New tools for the construction, analysis and interpretation of social indicators based on ordinal variables

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Premise

Issues in creating indicators representing phenomena, for evaluation and governance aims.

PREMISE → 1
BETWEEN ACCURACY AND AMBIGUITIES

Socio-economic phenomena can be measured and represented by means of

- "hard" approaches (e.g., financial analysis) → *sometimes*
- "soft" approaches → *often*

PREMISE → 1
BETWEEN ACCURACY AND AMBIGUITIES

This because the true nature of
socio-economic phenomena
↓
very often **qualitative** and **ordinal**
⇩
Ordinal data are
the true expression of real phenomena

not just a rough approximation of true precise, yet non-observable, variables;

PREMISE → 1
BETWEEN ACCURACY AND AMBIGUITIES

Ambiguities and nuances of socio-economic phenomena are not an obstacle to be removed; they often are what really matters.

PREMISE → 2
BETWEEN OBJECTIVITY AND SUBJECTIVITY

Defining and using data in socio-economic statistics inevitably involves **subjectivity**.

This is also true for decision making purposes.

PREMISE → 2
BETWEEN OBJECTIVITY AND SUBJECTIVITY

This is not an issue in itself, since the knowledge process always involves

- "objectivity", in observational methods
- "subjectivity", in definitions and other choices (conceptual framework, data definitions, analytical approaches, …)

The epistemological research of the last century clearly showed as objectivism cannot account for the knowledge process (just like idealism)

PREMISE → 2
BETWEEN OBJECTIVITY AND SUBJECTIVITY

So, using *subjectivity* is completely consistent with the aims of the socio-economic analysis.

The real issue is not whether using subjectivity or not; it is how to consistently combine subjectivity and the need to observe and analyse data consistently and objectively.

PREMISE → 2
BETWEEN OBJECTIVITY AND SUBJECTIVITY

Subjective choices are unavoidable and their use is fully justifiable.

Real issue → *how to build a sound methodological process, where the subjective choices are clearly stated, while their consequences are worked out in a formal and unambiguous way*.

↓

Final results will be clearly interpretable and the role of subjective inputs and sound formal computations can be clearly distinguished and understood.

PREMISE → 3
DATA METRICS

When dealing with ordinal data, common statistical practice is not quite clearly.

With the aim of pursuing metric analysis out of non-metric data, a lot of arbitrary choices are often taken in data analysis

↓

Final result depends upon subjective choices.

PREMISE → 3
DATA METRICS

In the end, it is not clear whether the results reflect real facts and sound interpretations or are induced by arbitrary methodological choices (e.g., how non-metric data are turned into metric scales).

INDICATORS CONSTRUCTION

- ***1.*** → **the process**
- ***2.*** → **methodological critical issues**
- ***3.*** → **the alternative approach**

AN APPLICATION

- ***4.*** → **traditional approch**
- ***5.*** → **alternative approach**
- ***6.*** → **state of the art and future perspectives**

The process

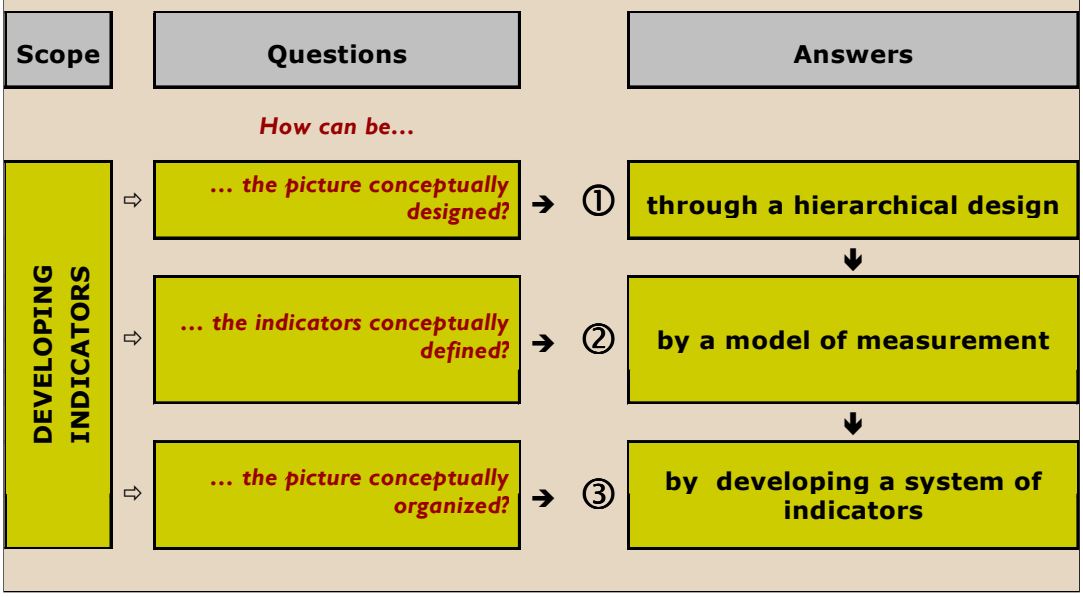
Two phases:

I. **CONCEPTUAL DEFINITION (FRAMEWORK AND STRUCTURE)**

II. **ANALYTICAL TOOLS AND STRATEGIES**

The process

I. CONCEPTUAL DEFINITION (FRAMEWORK AND STRUCTURE)



The process

hierarchical design ← ❶

Indicators should be developed through a **logical modelling process conducting from concept to measurement. Given its features, this logical design is defined** *hierarchical*, since each component is defined and finds its meaning in the ambit of the preceding one.

