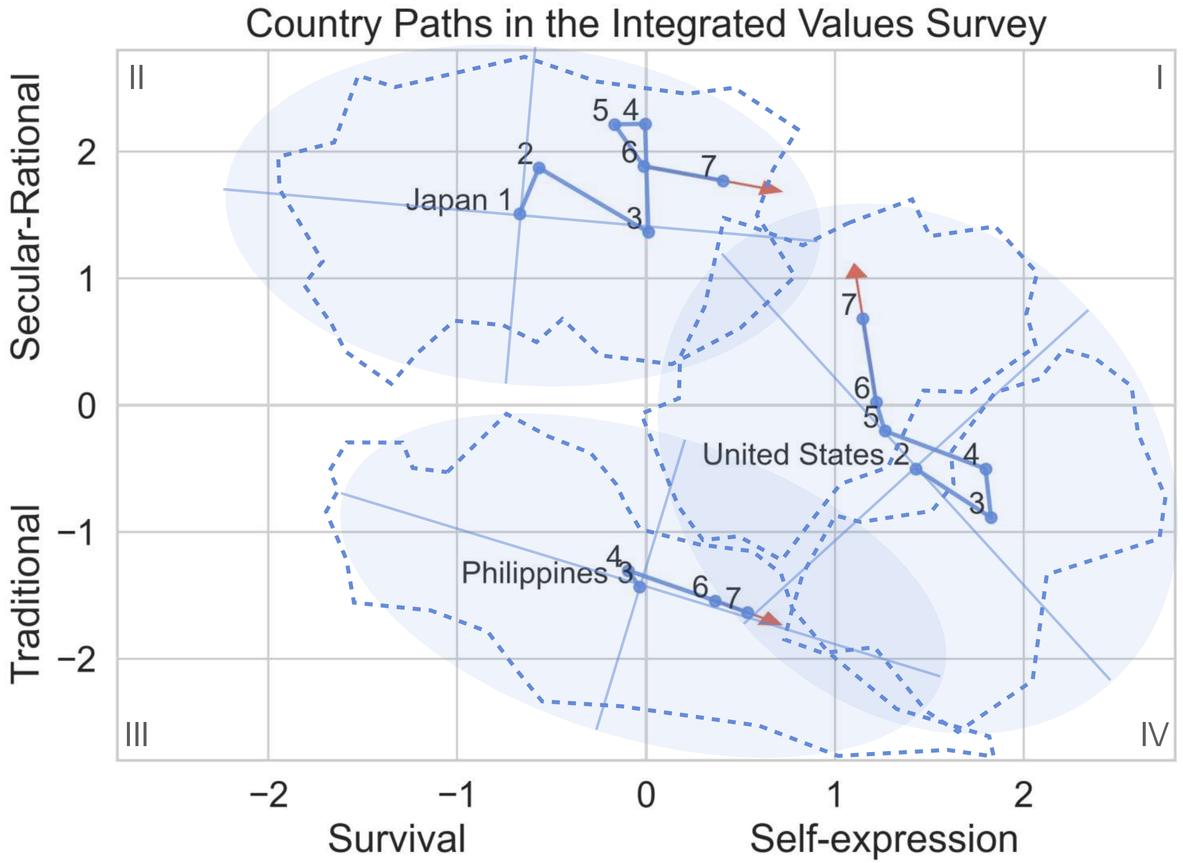


Contour maps (CM)
as possible measure of intra-country diversity.

Start of Wave 1: 1981

End of Wave 7: 2022

Average wave duration: 5.43 years

Statement of the problem

- measure cultural diversity within nations using the Integrated Values Survey
- predict cultural values and cultural diversity

Measuring cultural diversity

Existing diversity measures/features

- socio-economic measures of population heterogeneity [5]
  - fractionalization (diversity among people)
  - segregation (diversity among places)
- cultural dynamics and cultural diversity [6]
  - Axelrod models of cultural dissemination and networks - network structure characteristics (number of components, size of largest component, long bridges, etc.) as an indicator of diversity and polarization

[5] P. Nijkamp, J. Poot, and J. Bakens, The Economics of Cultural Diversity (Edward Elgar Publishing, Inc., 2015)
[6] Y. Kashima, “How can you capture cultural dynamics?,” Frontiers in Psychology 5 (2014)

Measuring cultural diversity

Fractionalization

$$FR_j = 1 - \sum_{i=1}^{N} s_{ij}^2$$

s_{ij} : share of group i $(i = 1,...N)$ in country j

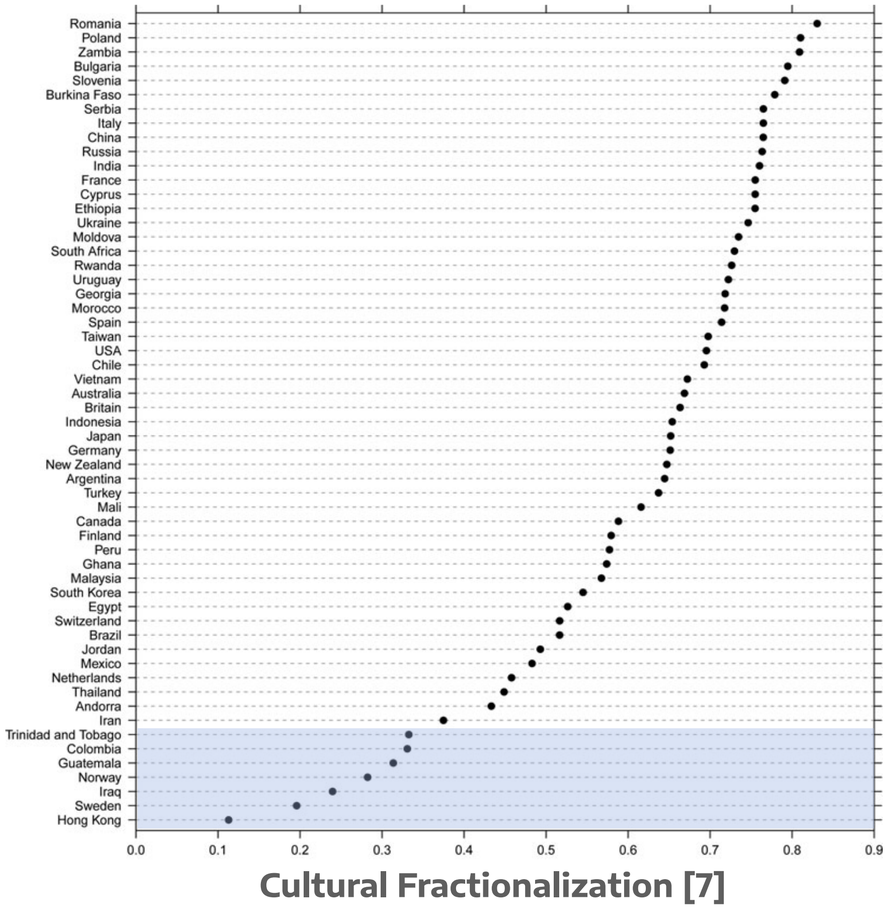
- FR ranges from 0 (all individuals belong to only one group) to 1 − 1/N (all groups have equal number of individuals) [5]
- three indices constructed: ethnic, linguistic, and religious fractionalization (data between 1983-2001)
- found that ethnic and linguistic fractionalization variables, more so than religious ones, are likely to be important determinants of economic success (GDP growth, literacy rate, infant mortality, extent of corruption, political freedom, etc.) [7]

[5] P. Nijkamp, J. Poot, and J. Bakens, The Economics of Cultural Diversity (Edward Elgar Publishing, Inc., 2015)
[7] A. Alesina, A. Devleeschauwer, W. Easterly, S. Kurlat, and R. Wacziarg, “Fractionalization,” Journal of Economic Growth 8, 155–194 (2003).

Measuring cultural diversity

Importance of accounting for intra-country diversity

- **most countries were found to be a mixture of subcultures** - a single national culture was found only for a few countries [8]
- when national culture is represented as a network of the distribution of individual cultural traits and the interdependence between them, results vary from Inglehart's but contributing factors to cultural distances between countries can be identified [9]



[8] L. Blaydes and J. Grimmer, "Political cultures: Measuring values heterogeneity," Political Science Research and Methods 8, 571–579 (2020)
[9] L. D. Benedictis, R. Rondinelli, and V. Vinciotti, "Cultures as networks of cultural traits: a unifying framework for measuring culture and cultural distances," Journal of the Royal Statistical Society Series A: Statistics in Society 186, 264–293 (2023).

