Using network theory to understand behavioural aspects of energy use

Casper Albers

university of groningen

Introduction

Collaborators

Nitin Bhushan

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Linda Steg

Mark Verschoor

How to reduce (household) electricity use

1. Technological advances
   More efficient refrigerators, tv's, etc.

2. Changing energy behaviour
   This requires understanding energy behaviour

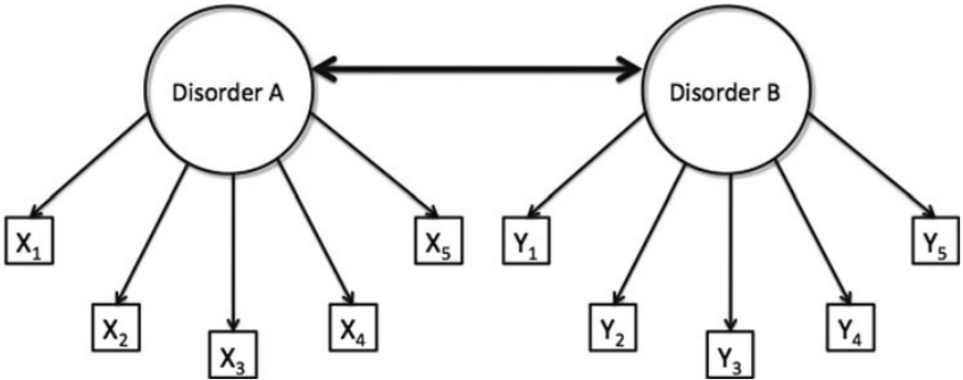
Special characteristics of psychological research

- Distinction between independent and dependent variables often not clear: everything affects everything
- Causal relations are hard. Often variables cause each other (A $\rightarrow$ B *and* B $\rightarrow$ A)
- Many variables involved. Often many overlapping theories involved.
- Technical background of psychologists more limited than of, e.g., biologists. Results should be interpretable for non-statisticians.

Solution: use psychological network models.

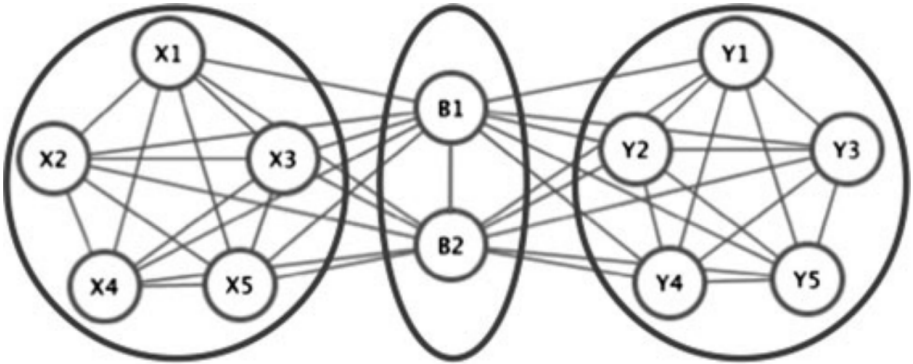
Psychological Networks

From latent variable models to network models



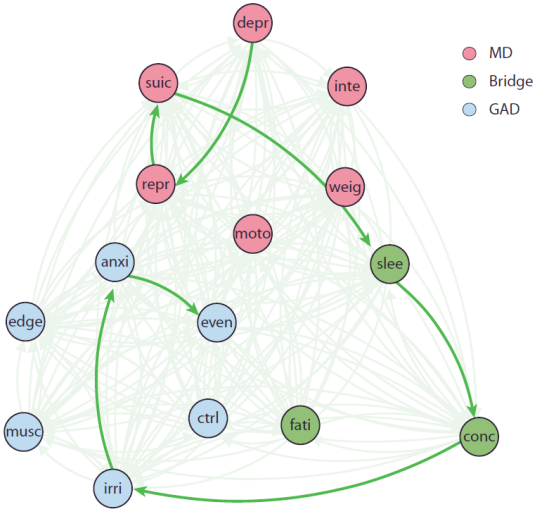
(Cramer et al., 2010)

From latent variable models to network models



(Cramer et al., 2010)

Example: General Anxiety Disorder & Major Depression



(Borsboom & Cramer, 2013)

Psychological network models

In essence, psychological network models are:

A set of nodes and edges, depicting random variables and their relations.