Conceptually, the hierarchical design is characterized by the following components:

(i) the conceptual model,

(ii) the areas to be investigated,

(iii) the latent variables, and

(iv) the elementary (basic) indicators.

The process

model of measurement ← ❷

A further component of the hierarchical design definition is represented by the relationships between:

- *Latent variables and the corresponding indicators*: these relations define the **model of measurement**. Consistently with the measurement model, also the relationship between the *elementary indicators* should be defined.
- *Latent variables* for a given area: these relations are defined in the ambit of the conceptual model and identify the structural pattern (**modelling indicators**).

The process

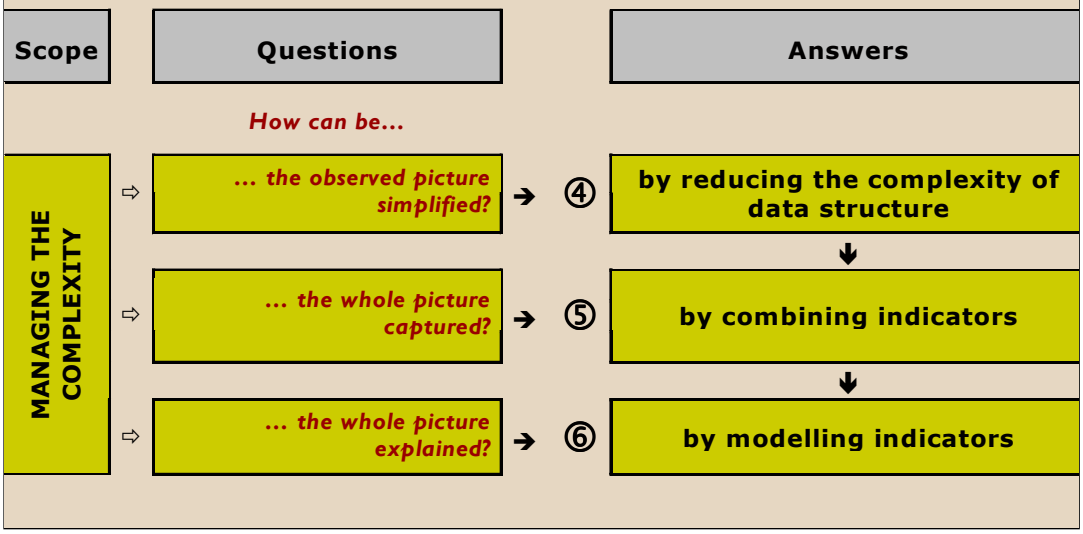
system of indicators ← ❸

A **system of indicators** represents the fulfilment of the conceptual framework. Moreover, it

- offers an effective organizational context, relying on methodological supports and allowing data to be managed;
- allows structured and systematic data to be used, observed in long-term longitudinal perspective. This is particularly demanding with reference to subjective data, which require a great use of resources (beyond a solid survey research methodology).

The process

II. ANALYTICAL TOOLS AND STRATEGIES



The process

reducing the complexity of data ← ❹

The consistent application of the hierarchical design produces a complex data structure (elementary indicators, cases, variables, areas, etc.). In order to manage the complexity:

- **aggregating elementary indicators** for each variable → re-constructing the conceptual variables consistently with the approach (reflective or formative) adopted at micro level (*construction of synthetic indicators)*
- **aggregating units/cases**: leading information observed at micro-level to the proper macro level (*definition of macro-units*).

The process

reducing the complexity of data ← ❹

	columns →	indicators		each case		a synthetic value
the aggregation goes through			with reference to		in order to obtain	
	rows →	units		each indicator		a macro-unit

The process

combining indicators ← ❺

In some occasion, the complexity of the system of indicators may require the indicators allowing for more comprehensive measurement, in order to (Noll, 2009)

- answer the call by 'policy makers' for condensed information
- improve the chance to get into the media (compared to complex indicator systems)
- make multi-dimensional phenomena uni-dimensional
- compare situations across time more easily
- compare cases (e.g. nations) in a transitive way (ranking)
- to observe and record change across time, difference between groups of population or comparison between cities, countries, ...

Dashboards or **composite indicators** → useful approaches for summarising indicators.

The process

modelling indicators ← ❻

This stage is aimed at analysing different aspects of the defined model (e.g. objective and subjective indicators) in order to find explanation by identifying the proper analytical approaches.