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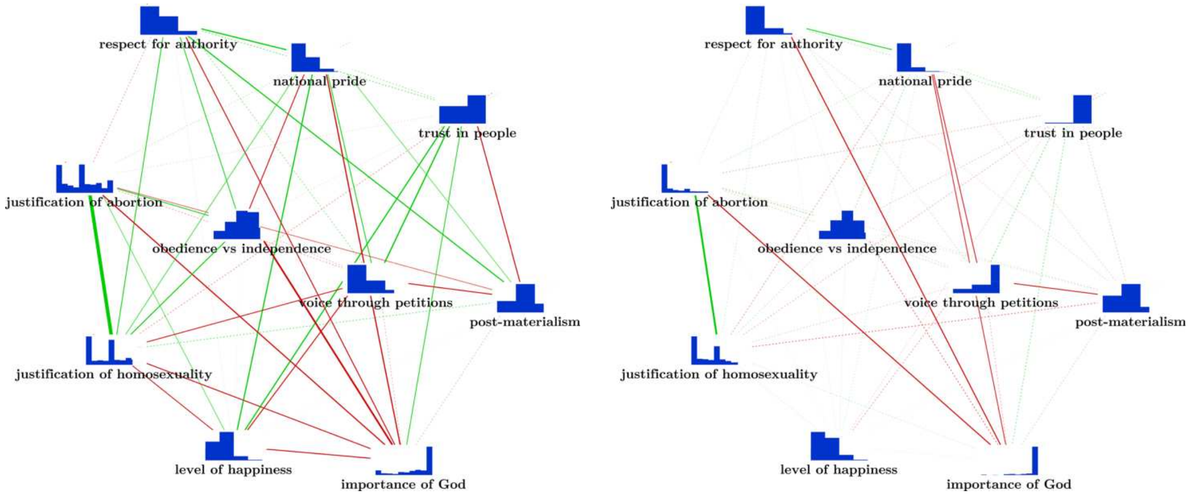

US cultural network (left) and PH cultural network (right) [8]

[8] L. Blaydes and J. Grimmer, "Political cultures: Measuring values heterogeneity," Political Science Research and Methods 8, 571–579 (2020)
[9] L. D. Benedictis, R. Rondinelli, and V. Vinciotti, "Cultures as networks of cultural traits: a unifying framework for measuring culture and cultural distances," Journal of the Royal Statistical Society Series A: Statistics in Society 186, 264–293 (2023).

Axelrod model

Predicting the trajectory of cultural values

- Agent-based model that simulates
  - **social influence**: culture (set of individual attributes subject to social influence) becomes more similar between individuals as they interact
  - **homophily**: higher probability of cultural transmission when individuals have similar traits in their individual attributes
- Original model
  - Each agent i is characterized by vector $X(i, t)$ consisting of F cultural attributes that can take any of the allowed q values (traits): $X(i, t) = (\sigma 1(i, t), \dots, \sigma f(i, t))$, where $\sigma f(i, t) \in \{1, 2, \dots, q\}$ for $f = 1, 2, \dots, F$
  - Agents are arranged in a 2D lattice (non-toroidal) and can interact with von Neumann neighborhood, with probability dependent on cultural overlap
  - phase transition in final state: ordered phase (culturally polarized) or disordered phase (culturally fragmented)

[10] R. Axelrod, “The Dissemination of Culture: A Model with Local Convergence and Global Polarization,” Source: The Journal of Conflict Resolution 41, 203–226 (1997)

Axelrod model: Extensions

Predicting the trajectory of cultural values

cultural similarity

- cultural overlap:
  $$\omega_{ij} = \frac{1}{F}\sum_{k=1}^{F}\delta(x_i^k, x_j^k)$$
- cultural distance:
  $$d_{ij} = \sum_{k=1}^{F} |x_i^k - x_j^k|$$
- bounded confidence: threshold θ required on ω_{ij} for interaction to occur

topology of social connections

- 2D lattice (spatial)
- graphs (random, Barabasi-Albert, etc.)
- none (complete graph - interactions are dependent only on cultural graph)

other phenomena

- cultural drift - random noise is introduced to simulate random changes in individual values
- short-term micro-level behavior on long-term cultural diversity
- initial conditions based on survey data

[11] L. Valori, F. Picciolo, A. Allansdottir, and D. Garlaschelli, “Reconciling long-term cultural diversity and short-term collective social behavior,” PNAS 109 (2012).
[12] K. Klemm, V. M. Egu´ıluz, R. Toral, and M. S. Miguel, “Global culture: A noise-induced transition in finite systems,” Physical Review E - Statistical, Nonlinear, and Soft Matter Physics 67, 451011–451014 (2003)
[13] A. Dinkelberg, P. MacCarron, P. J. Maher, and M. Quayle, “Homophily dynamics outweigh network topology in an extended Axelrod’s Cultural Dissemination Model,” Physica A: Statistical Mechanics and its Applications 578 (2021)

Scope and limitations

Scope

- area-based and vector-based diversity metrics per country
- proof of concept on predicting cultural values using the Axelrod model
  - simplest case of the Axelrod model - interaction probability only depends on cultural distance

Limitations

- we focus on methods to measure, rather than interpret, cultural diversity
- we have not made attempts to detect each country’s respondent distribution and corresponding phenomena (polarization, etc.)

Measuring cultural values

Transforming respondent-level points

	Feeling of happiness	Trust in people	Respect for authority	Political action by signing a petition	Importance of God in your life	Justifiability of homosexuality	Justifiability of abortion	Pride in nationality	Post-materialist index	Autonomy index
person 1	1	1	4	1	10	3	2	1	1	-1
person 2	3	0	2	3	2	10	10	2	2	2
person 3	2	1	?	2	4	5	5	5	?	1
person 4	?	0	1	?	2	9	8	4	-1	2
person 5	1	1	1	3	1	8	9	3	2	1
...										

↓

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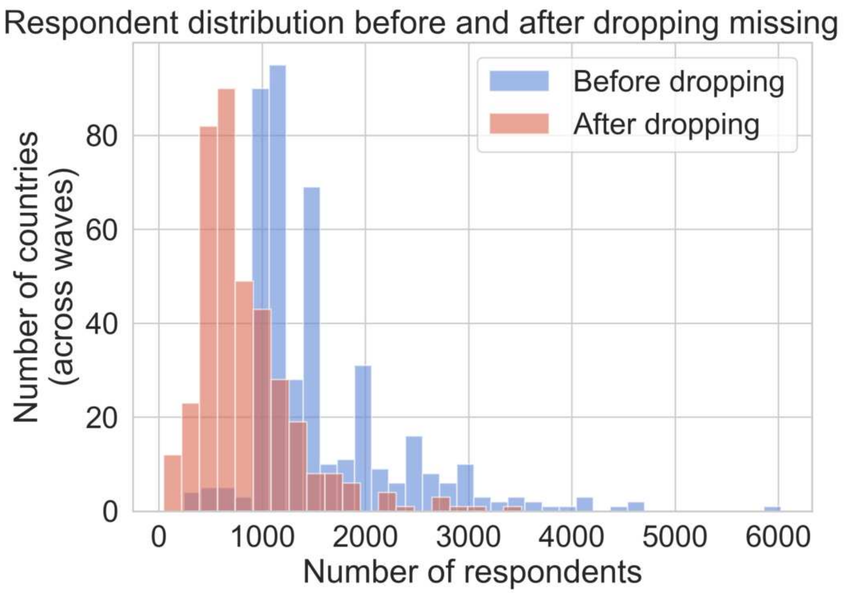