Gaussian graphical models are a specific case of psychological network models.

Psychological networks vs. social networks

Networks

- Network of things

Psychological networks

- Network of variables

Psychological networks vs. social networks

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- Examples: social networks, traffic networks

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- Main goal: explain (co)occurrence of certain nodes
- Conceptually improvement to latent variable models

(Table: Sacha Epskamp)

Psychological networks

$$X \sim N(\mu, \Sigma), \quad X : n \times p$$

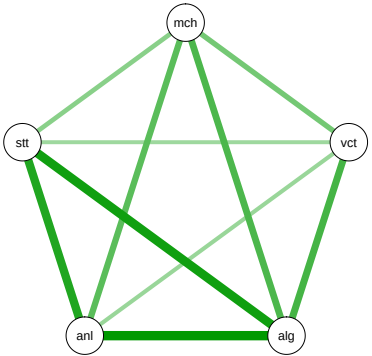
Example: grades for $n = 44$ students on $p = 5$ grades. Correlations:

	mechanics	vectors	algebra	analysis	statistics
mechanics	1.00	0.32	0.41	0.38	0.27
vectors	0.32	1.00	0.43	0.23	0.22
algebra	0.41	0.43	1.00	0.58	0.55
analysis	0.38	0.23	0.58	1.00	0.51
statistics	0.27	0.22	0.55	0.51	1.00

Psychological networks

$$X \sim N(\mu, \Sigma), \quad X : n \times p$$

Example: grades for $n = 88$ students on $p = 5$ grades.
Correlations (from $\hat{\Sigma}$) and partial correlations (from $\hat{\Sigma}^{-1}$):



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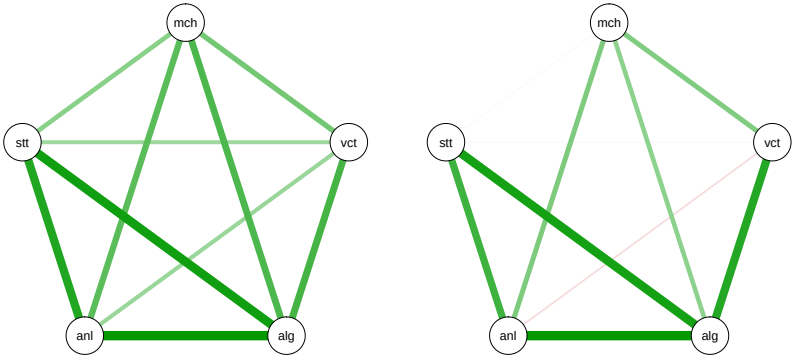
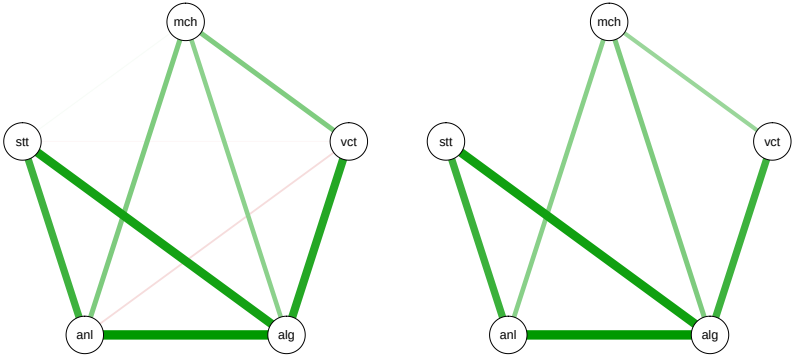


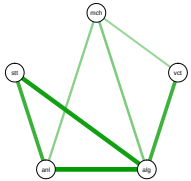
Psychological networks: fewer edges

I nodes $\rightarrow I(I-1)/2$ potential edges. Quickly too many.