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Methodological critical issues

social indicators construction

↓

consolidated tradition

however

critical issues remained unsolved and unsettled

Methodological critical issues

with reference to difficulty in dealing with data which

- refer to a complex reality
- are ambiguous and softened
- are multidimensional
- are dynamic and evolutionary
- are qualitative also when quantitatively measured
- contain errors and approximations
- are sensitive

Methodological critical issues

new challenges and perspectives

to improve technical tools strategies

with reference to

- reducing data structure in order to aggregate
  - units
  - indicators
- combining indicators
- communicating the “picture” obtained through the indicators (correctly and significantly representing and showing results).

Methodological critical issues

new challenges and perspectives
to improve analytical tools and strategies
which should take into account

- nature of data → generally ordinal
- process and trends of phenomena → monotonic

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Introduction

The particular application presented here is aimed at just illustrating in a simple way and

comparing

the traditional and alternative approach

in reducing the complexity of data structure,

by using subjective and objective data provided by the European Social Survey project.

Introduction

Just for illustrative reasons, we selected

- the first eight countries (alphabetical order) in the dataset (AT, BE, CH, CZ, DE, DK, ES, FI)
- the following variable (and corresponding items)

Introduction

European Social Survey					
Area	Variable	Items	Item number R1 (2002)	Scaling technique	Model of measurement
Immigration and asylum issues	Acceptance of immigration: allow	many/few immigrants of same race/ethnic group as majority	D4 IMSMETN	1. allow many 2. allow some 3. allow a few 4. allow none to come and live here	reflective
		many/few immigrants of different race/ethnic group from majority	D5 IMDFETN		
		many/few immigrants from richer countries in Europe	D6 EIMRCNT		
		many/few immigrants from poorer countries in Europe	D7 EIMPCNT		
		many/few immigrants from richer countries outside Europe	D8 IMRCNTR		
		many/few immigrants from poorer countries outside Europe	D9 IMPCNTR		

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Traditional approach

First stage: synthesizing indicators at individual level

Goal: synthesizing indicators related to each variable consistently with the adopted model of measurement (reflective or formative).

Traditional approach

First stage: synthesizing indicators at individual level

First level

Non-acceptance of immigration

Variable	Items	Item code	Loading
Acceptance of immigration: allow	many/few immigrants of same race/ethnic group as majority	IMSMETN	.8
	many/few immigrants of different race/ethnic group from majority	IMDFETN	.9
	many/few immigrants from richer countries in Europe	EIMRCNT	.7
	many/few immigrants from poorer countries in Europe	EIMPCNT	.9
	many/few immigrants from richer countries outside Europe	IMRCNTR	.8
	many/few immigrants from poorer countries outside Europe	IMPCNTR	.9
	Total variance explained (%)		70
	Cronbach's alpha		.94

Since the selected items are reflective, the statistical approach adopted in order to test the uni-dimensionality is Factor Analysis (not Principal Component Analysis). The positive results (supported also by the high value in Cronbach's alpha) allowed the individual synthetic score to be calculated.

Traditional approach

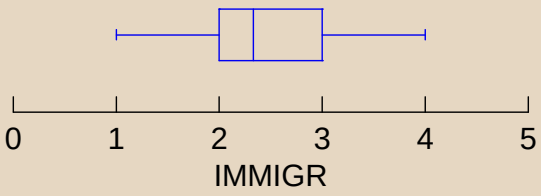
First stage: synthesizing indicators at individual level

First level

Non-acceptance of immigration

Synthetic score (IMMIGR)

Minimum	1.00
Maximum	4.00
Median	2.33
Mean	2.40
Standard Dev	0.69
Skewness	-0.03
Kurtosis	-0.16



1 (allow many) – 4 (allow none)

Traditional approach

First stage: synthesizing indicators at individual level

Second level

An attempt has been made in order to synthesise the "non-acceptance" score with other subjective indicators, by applying a traditional synthesis technique (PCA).

European Social Survey					
Area	Variable	Items	Item number R1 (2002)	Scaling technique	Model of measurement
Politics	Self-placement	placement on left-right scale	B28 LRSCALE	0 (left) – 10 (right)	
Subjective aspects	Life satisfaction	how satisfied with life as a whole	B29 STFLIFE	0 (extremely dissatisfied) – 10 (extremely satisfied)	
Socio-demographic profile	Income	feeling about household's income nowadays	F31 HINCFEL	1. living comfortably 2. coping 3. difficult 4. very difficult on present income	

The statistical results of this part of the analysis is not presented and is not performed through the alternative approach.