Measuring cultural values

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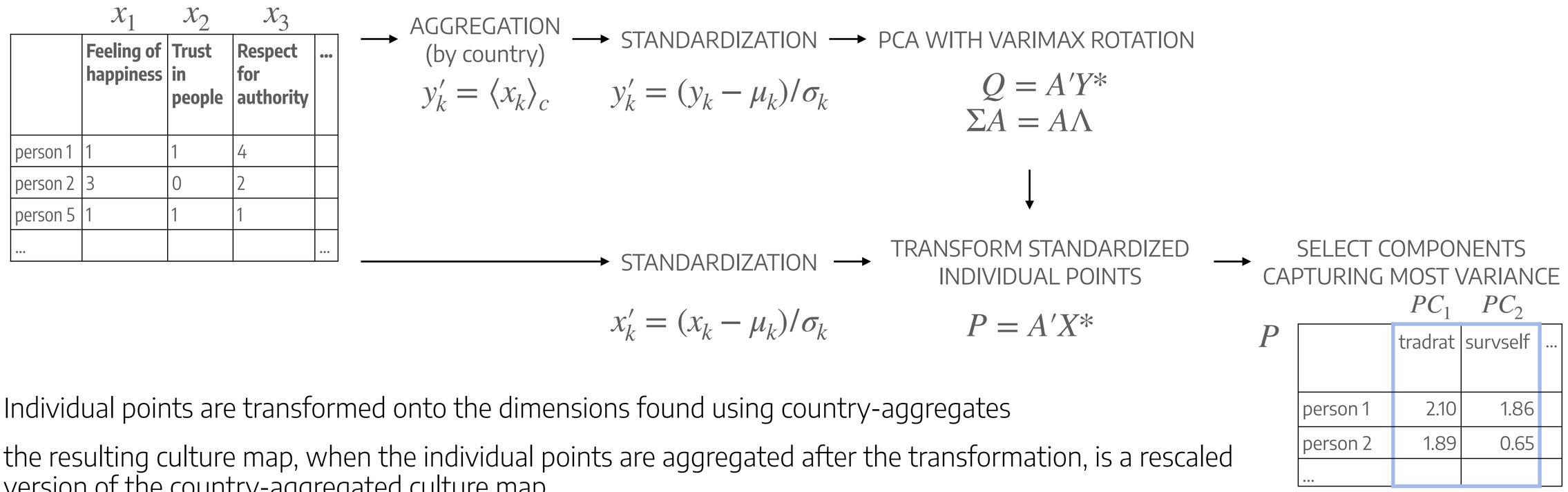
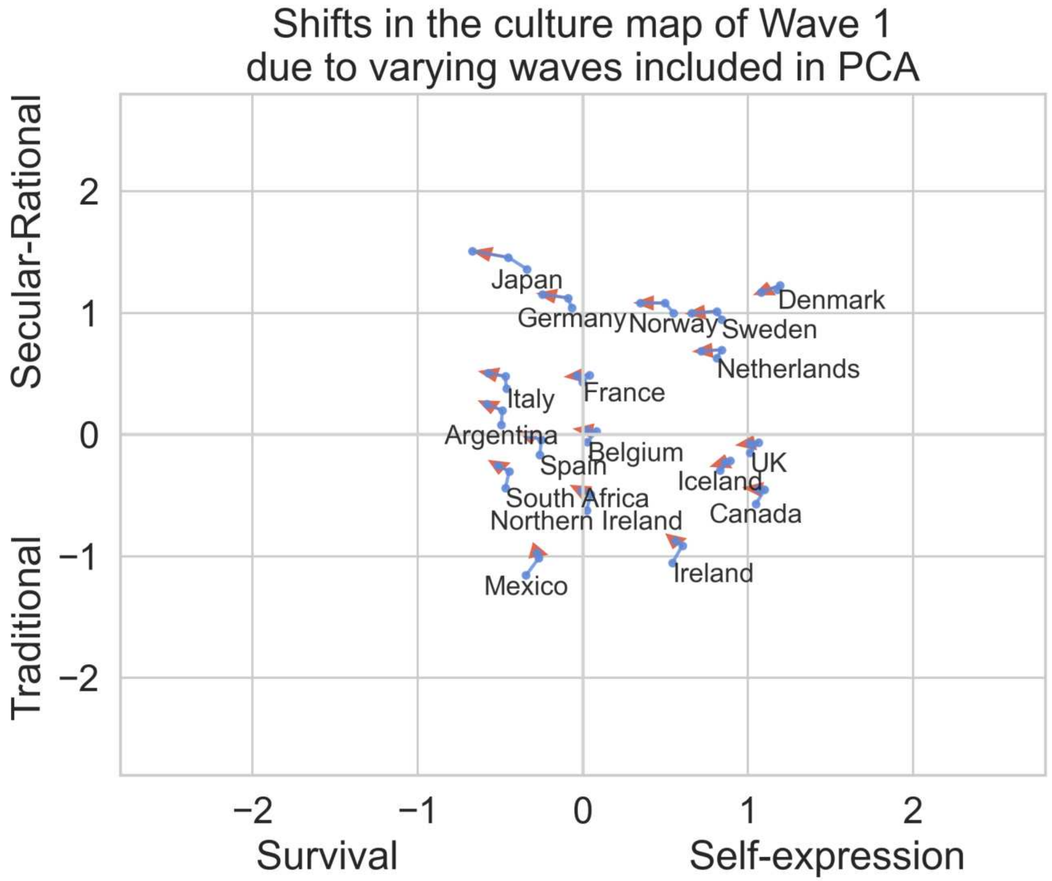
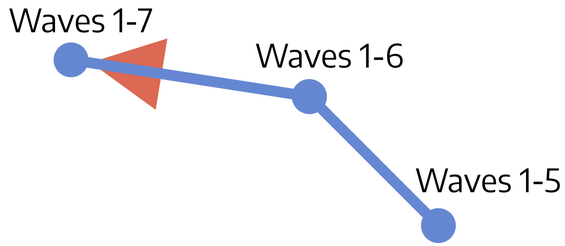


- Individual points are transformed onto the dimensions found using country-aggregates
- the resulting culture map, when the individual points are aggregated after the transformation, is a rescaled version of the country-aggregated culture map
  - rescaled because the standard deviation varies between individual points and country-aggregate points

Using culture dimensions for predictions: error analysis

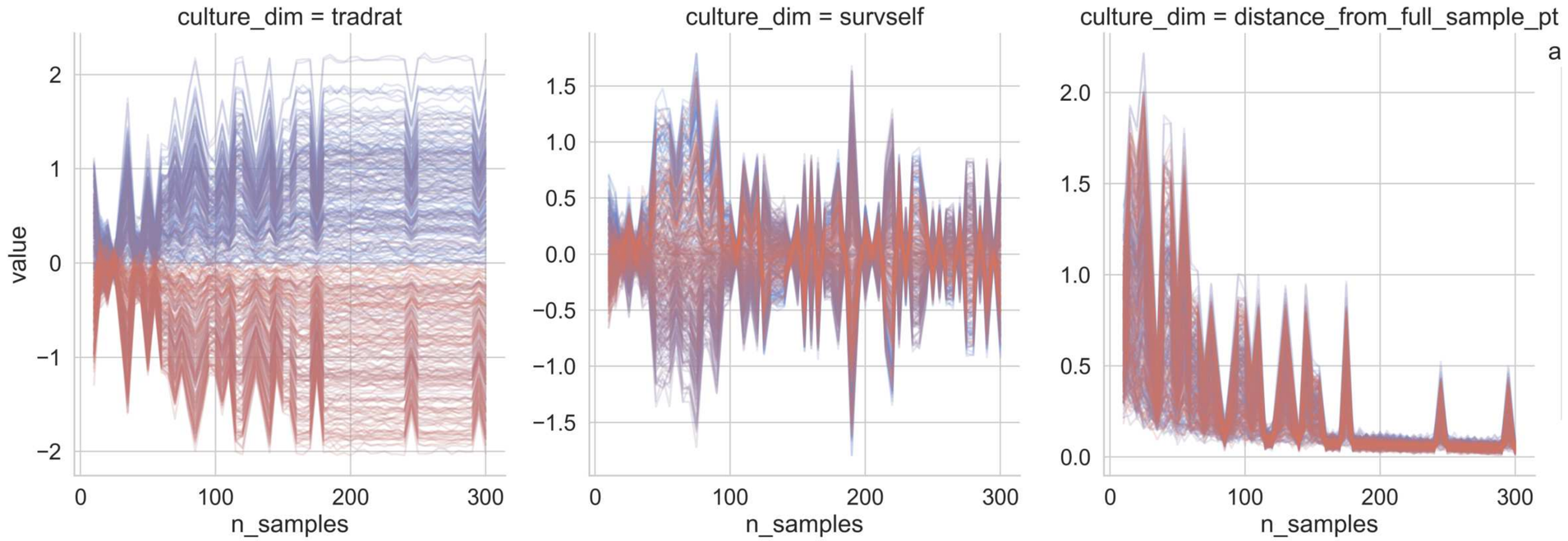
Shifts in country positions with additional datasets from more Waves





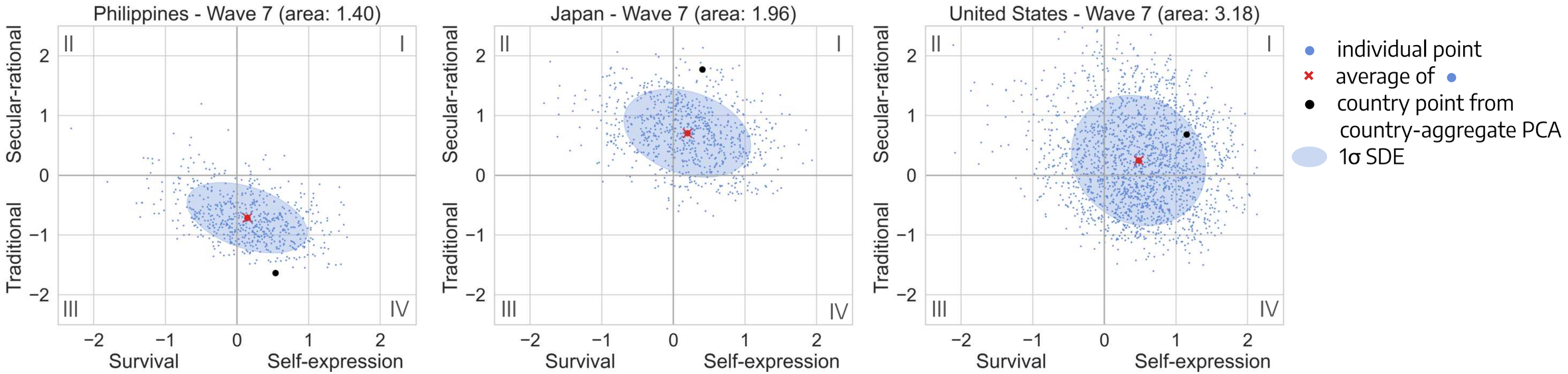
Using culture dimensions for predictions: error analysis