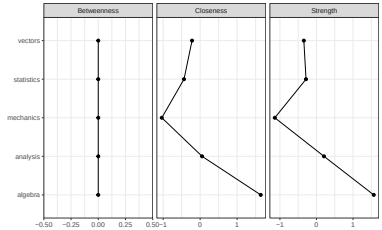
Graphical lasso. Estimate Σ^{-1} subject to L_1-penalties. Commonly used is the Graphical lasso (Friedman, Hastie, Tibshirani, Biostatistics, 2008) approach with the extended BIC to select tuning parameter.



Which nodes matter most?



Network

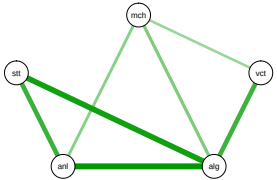


Centrality Measures (standardised)

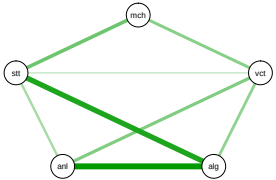
W_{ij}: matrix with weights ($\in [-1, 1]$) in the network. SD_{ij}: shortest distance from node i to node j.

- Node strength/centrality: $S_i = \sum_j W_{ij}$
- Closeness: $CL_i = (\sum_j SD_{ij})^{-1}$
- Betweenness: $B_i = \#(\text{paths through node } i)/\#(\text{all paths})$

Comparing networks



Below median score for mechanics



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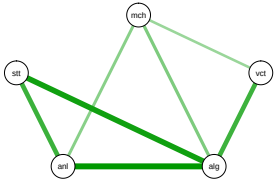

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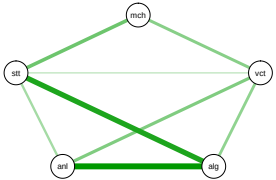

Above median score for mechanics

- Structural Hamming Distance.
  Count number of edges that (dis)appeared/changed sign.
  Here: 5 out of 10.
- Network Comparison Test (Van Borculo et al.)
  Statistical permutation test, similar to Mantel's test (1967).
  Here: $p = .62$.

Psychological networks: Beyond the basics

In this talk, only undirected GGM.

Network models also possible for:

- Directed graphs, when visualising temporal dynamics (e.g. VAR-models; Bringmann et al.) or causal models (DAGs).
- Ordinal data: polychoric rather than Pearson correlations.
- Binary data: Ising-models.

Furthermore, all estimates (e.g. edge weights) can be equipped by bootstrap CI's (Epskamp et al, 2017).

Environmental Applications

Buurkracht: Introduction

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- Community energy initiative for promoting sustainable energy behaviour.
- Research on energy behaviour usually focused on individual.
- Community efforts might be more effective.
- Combination of various psychological and sociological theories at play.

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Buurkracht

- Community energy initiative for promoting sustainable energy behaviour.
- Research on energy behaviour usually focused on individual.
- Community efforts might be more effective.
- Combination of various psychological and sociological theories at play.

- $N_1 = 334$ initiative participants, $N_2 = 360$ right-door-neighbours.
- Data on 22 variables, and 65 items, 7-point Likert scales.

Buurkracht: Variables in the study

Personal factors Values. Environmental self-identity. Personal importance of sustainable energy behaviour. Outcome efficacy.

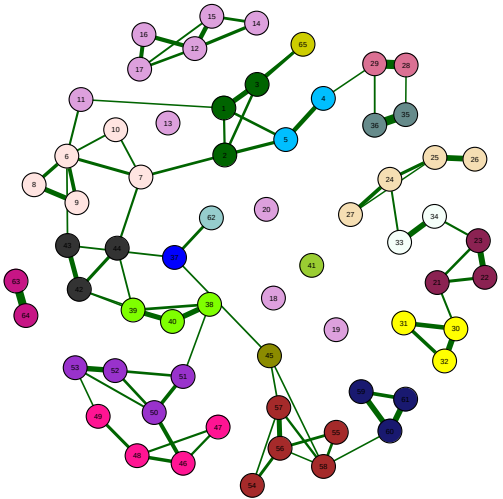
Social context Need to belong Need to be unique. Neighbourhood identification. Neighbourhood homogeneity. Neighbourhood interaction. Neighbourhood environmental identity. Neighbourhood importance of sustainable energy behaviour.