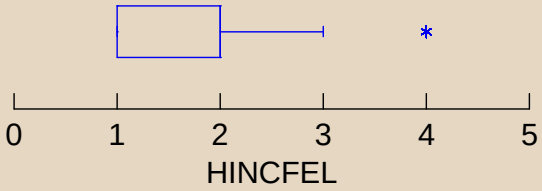
Traditional approach

First stage: synthesizing indicators at individual level

Second level

feeling about household's income nowadays

Synthetic score (HINCFEL)	
Minimum	1.00
Maximum	4.00
Median	2.00
Mean	1.86
Standard Dev	0.77
Skewness	0.71
Kurtosis	0.26



1 (comfortably) – 4 (difficult)

Traditional approach

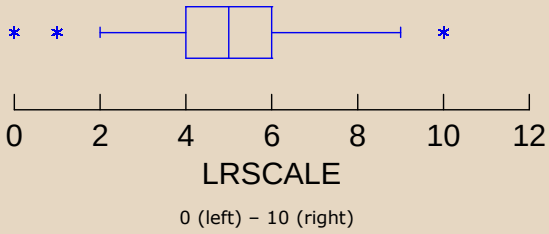
First stage: synthesizing indicators at individual level

Second level

Political placement on left-right scale

Synthetic score (LRSCALE)

Minimum	0.00
Maximum	10.00
Median	5.00
Mean	4.95
Standard Dev	2.03
Skewness	-0.01
Kurtosis	0.23



0 (left) – 10 (right)

Traditional approach

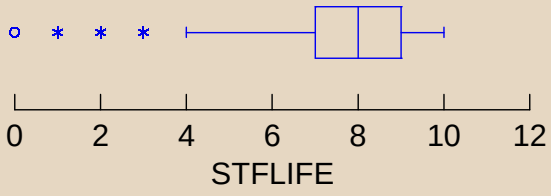
First stage: synthesizing indicators at individual level

Second level

how satisfied with life as a whole

Synthetic score (STFLIFE)

Minimum	0.00
Maximum	10.00
Median	8.00
Mean	7.41
Standard Dev	2.07
Skewness	-1.11
Kurtosis	1.20



0 (extremely dissatisfied) – 10 (extremely satisfied)

Traditional approach

First stage: synthesizing indicators at individual level

Second level

In our case, the PCA results did not allow any meaningful synthesis since it produced two components on four indicators (!!!)

Traditional approach

Second stage: defining macro-units

Goal: synthesizing indicators observed at individual level in order to ascribe a synthetic value to groups.

The aggregation can be done through

- *additive* approach: a single value synthesizes the values observed at micro level (also through further indicators aggregation processes "second-level indicators aggregation");
- *compositional* approach: when micro-units' macro-units' values are obtained by aggregating individual values in a certain number of homogeneous sub-groups

In our case, we adopted the latter approach in order to simultaneously aggregate indicators and cases.

This part of the analytical process is not performed by the alternative as a separate stage.

Traditional approach

Country level of non-acceptance

Country	Acceptance mean score
AT	2.61 (rank → 8)
BE	2.41 (rank → 5)
CH	2.18 (rank → 1)
CZ	2.46 (rank → 6)
DE	2.32 (rank → 3)
DK	2.31 (rank → 2)
ES	2.38 (rank → 4)
FI	2.53 (rank → 7)
Overall	2.40

This output shows the outcomes yielded by the traditional approach in which mean values allow countries to be classified and compared. However, it should be noticed that the mean values are difficult to be manage especially because do not correspond to any concrete observed score (actually, just four ordered categories). In other words, the obtained countries ranking is obtained through values corresponding to nothing concrete. In order to respect data quality, each country should show a mean score of 1, 2, 3, or 4 (AT=3, BE=2, CH=2, CZ=3, DE=2, DK=2, ES=2, FI=3) with difficult possibility to discriminate.
Moreover, the mean scores (even if obtained on distribution that could be assimilated to normal) are based upon individual mean scores yielded though a process that does not explore in depth relationships between items.

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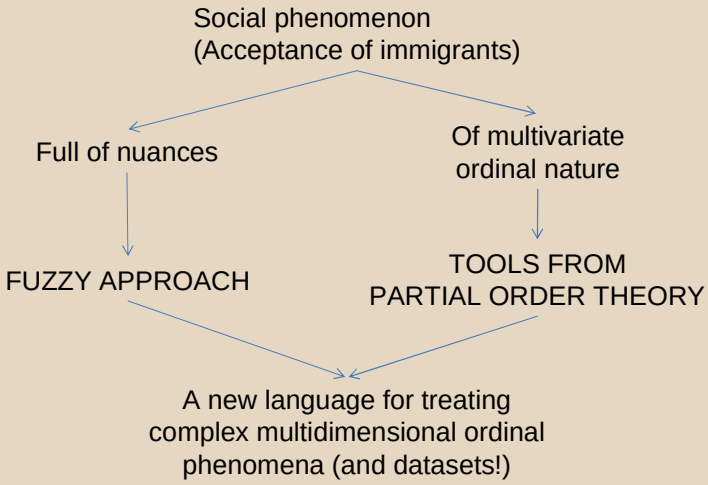
Alternative approach

Searching for new formal languages…



Alternative approach

Partial order analysis through a simple example

Many ordinal variables recorded on a population,

⇩

individuals cannot be directly ordered,
since each variable is likely to induce different rankings

The most natural way to represent such data is through a partial order.