Shifts due to the varying number of respondent samples



Measuring cultural diversity

Standard deviational ellipse (SDE)

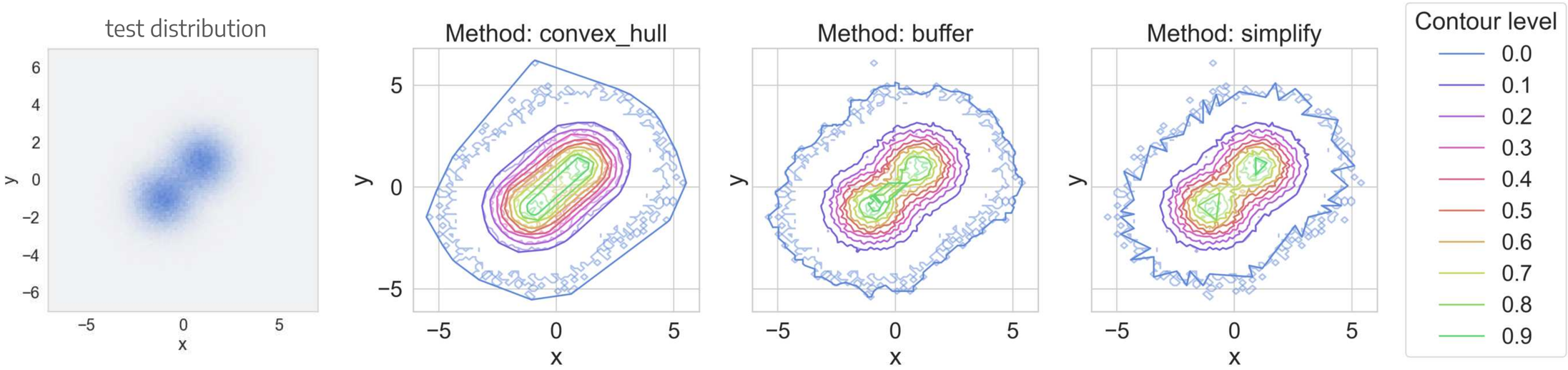


Parameters of an ellipse (semi-major and semi-minor axes, orientation angle) are fitted on the individual respondent distribution (1σ and 2σ from the mean)

[14] R. S. Yuill, “The Standard Deviational Ellipse; An Updated Tool for Spatial Description,” Geogr. Ann. Ser. B Hum. Geogr., 53 (1), 28–39 (1971)

Measuring cultural diversity

Contour map (CM)

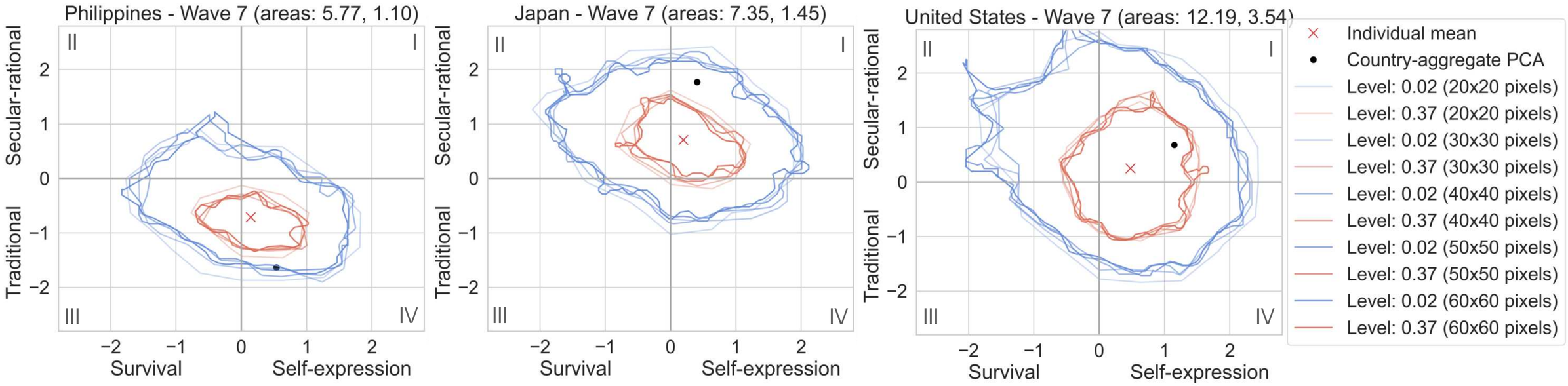


- histogram obtained for the individual points to create the initial contour map, for varying selected resolution values
- initial contour map converted into polygons
- multiple polygons for each level are combined into a single polygon
  - buffer method - we look for the minimum buffering distance at which a single polygon is formed (Minkowski sum)

[15] “Shapely Documentation,” available online at: https://shapely. readthedocs.io/en/stable/, last accessed on 11.03.2023.

Measuring cultural diversity

Contour map (CM)

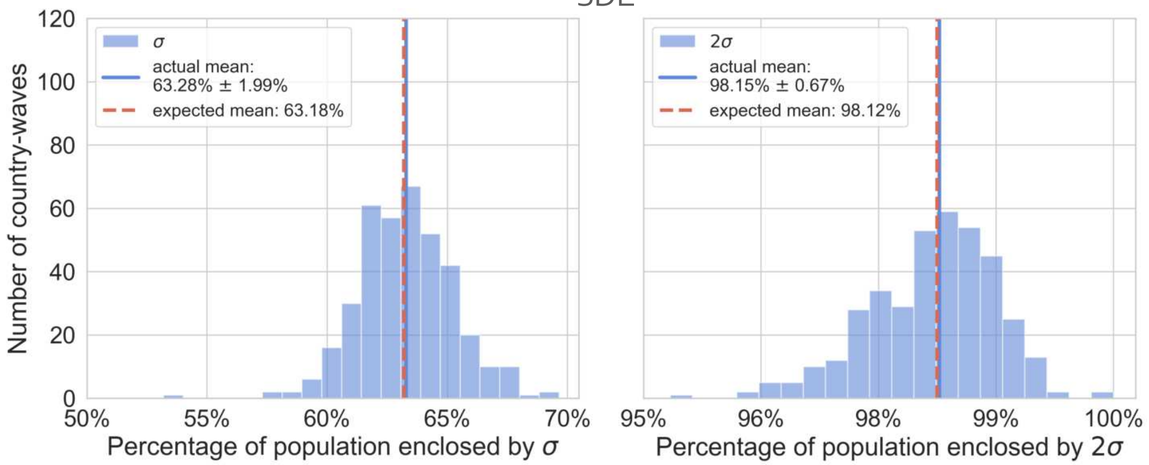


- optimal resolution can be determined for each contour level per country per wave by minimizing the error in the population percentage captured
- no units for area - we use area for relative comparison instead (higher area = higher cultural diversity)