Opinions on energy companies and the government Group-based anger.

Sustainable energy intentions and behaviour Household sustainable energy intentions. Collective sustainable energy intentions. Collective social intentions. Self-reported sustainable energy behaviour.

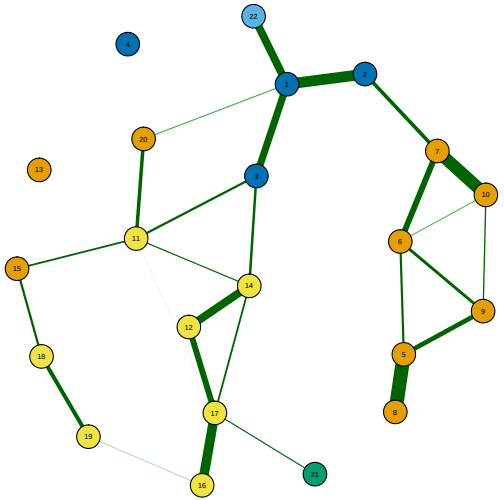
Initiative membership

Buurkracht: Findings



- Altruistic values
- Biospheric Values
- Collective energy intentions
- Collective social intentions
- Egoistic Values
- Environmental Self_identity
- Group−based anger
- Hedonic Values
- Homogeneity in neighbourhood
- Individual energy intentions
- Initiative outcome efficacy
- Interaction in neighbourhood
- Interaction with neighbourhood
- Membership
- Need to be Unique
- Need to belong
- Neighbourhood energy norms
- Neighbourhood environmental Identity
- Neighbourhood identification
- Past energy behavior
- Personal Energy Norms
- Personal outcome efficacy

Buurkracht: Findings



Factors related to the social context
- 5: Neighbourhood environmental Identity
- 6: Neighbourhood identification
- 7: Interaction with neighbourhood
- 8: Neighbourhood energy norms
- 9: Homogeneity in neighbourhood
- 10: Interaction in neighbourhood
- 13: Need to belong
- 15: Need to be Unique
- 20: Initiative outcome efficacy

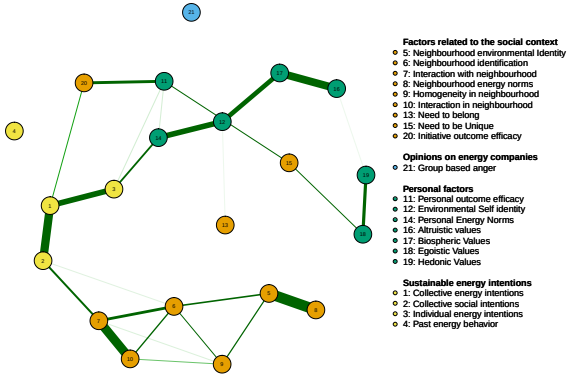
Membership
- 22: Membership

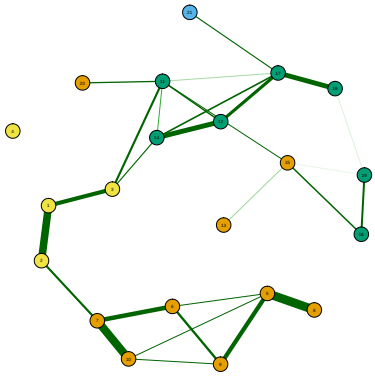
Opinions on energy companies
- 21: Group based anger

Personal factors
- 11: Personal outcome efficacy
- 12: Environmental Self identity
- 14: Personal Energy Norms
- 16: Altruistic values
- 17: Biospheric Values
- 18: Egoistic Values
- 19: Hedonic Values

Sustainable energy intentions
- 1: Collective energy intentions
- 2: Collective social intentions
- 3: Individual energy intentions
- 4: Past energy behavior

Buurkracht: Findings





Structural Hamming Distance: 12

ESS: Introduction

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- Open Data, www.europeansocialsurvey.org
- "Public Attitudes to Climate Change, Energy Security, and Energy Preferences"
- $N = 38,437$ participants from 18 countries (880 to 2,766 per country).