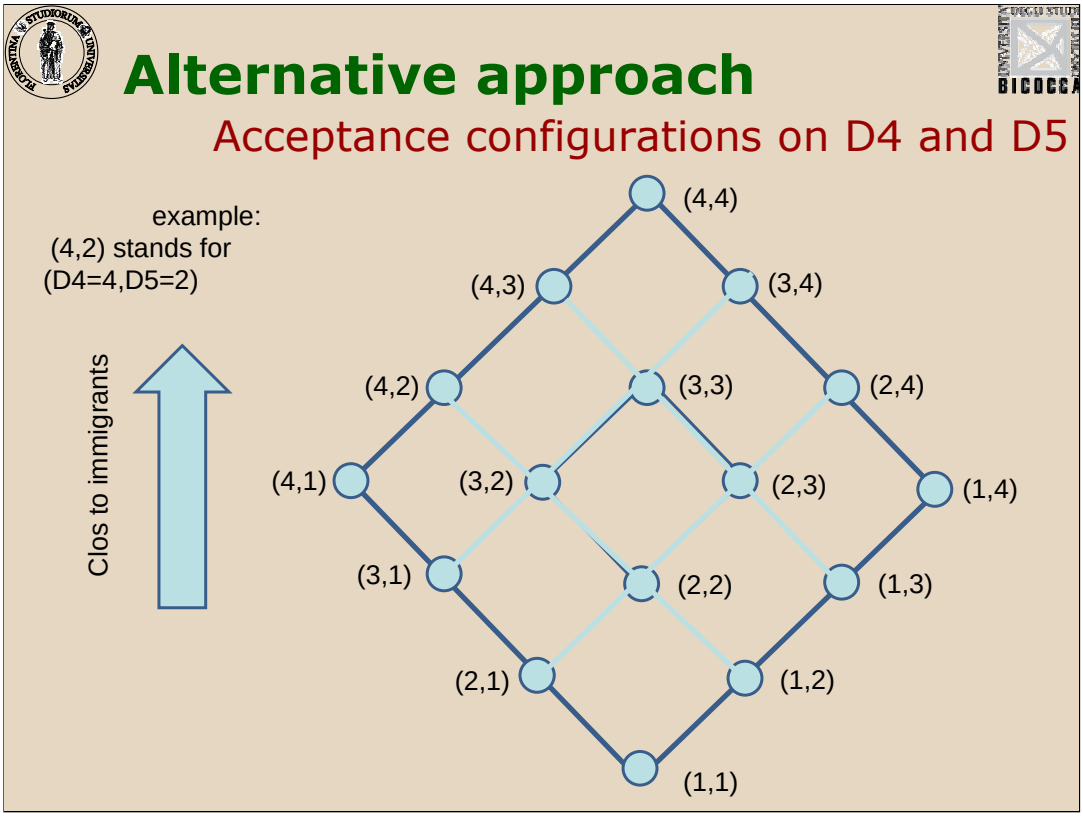
Alternative approach

Partial order analysis through a simple example

We introduce basic concepts using a simple example, based on considering two variables from the European Social Survey, namely variables D4 (IMSMETN) and D5 (IMDFETN):

- D4: acceptance of many/few immigrants of same race/ethnic group as majority;
- D5: acceptance of many/few immigrants of different race/ethnic group from majority.

Both variables are recorded on a four grade scale from 1 (allow many) to 4 (allow none).



There are 4x4=16 possible pairs of scores (D4,D5), namely (1,1), (1,2), (1,3), (1,4), (2,1), (2,2), (2,3)… and so on.

Pairs like (1,2) and (2,2) can be ordered, since each component of (2,2) is greater or equal to each component of (1,2). So we can write (1,2) ≤ (2,2), that is an individual scoring (1,2) is less against immigrants than an individual scoring (2,2).

Pairs like (1,3) and (2,1) are incomparable and cannot be ordered.

Graphically, the resulting poset can be easily depicted by a Hasse diagram, which is a graph to be read from top to bottom. Each configuration (x,y) is represented as a node. Two nodes are linked if the node above in the graph represent a configuration greater than that represented by the node below.

So, descending paths (called “chains”) identify sequences of comparable pairs.

Alternative approach

Assessing the degree of acceptance

It is clear that if $(a,b) \leq (c,d)$, then the degree of rejection of immigration of (c,d) is greater than that of (a,b). But:

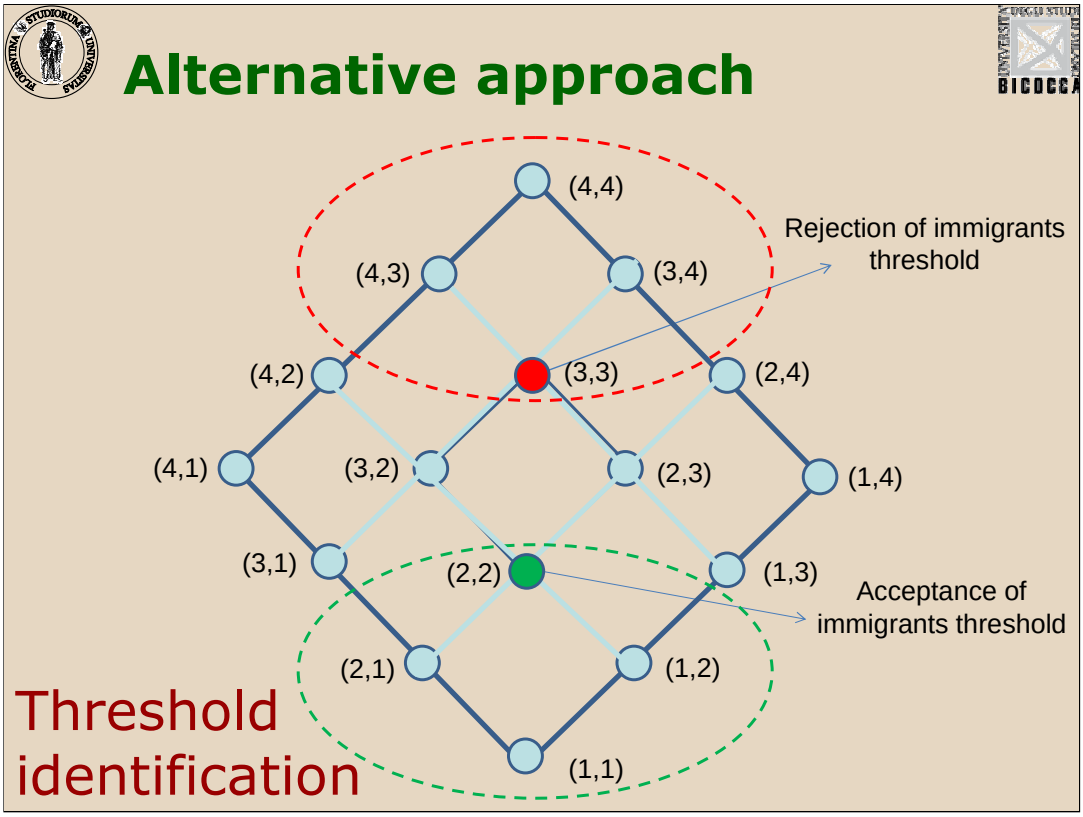
- Is it possible to assess to what extent it is greater?
- Is it possible to assign to each configuration the corresponding degree?

Alternative approach

Assessing the degree of acceptance

Yes, if we suppose that some configurations are identified as definitly representing closeness to immigrants or acceptance of immigrants, that is, if suitable rejection and acceptance thresholds are identified.

Here subjectivity enters but all the implications of the choice of such thresholds are then derived based only on the data structure.



For sake of simplicity, let us consider thresholds composed on just one state.
For example, let us agree that if an individual is in the state (3,3), he is definitely against immigrants.
As a consequence, states above (3,3) represent definitley rejection of immigrants as well (red ellipse).
Similarly, let us agree that state (2,2) represents total acceptance of immigrants.
As a consequence, states below (2,2) represent definitley acceptance of immigrants (green ellipse).
All other states are in an ambigous position, since they do not represent definitely rejection, nor acceptance.

Alternative approach

Assessing the degree of acceptance

- Let us agree, in a fuzzy evaluation perspective (so as to take explicitly into account nuances), that nodes in the red ellipse has degree of rejection of immigration equal to 1 (the maximum) and that nodes in the green ellipse has degree of rejection of immigration equal to 0 (i.e. the minimum).

- All other nodes should receive a degree of rejection between 0 and 1, reproducing the ambiguities in the phenomenon.

Alternative approach

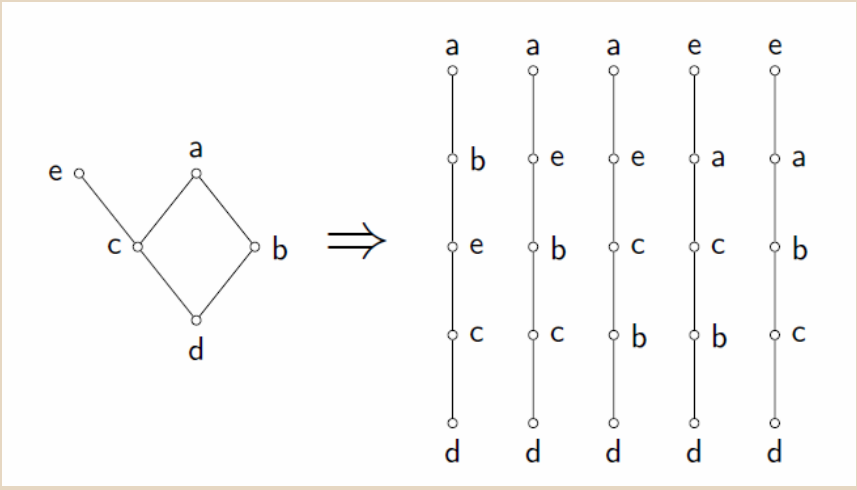
Assessing the degree of acceptance

- The computation of such degrees is based only on the analysis of the partial order structure of the poset, that is, it is based on the analysis of the different relational position of each node, with respect to the thresholds selected.