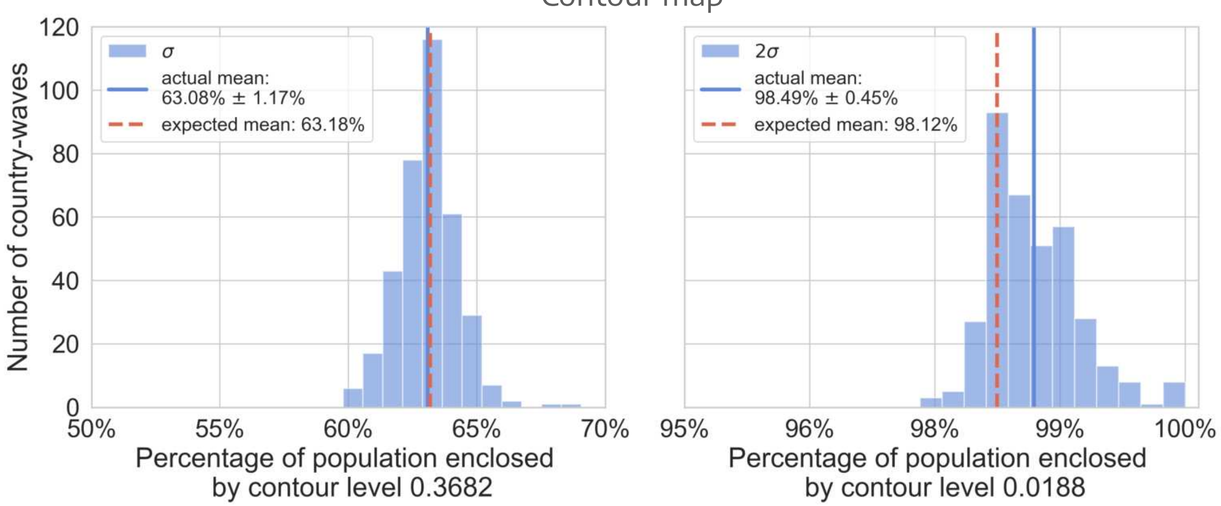
Measuring cultural diversity

Standard deviational ellipses vs. Contour maps

SDE



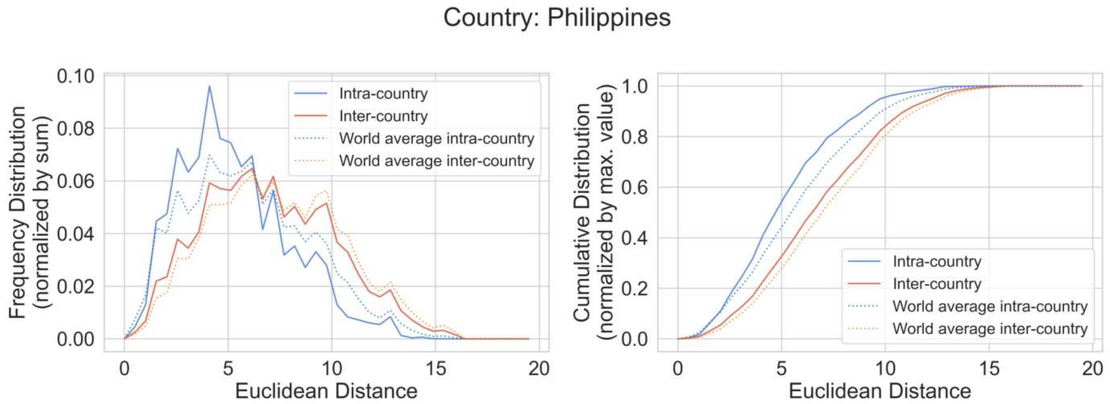
Contour map

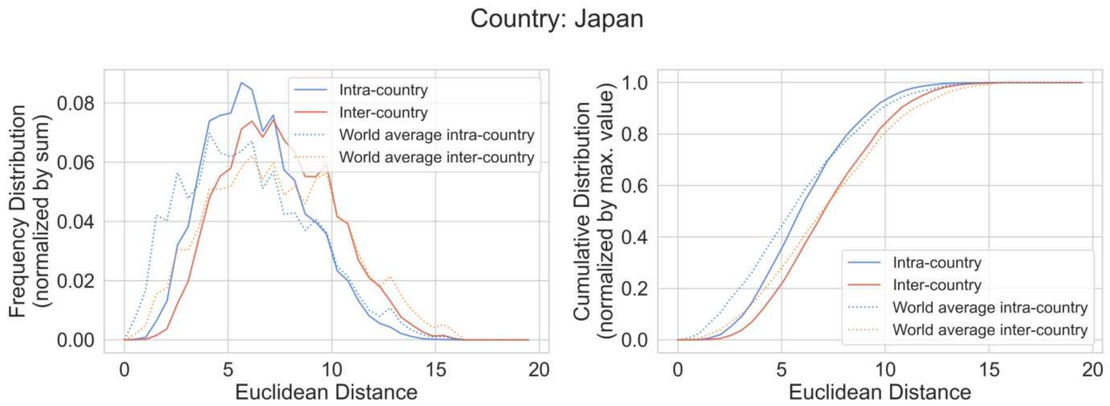


- contour maps capture more precisely the area for a specific population percentage
  - lower accuracy for higher percentage values
    - high accuracy: small difference between actual mean (blue line) and expected mean (dotted red line)
    - expected mean value is determined by Monte Carlo method
- potential improvement: also optimize on buffer size

Measuring cultural diversity

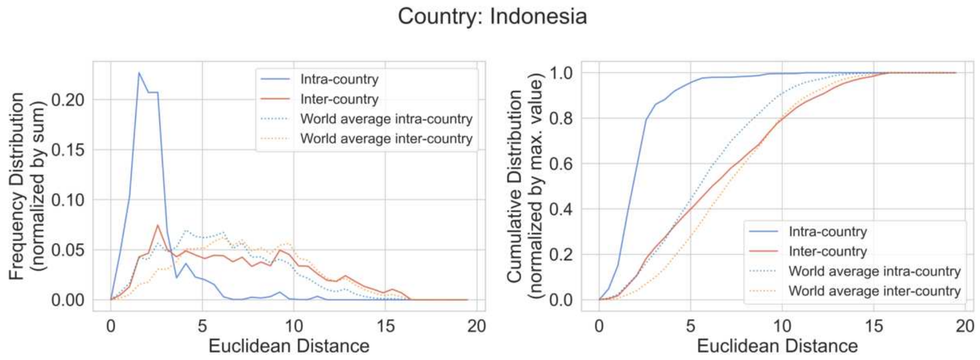
Euclidean distance





$$\mathrm{d}_e(\vec{x}_i, \vec{x}_j) = \|\vec{x}_i - \vec{x}_j\|$$

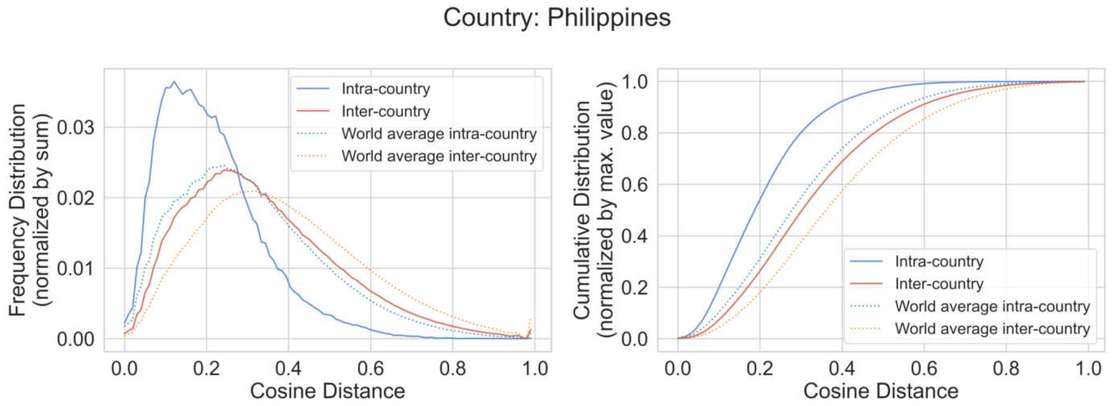
- distance distribution between any two individuals within the same country (blue) and from different countries (orange)
- culturally similar individuals have smaller distances → more diverse countries have higher average Euclidean distance
- using the area under the cumulative distribution curve is more robust against the variety of distributions (vs. mean distance)