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Research questions:

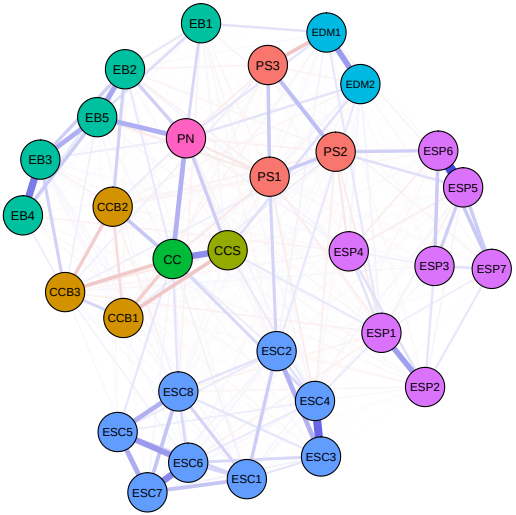
1. What, and how strong, are the relations between the variables?
2. Are these relations the same across countries?

ESS: the Module

The module “Public Attitudes to Climate Change, Energy Security, and Energy Preferences” includes 32 items in the areas:

1. Beliefs on climate change
2. Concerns about climate change and energy security
3. Personal norms, efficacy and trust
4. Energy preferences.

ESS: findings



Policy support
- PS1: Increasing taxes on fossil fuels
- PS2: Subsidise renewable energy
- PS3: Ban least energy efficient appliances

Climate change beliefs
- CCB1: Belief in climate change
- CCB2: Climate change cause
- CCB3: Impact of climate change

Climate change salience
- CCS: Thought about climate change before today

Climate concern
- CC: Climate change worry

Efficacy beliefs
- EB1: Could use less energy
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- EB5: My impact on climate change

Energy demand measures
- EDM1: Buy energy efficient appliances
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Energy security concern
- ESC1: Power cuts
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- ESC8: Terrorist attacks

Energy supply source preference
- ESP1: Coal
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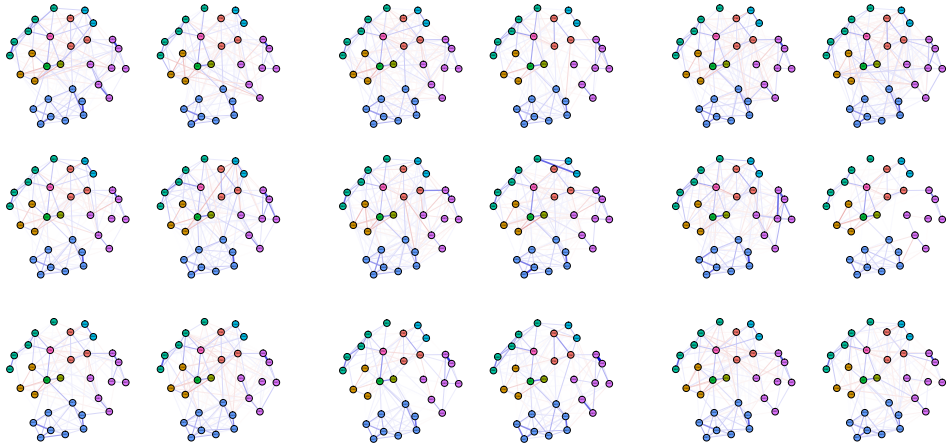
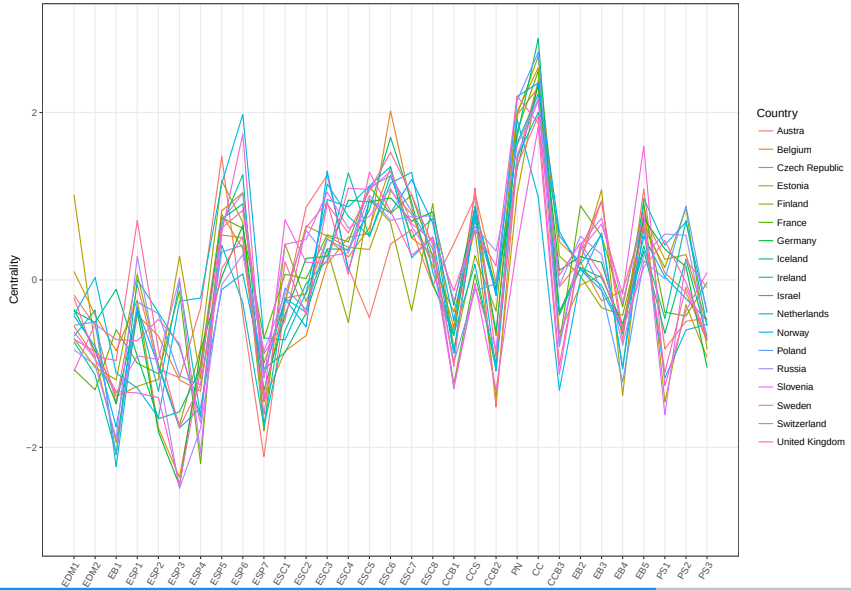
Personal norms
- PN: Personal responsibility to reduce climate change