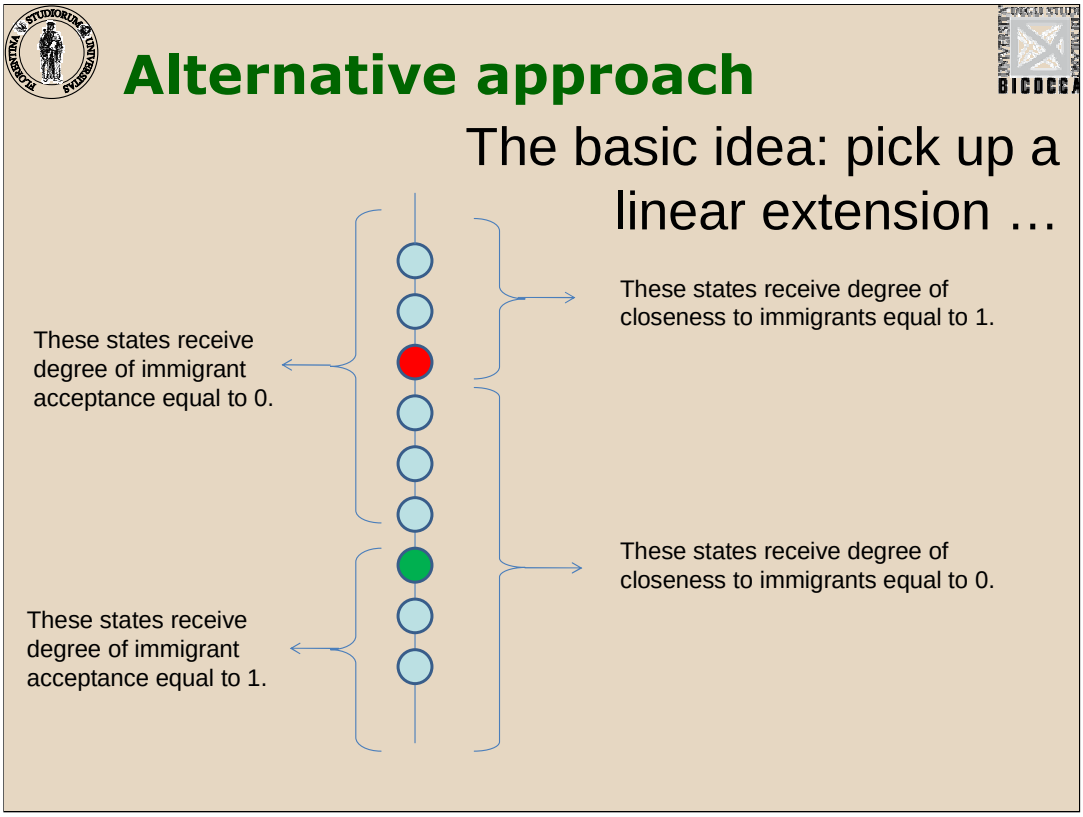
- The required information about the degree of acceptance/rejection of immigration is extracted from the structure of the poset and not on the aggregation of variable scores (which are treated as they are, i.e. as ordinal variables).

Alternative approach

Linear extensions of a poset



- Any (finite) poset can be described in terms of the set of those linear orders (complete rankings, here called linear extensions), where the nodes of the poset are ranked consistently with the poset structure.
- "Consistently with the poset structure" means that if nodes a and b are such that a≤b in the poset, then in each linear order a≤b must hold (The slide reports a simple example).



- If in a linear order a node x=(x1,x2) is ranked above the (for example) red threshold, then in that ranking (x1,x2) is assigned a degree of rejection of immigrants equal to 1. On the contrary, if it is ranked below the red node, it will receive a degree of rejection of immigrants equal to 0.
- Given a node x, generally speaking some linear extensions will rank it above the red node, while other will rank it below the red node. Computing the proportion of linear orders assigning degree of rejection 1 to x, we get the degree of rejection associated with the node (x1,x2).
- A similar reasoning can be pursued in terms of the green threshold. If x is ranked above the green node, then it recieves immigration acceptance degree 0; if it is ranked below, it recieves acceptance degree 1.

Alternative approach

The basic idea

- In the end, for each state we get two degrees:
  - the first measures to what extent it can be classified as belonging to the group of states representing people who do not accept immigrants; → **deg1**
  - the second measures to what extent it can be classified as belonging to the group of states representing people who do accept immigrants. → **deg2**
- Turning **deg1** into **1-deg1** we get an alternative measure of acceptance of immigrants (in terms of non-rejection of them).

Alternative approach

The basic idea

- So, given the
  - *rejection threshold* (red) and
  - *acceptance threshold* (green)

  we get two different assesments of the degree of acceptance of immigrants, corresponding to each node.
- To get the final degree of immigration acceptance, for each node we compute the average of **1-deg1** and **deg2** (it can be shown that this is the only way to get a mathematically consistent fuzzy assessment of acceptance degree, out of the two "original" assessments).