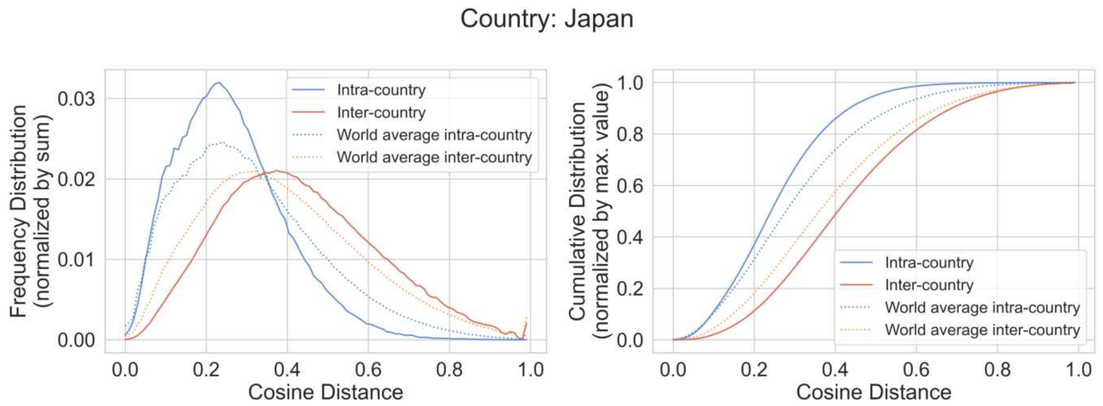


Measuring cultural diversity

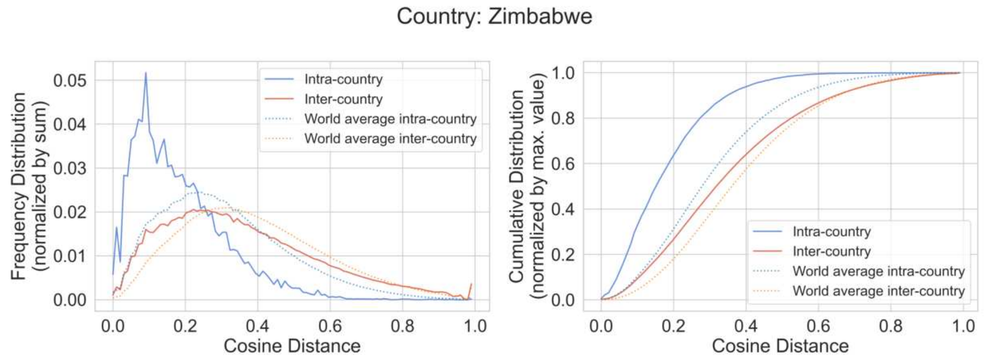
Cosine distance

$$d_c(\vec{x}_i, \vec{x}_j) = 1 - \frac{\vec{x}_i \cdot \vec{x}_j}{|\vec{x}_i||\vec{x}_j|}, \quad \vec{x}_i : \text{scaled to } [0, 1]$$



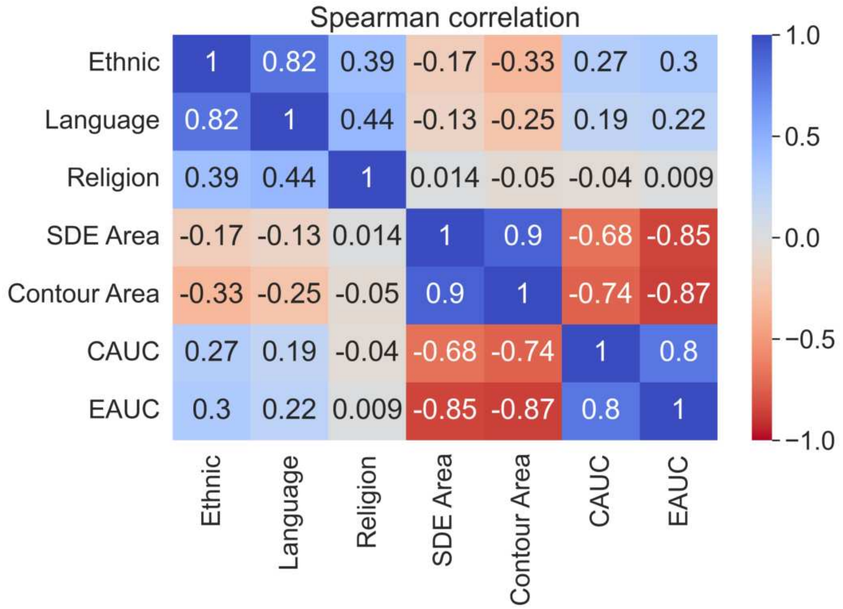


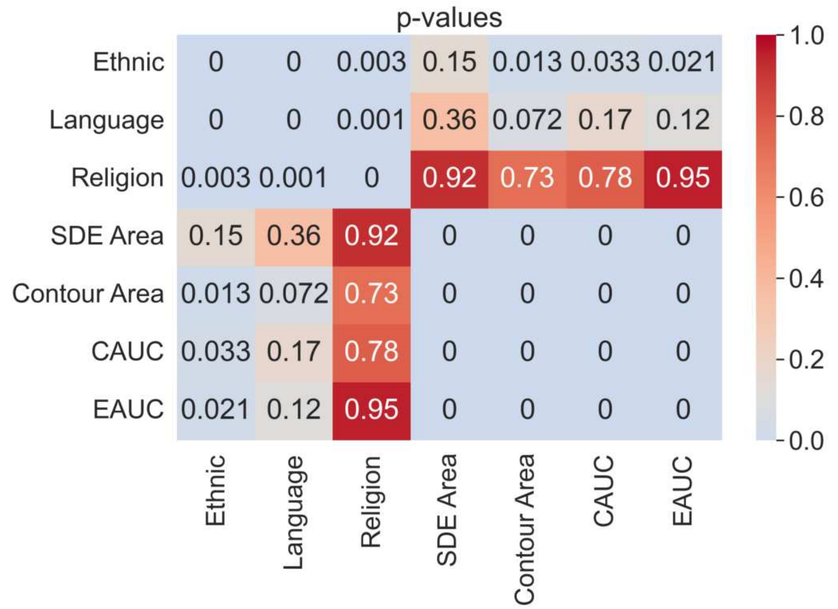
- distance distribution between any two individuals within the same country (blue) and from different countries (orange)
- culturally similar individuals have smaller distances → more diverse countries have higher average cosine distance
- using the area under the cumulative distribution curve is more robust against the variety of distributions (vs. mean distance)



Measuring cultural diversity

Comparison of various metrics





- CAUC = area under the cumulative distribution curve (cosine distance)
- EAUC = area under the cumulative distribution curve (Euclidean distance)
- SDE = Standard Deviational Ellipse

- Spearman's rank correlation between fractionalization metrics and IVS-based metrics (Wave 4)
- Fractionalization metrics are correlated with each other; IVS-based metrics are correlated with each other

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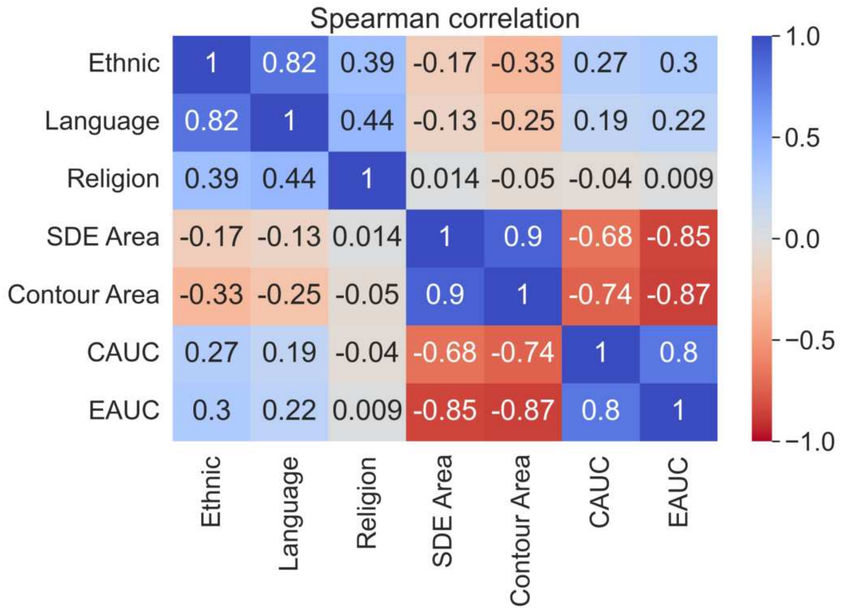
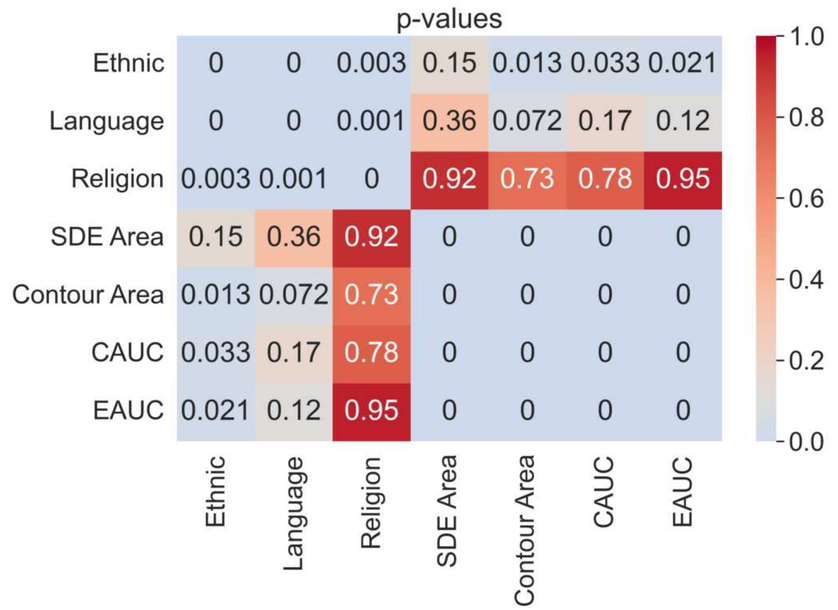
Comparison of various metrics