ESS: findings

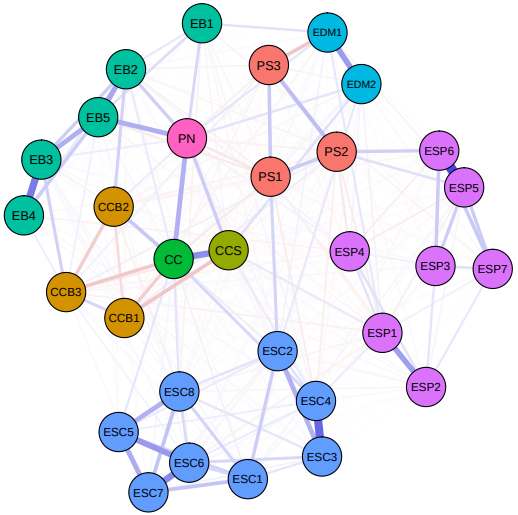


No major between-network differences. *K*-means clustering yields 1 cluster.

ESS: findings



ESS: zooming in



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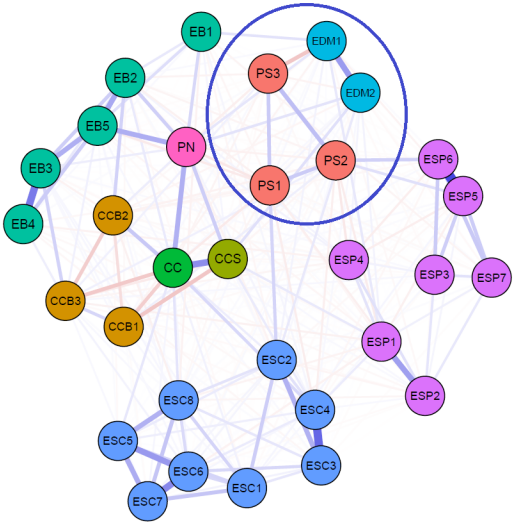

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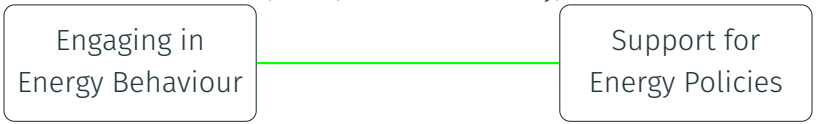
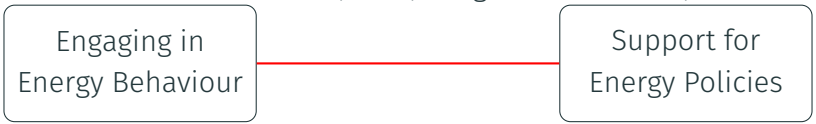
Detailed look at five variables

Werfel, 2017; Noblet & McCoy, 2017:

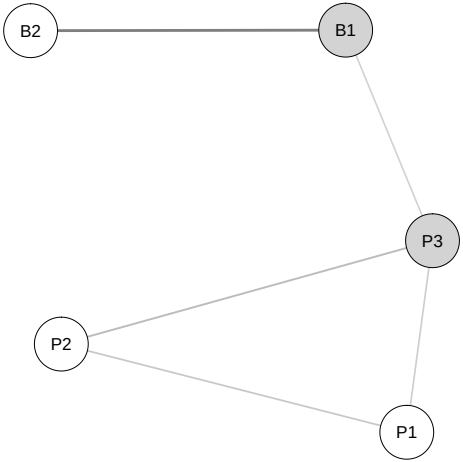


Steinhorst & Matthies, 2016; Thøgersen & Noblet, 2012:



Desire for consistency:
Stronger relation between related concepts

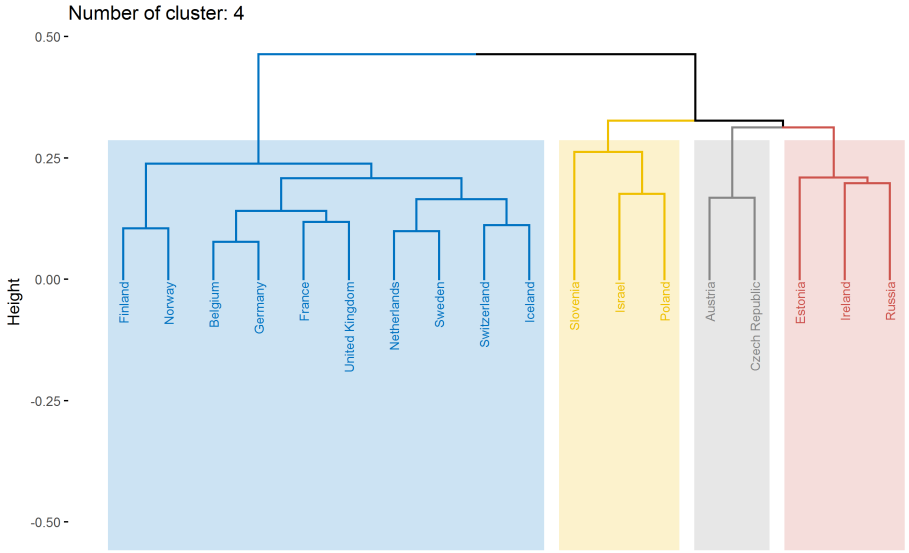
Detailed look at five variables



Behaviour
B1: Buying an energy−efficient appliance
B2: Energy−saving behaviour

Policy support
P1: Taxes on fossil fuels
P2: Subsidies for renewable energy
P3: Ban on inefficient appliances

Country comparison



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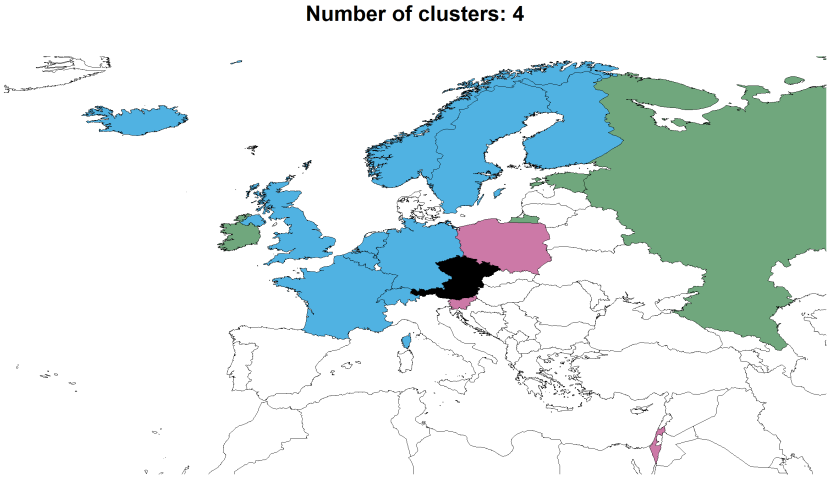

