Quality Assurance and Robustness

The European Commission's science and knowledge service

Joint Research Centre

Competence Centre on COmposite INdicators and Scoreboards

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European Commission


rankings are here to stay, and it is therefore worth the time and effort to get them right

Some feedback

Rankings range from irresponsible musings by self-appointed experts and money-making schemes by commercial organizations to, at their best, serious efforts by academic or research organizations (Aitbach, 2015)

Notwithstanding recent attempts to establish good practice in composite indicator construction (OECD, 2008), "there is no recipe for building composite indicators that is at the same time universally applicable and sufficiently detailed" (Cherchye et al., 2007).

Booysen (2002, p.131) summarises the debate on composite indicators by noting that "not one single element of the methodology of composite indexing is above criticism".

Andrews et al. (2004)] argue that "many indices rarely have adequate scientific foundations to support precise rankings: […] typical practice is to acknowledge uncertainty in the text of the report and then to present a table with unambiguous rankings"

Tools for “serious efforts”

Quality Assurance

Robustness

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Tools for "serious efforts"

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Ensuring statistical coherence (see previous lectures)

How do indicators contribute to the composite?

Robustness

How sensitive is the composite indicator to its assumptions?

- Transparency
- Exploration of uncertainty
- Anticipate criticism

We use Monte Carlo methods and sensitivity analysis

TIMES HIGHER EDUCATION WORLD UNIVERSITY RANKINGS

QS WORLD UNIVERSITY RANKINGS®

Definition of the university *is broad*

A university – as the name suggests – tends to encompass a broad range of purposes and dimensions, focus and missions. It is difficult to condense into a compact measure.

But measuring and benchmarking excellence is still in demand:

- Governance
- Accountability
- Transparency

The growing mobility of students and researchers has also created a market for these measures among the prospective students and their families.

UK universities tumble in world rankings amid Brexit concerns

Uncertainty over research funding and immigration rules blamed for decline, as Cambridge slips out of top three for first time

- Top 200 universities in the world - the table

Cambridge University, now ranked fourth in the world. Photograph: Bloomberg via Getty Images

> The surveys that informed the rankings were carried out before the UK voted in June to leave the EU

An extreme impact of global rankings

What - 2005 THES created a major controversy in Malaysia: country's top two universities slipping by almost 100 places compared to 2004.

Why - change in the ranking methodology (not well known fact and of limited comfort)

Impact - Royal commission of inquiry to investigate the matter. A few weeks later, the Vice-Chancellor of the University of Malaysia stepped down.

Composite indicators move money

(policy-makers are listening)

Composite indicator	Budget programme	2018 Budget
International Logistics Performance Index	Customs 2020	80.2 Million
Inform Index for Risk Management	Humanitarian aid	1.1 Billion
Corruption index, Press freedom Index, Ease of Doing Business Index + others.	Instrument for Pre-accession Assistance	1.7 Billion
Worldwide Governance Indicator	Development Cooperation Instrument	3.0 Billion