- CAUC = area under the cumulative distribution curve (cosine distance)
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- SDE = Standard Deviational Ellipse

- Diversity measured through the IVS measures a different facet of cultural diversity from ethnic and linguistic fractionalization
- IVS was designed to measure the relationship between culture and modernization

Axelrod model

- Each agent i is characterized by:
  - vector $x_{i,k}(t)$ consisting of F cultural attributes that can take any of the allowed q values (traits): $x_{i,k}(t) = (\sigma_{1,k}(t), \ldots, \sigma_{i,k}(t))$, where $\sigma_k(i, t) \in \{1, 2, \ldots, q\}$ for $k = 1, 2, \ldots, F$
- Parameters:
  - Initialized each $x_{i,k}(t)$ with data from IVS Wave 4
    - maximize number of countries with at least 400 respondents over consecutive waves → Waves 4-7
    - 6400 total individual respondents
  - interactions: solely based on cultural distance. no social network or spatial dependence
  - bounded confidence with overlap threshold 0.70
  - 10 trials, 100 timesteps

[8] R. Axelrod, “The Dissemination of Culture: A Model with Local Convergence and Global Polarization,” Source: The Journal of Conflict Resolution 41, 203–226 (1997)

Axelrod model

1. For each agent i, randomly select a “neighbor” agent weighted by interaction probability $1 - d_{ij} > \theta$, where

   cultural distance: $d_{ij} = \frac{1}{F} \sum_{k=1}^{F} \left[f_{nom}^{k}(1 - \delta(x_{i,k}, x_{j,k})) + (1 - f_{nom}^{k}) \frac{|x_{i,k} - x_{j,k}|}{q_k - 1} \right]$

   f_{nom}^{k} : binary variable encoding the type of feature k (1 for nominal and 0 for ordinal)

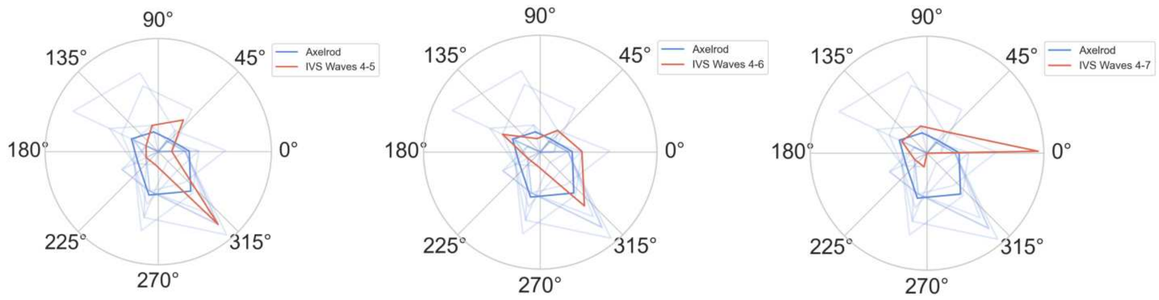
   bounded confidence threshold: $\theta, \quad 0 < \theta < 1$

2. Choose a random cultural attribute k' that will be the subject of interaction between the above agents. Note that the chosen attribute needs to have different values for both players ($x_{i,k'}(t') \neq x_{j,k'}(t')$).

3. Perform an interaction between the chosen agents on the chosen cultural attribute. If there were no different attributes, no interaction will occur.

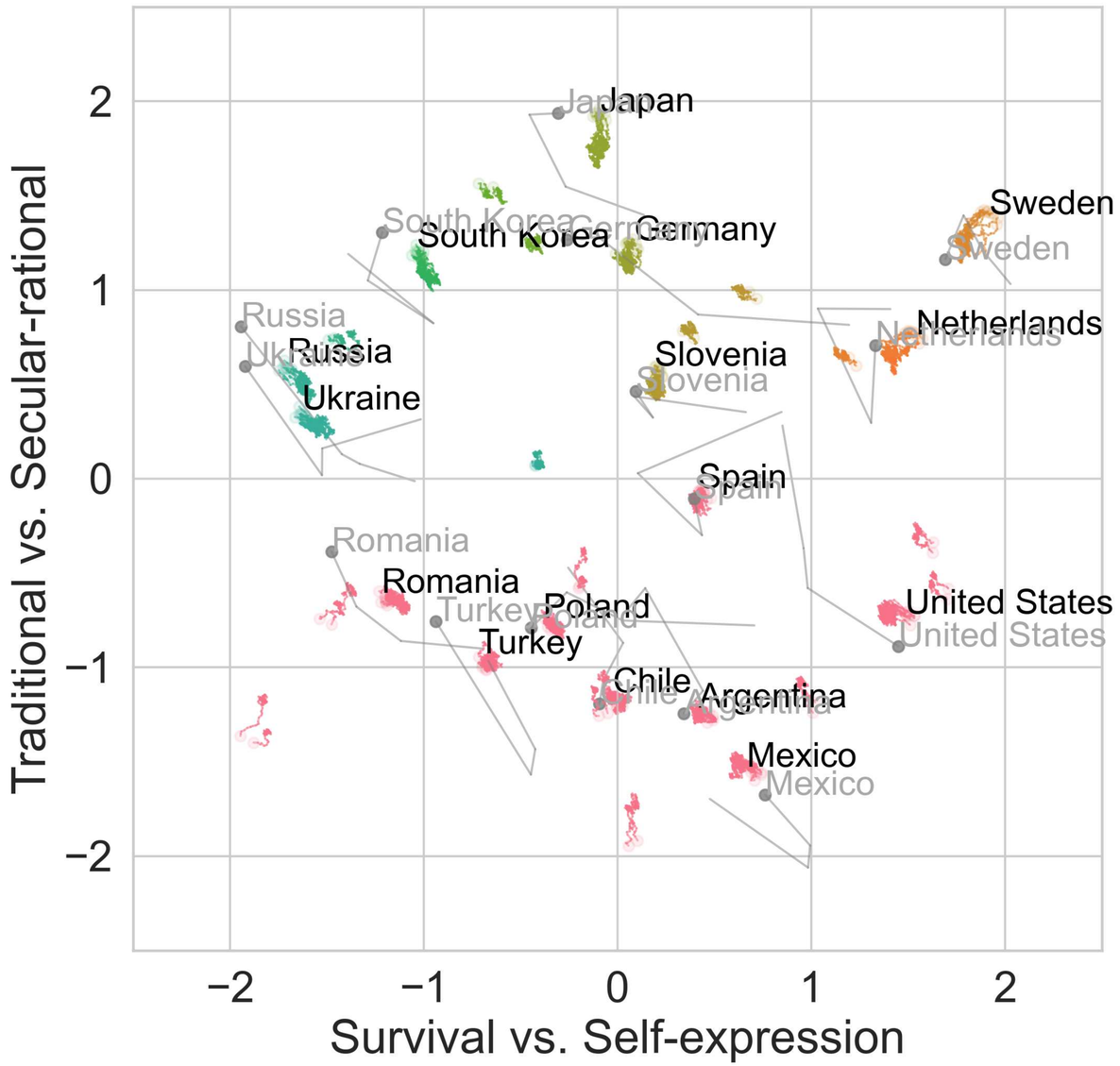
4. Repeat steps 1–4 (one repetition = one iteration) until the **time constraint** (max. number of time steps) is reached