Alternative approach

Results

State	Acceptance degree: Acceptance threshold (2,2)	Rejection degree: Rejection threshold (3,3)	Final acceptance degree
(1,1)	1,00	0,00	1,00
(1,2)	1,00	0,00	1,00
(1,3)	0,71	0,00	0,86
(1,4)	0,42	0,09	0,66
(2,1)	1,00	0,00	1,00
(2,2)	1,00	0,00	1,00
(2,3)	0,00	0,00	0,50
(2,4)	0,00	0,39	0,31
(3,1)	0,71	0,00	0,86
(3,2)	0,00	0,00	0,50
(3,3)	0,00	1,00	0,00
(3,4)	0,00	1,00	0,00
(4,1)	0,42	0,09	0,66
(4,2)	0,00	0,39	0,31
(4,3)	0,00	1,00	0,00
(4,4)	0,00	1,00	0,00

Due to symmetries in the partial order, some states have the same final acceptance degree.

Alternative approach

Country level of acceptance

Country	Acceptance degree (D4 and D5)
AT	0.49 (rank → 7.5)
BE	0.62 (rank → 4)
CH	0.74 (rank → 1)
CZ	0.52 (rank → 6)
DE	0.65 (rank → 2)
DK	0.63 (rank → 3)
ES	0.54 (rank → 5)
FI	0.49 (rank → 7.5)
Overall	0.62

The average acceptance degree (given the selected thresholds) concerning variables D4 and D5 for the population considered can be directly computed assigning to each individual the degree of acceptance corresponding to the state he occupies and taking the arithmetic mean of the resulting degrees over the entire population. The table reports averages both at single country level and at overall level.

(NB. The overall number of individuals considered is 14138, subdivided into 8 different countries)

Alternative approach

A more complex example

- A similar analysis has been performed on the four variables D6, D7, D8, D9.
- The resulting poset has 4x4x4x4=256 states and cannot be depicted.
- The red (*rejection*) threshold has been identified as the state (2,3,2,3).
- The green (*acceptance*) threshold has been identified as the state (2,2,2,2) .
- In both cases, the thresholds have been identified for explanation purposes. A more meaningful choice requires expert's judgment and/or further analysis.

Alternative approach

Country level of acceptance

Country	Acceptance degree (D6, D7, D8, D9)
AT	0.33 (rank → 8)
BE	0.52 (rank → 3)
CH	0.64 (rank → 1)
CZ	0.50 (rank → 4)
DE	0.53 (rank → 2)
DK	0.49 (rank → 5)
ES	0.48 (rank → 6)
FI	0.37 (rank → 7)
Overall	0.48

(given the thresholds)

At individual level, the correlation between the acceptance degrees on D4-D5 and on D6-D7-D8-D9 (given the thresholds selected in both cases) is 0.77.

Alternative approach

Comparing the two approaches

In order to compare the results and to assess the effectiveness of the two methodologies in extracting information out of the data,

we computed the CVs of the distributions pertaining the acceptance degrees.

CV = The coefficient of variation is the standard deviation divided by the sample mean.

Alternative approach

Comparing the two approaches

	CV
Traditional approach	0.05
Alternative approach (D4, D5)	0.14
Alternative approach (D6, D7, D8, D9)	0.19

CV = The coefficient of variation is the standard deviation divided by the sample mean.

Alternative approach

Comparing the two approaches

The results show how the poset approach is capable of differentiating countries far better than the traditional approach

(whose nature is mainly compensative / aggregative).

In other words

identifying the thresholds and extracting information out of the relational structure of the data result in a great increase of the informative content of the computations.

Alternative approach

Comments

- We have given a brief example of how poset theory can be used to compute social indicators out of ordinal data, without turning them into numerical scores.
- Due to the exemplificative nature of the slides, the computed numbers should be taken just as rough measures. They depend upon the choice of the thresholds and some sensitivity analysis should be added.
- The poset describing variables D4 and D5 is very small (for presentation purposes), so the variability of the acceptance degrees over its 16 nodes is small compared to that of nodes in the poset concerning D6-D7-D8-D9 (that comprises 256 nodes). Also for this reason, the final numbers obtained in the two cases are not directly comparable.

INDICATORS CONSTRUCTION

- ***1.*** → **the process**
- ***2.*** → **methodological critical issues**
- ***3.*** → **the alternative approach**

AN APPLICATION

- ***4.*** → **traditional approach**
- ***5.*** → **alternative approach**
- ***6.*** → **state of the art and future perspectives**

State-of-the-art and future perspectives

State of the art

- This approach has been (and is being currently) applied to the study of material deprivation, based on EU-SILC data. We are planning to study also other social phenomena.
- Approximated analytical formulas are being developed, so that the computations involved in this approach can be performed without relying on heavy and complex numerical algorithms.
- It is already possible to define thresholds composed of more than a single node. This makes the proposed approach more flexible to real situations.

State-of-the-art and future perspectives

Future perspectives

- Integration of poset analysis and Structural Equation Modeling.
- Definition of algorithms to help identifying thresholds.
- Definition of "weighting" schemes for ordinal variables, i.e. of a way to take into account the different relevance of different variables, without introducing numerical weights.
- Definition of clustering algorithms, for reducing the dimension of posets, when the number of variables and/ot the number of possible scores for each variable is high.

In practice: developing a full set of analytical tools for dealing with ordinal variables in a consistent way.

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