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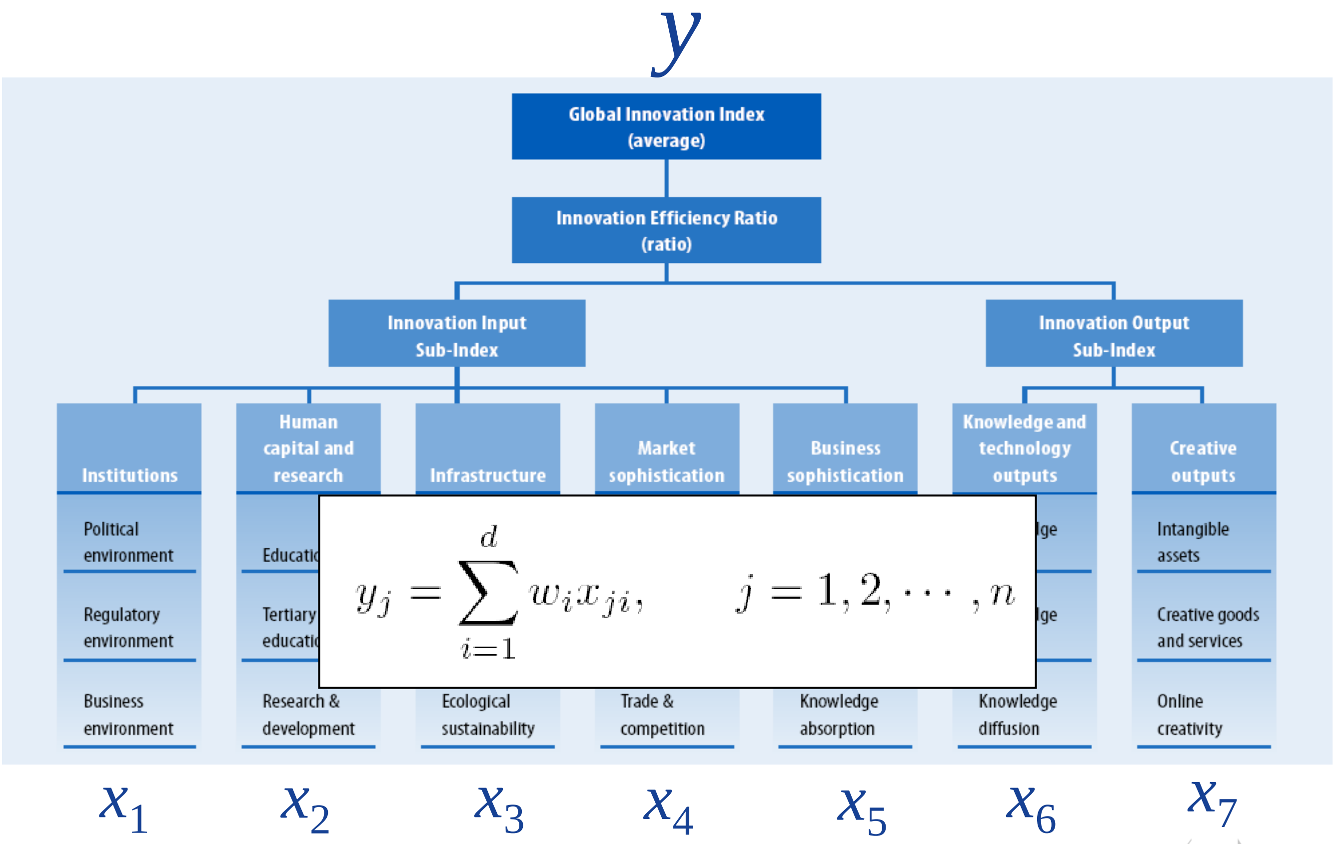
Part 1: Quality assurance—Weighting

"a general criticism that is frequently addressed at composite indicators, i.e. the arbitrary character of the procedures used to weight their various components"

- the Stiglitz Report, 2010



$$y_j = \sum_{i=1}^{d} w_i x_{ji}, \qquad j = 1, 2, \cdots, n$$

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What do we want to achieve by weighting?

- Equal weighting: indicators should be equally important/influential
- Principle component analysis