Axelrod model

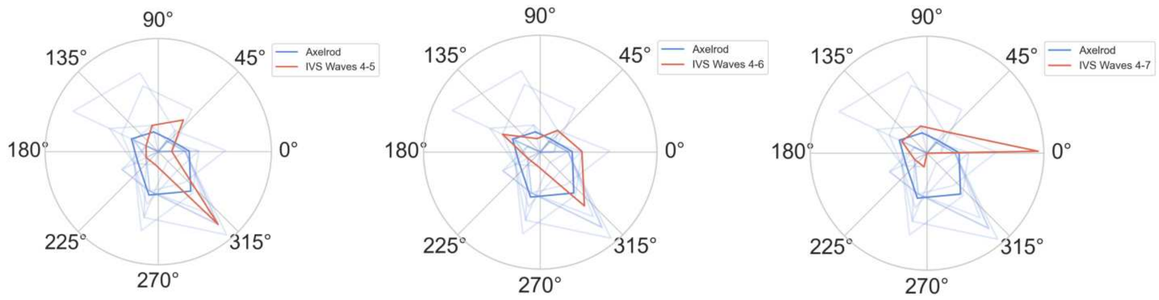


- total displacement of predicted trajectory for each country unable to reach the same as IVS
- predicted directions are generally in agreement within 1-2 waves
- Philippines was not part of the Wave 5 survey (2005-2009)

countries with at least 400 respondents from Waves 4 to 7



Axelrod model



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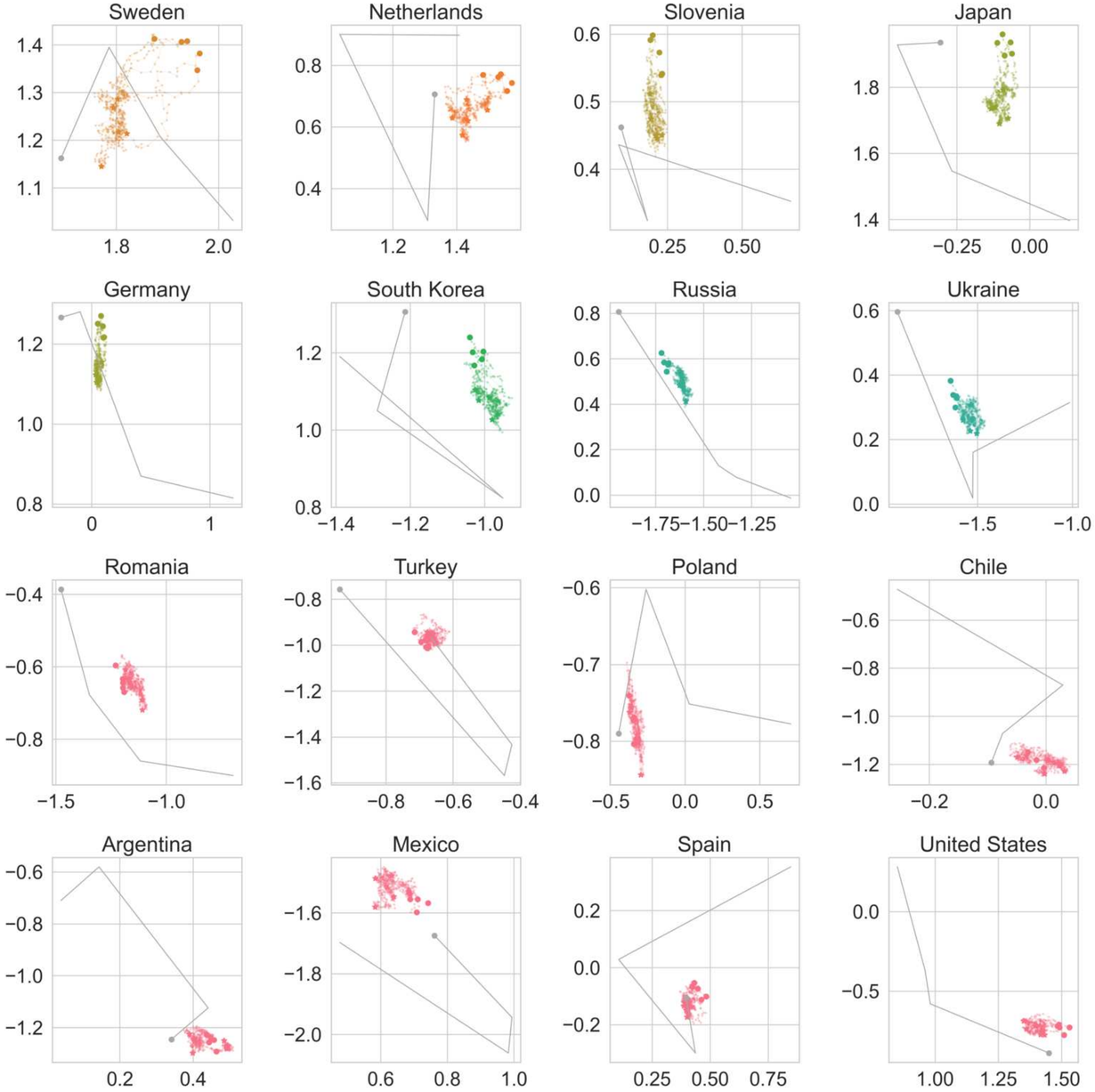
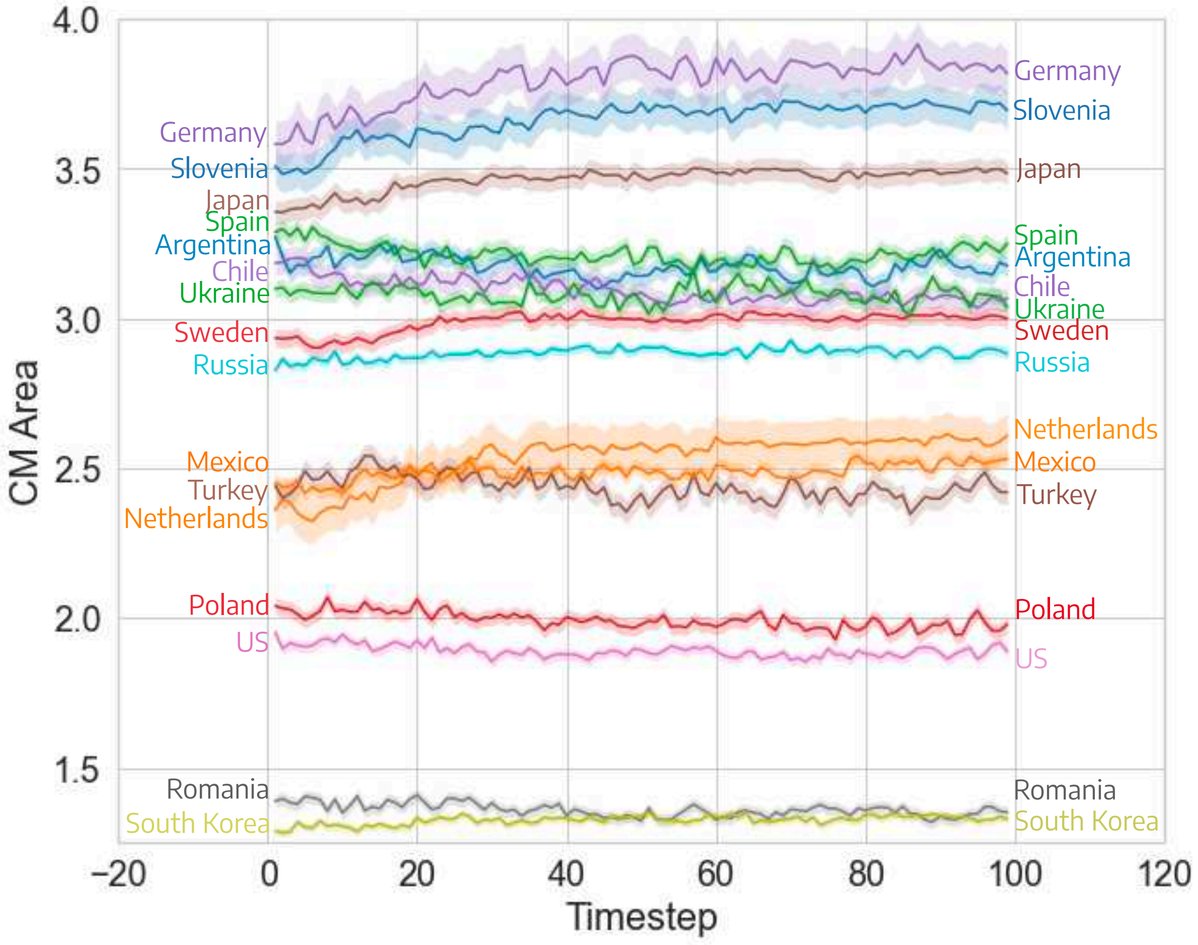


Axelrod model

Contour map area (covering 63% of respondents) vs. Time-step



- Diversity metrics can be predicted since the Axelrod model operates on individual agents
- average over 10 trials, shaded region corresponding to 1 standard deviation from the mean

Summary

- **We have shown several methods to measure cultural diversity from the Integrated Values Survey (IVS)**
  - compared to standard deviational ellipses (SDEs), contour maps (CMs) can more precisely capture the desired proportion of the population across countries without explicit regard to their distributions, but tends to be less accurate for higher population percentage enclosed
  - implemented a vector-based measure of diversity by using Euclidean and cosine distance - diversity metric being the area under the cumulative distribution curve of the intra-country cosine distances (CAUC)

Summary

- **We have presented an initial implementation of the Axelrod model initialized with IVS Wave 4 data**
  - original Axelrod model with bounded confidence, complete graph, and data-based initialization
  - predictions do not reach the same displacement as the data does, but can generally predict direction
  - predicted intra-country cultural diversity
  - possible future work: investigate more simulation parameters, consider phenomena such as cultural drift, and investigate effect of adding an underlying social network

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Thank you!

Measuring intra-country cultural diversity

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