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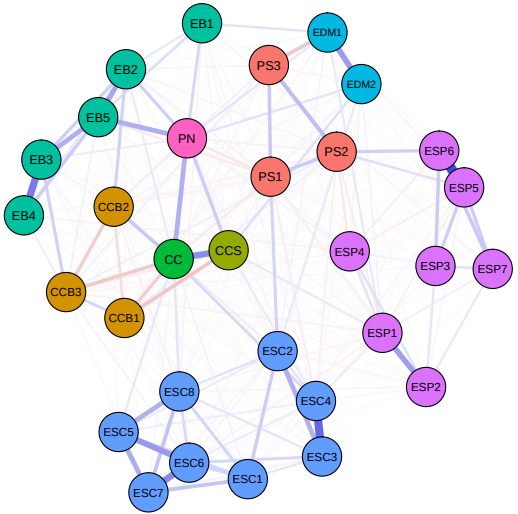

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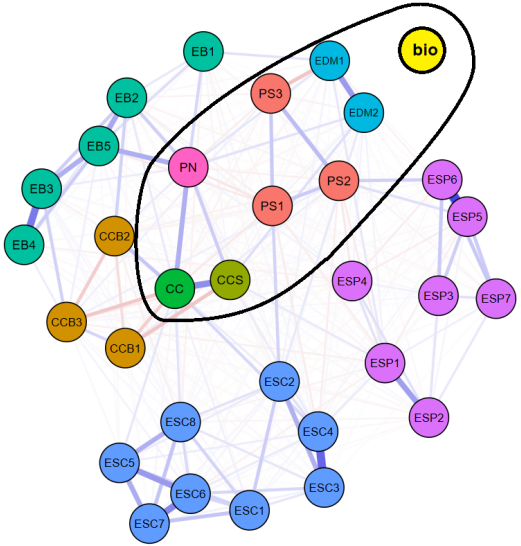

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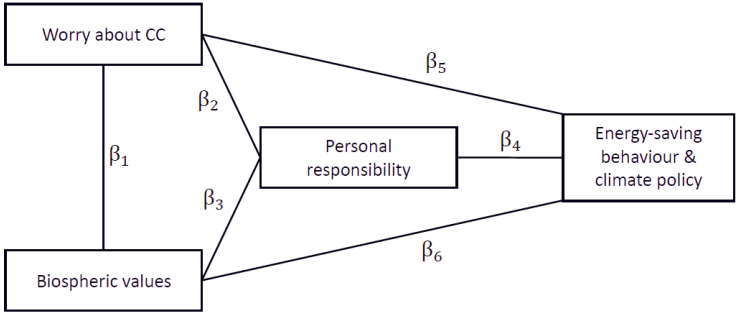
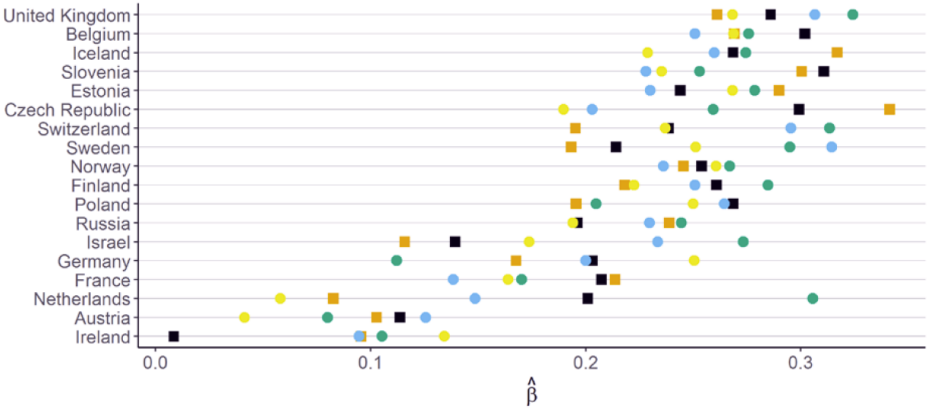
- ESP7: Biomass energy

Personal norms
- PN: Personal responsibility to reduce climate change

ESS: zooming in



ESS: zooming in



Strong relation between the various correlations per country.

Conclusions

Summary

Psychological networks are useful for:

- Exploratory analyses of (relatively) high-dimensional data
- Validation of scales of various items
- Testing hypotheses on the absence/presence, direction or strength of relations
- Testing hypotheses on the co-occurrence of relations

With these models, we explored and confirmed theories on energy-related behaviour and found differences and similarities between countries.

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