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1.05E+08	7.24E+05	2.94E+08	6.97E+06	1.09E+06	4.08E+06	1.14E+08	8.34E+08	1.27E+06	3.84E+08	7.45E+05	8.36E+07	2.59E+06	2.01E+06	1.97E+07	2.10E+05	1.16E+07	2.84E+06	1.12E+08	4.03E+06	1.09E+08	1.09E+08	4.57E+07	3.55E+07	2.75E+07	5.90E+07	9.19E+06	9.72E+06	5.55
5.75E+06	1.11E+06	3.23E+07	3.17E+07	3.68E+06	1.64E+07	2.32E+09	3.36E+08	9.97E+06	4.86E+07	5.89E+06	3.79E+08	4.68E+06	4.66E+06	2.45E+08	1.04E+06	1.79E+08	8.52E+06	1.19E+08	7.52E+07	7.72E+07	2.33E+07	3.83E+06	3.76E+08	7.37E+07	1.69E+07	4.45E+07	5.69E+06	4.01
2.19E+05	5.61E+05	6.57E+06	3.33E+05	1.79E+05	1.49E+05	7.58E+06	8.87E+06	1.58E+06	2.74E+06	8.50E+03	3.54E+06	4.05E+05	2.42E+05	2.38E+05	7.10E+04	4.42E+05	3.04E+05	2.08E+06	2.38E+05	8.63E+06	1.05E+06	8.80E+04	1.40E+07	1.02E+06	6.58E+05	2.69E+06	5.90E+05	1.03
0.00E+00	0.00E+00	0.00E+00	3.53E+05	0.00E+00	0.00E+00	1.70E+07	3.32E+07	0.00E+00	2.05E+07	0.00E+00	1.02E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.22E+05	0.00E+00	1.73E+06	0.00E+00	0.00E+00	0.00E+00	1.10E+08	0.00E+00	3.55E+06	2.84E+06	2.43E+05	4.38E+06	0.00
2.51E+05	0.00E+00	5.36E+06	1.00E+06	9.77E+04	1.50E+06	1.38E+07	1.24E+07	8.64E+06	3.22E+06	7.09E+05	1.76E+06	6.09E+05	2.36E+05	3.44E+05	7.40E+04	7.98E+05	7.06E+05	1.41E+06	1.72E+05	8.96E+06	5.55E+05	3.90E+04	1.57E+06	8.54E+06	1.70E+06	3.59E+07	1.39E+07	1.36
1.34E+07	3.82E+05	0.00E+00	2.95E+06	5.69E+05	1.26E+06	6.28E+07	6.75E+07	5.83E+05	3.82E+07	8.97E+05	1.74E+07	1.31E+06	2.05E+06	7.15E+05	6.90E+04	7.40E+06	9.11E+05	4.41E+07	8.03E+05	1.81E+07	1.01E+09	1.35E+06	1.17E+07	9.59E+06	4.19E+06	7.72E+06	4.25E+06	4.54
2.15E+06	4.11E+05	7.94E+06	0.00E+00	4.40E+06	9.76E+06	9.05E+07	1.43E+08	6.82E+05	3.22E+07	1.24E+06	1.98E+07	1.43E+07	1.97E+07	1.29E+07	1.96E+05	9.80E+06	5.94E+07	5.48E+07	3.65E+06	2.02E+07	4.78E+06	7.95E+05	5.07E+07	1.75E+08	1.00E+07	1.55E+07	1.18E+07	2.21
3.00E+04	2.60E+04	4.11E+05	6.15E+05	0.00E+00	5.60E+06	2.46E+06	5.01E+06	7.10E+03	7.08E+05	1.02E+05	8.28E+05	1.20E+07	3.89E+06	3.44E+05	0.00E+00	1.65E+05	4.09E+05	9.08E+05	8.90E+04	8.10E+04	4.80E+04	1.60E+04	1.27E+06	3.25E+06	1.46E+05	3.98E+05	2.26E+05	1.91
5.45E+05	3.46E+05	4.97E+06	5.17E+06	1.01E+08	0.00E+00	3.01E+07	2.82E+07	2.89E+05	1.68E+07	4.26E+05	6.90E+06	4.61E+06	1.84E+06	2.41E+06	7.00E+04	2.10E+06	5.41E+06	5.97E+06	1.05E+06	3.18E+06	5.49E+05	7.90E+04	1.79E+07	2.87E+08	4.13E+06	4.70E+06	4.53E+06	3.47
2.69E+07	2.36E+06	6.42E+07	3.39E+07	2.65E+06	9.59E+06	0.00E+00	9.62E+08	4.08E+06	8.74E+07	7.62E+06	1.19E+09	8.37E+06	5.62E+06	3.44E+08	9.60E+05	6.03E+07	1.19E+07	1.90E+08	1.52E+09	8.38E+07	1.50E+07	6.44E+06	2.74E+09	8.12E+07	3.63E+08	6.05E+05	2.61E+07	8.95
6.18E+08	2.73E+06	1.03E+09	1.44E+08	3.68E+07	5.33E+07	2.12E+09	0.00E+00	7.65E+07	9.97E+08	1.26E+07	1.31E+09	6.25E+07	8.92E+07	5.75E+08	1.18E+06	2.14E+08	2.86E+07	2.12E+09	3.39E+08	6.47E+08	2.42E+08	9.85E+07	1.03E+09	1.84E+08	2.29E+08	1.09E+08	4.96E+07	1.21
1.16E+06	2.51E+07	8.72E+06	1.54E+06	8.24E+04	9.33E+05	1.89E+07	4.49E+07	0.00E+00	7.27E+06	2.46E+05	1.04E+07	5.15E+05	7.93E+05	1.90E+07	3.80E+04	5.25E+06	3.30E+04	1.95E+07	9.00E+03	5.34E+07	1.02E+06	1.10E+06	1.54E+05	2.17E+07	2.22E+05	7.08E+06	4.09E+06	2.86
6.35E+06	6.55E+05	1.17E+07	1.99E+06	3.92E+05	1.96E+06	5.32E+07	1.37E+08	4.36E+05	0.00E+00	6.78E+05	1.29E+07	4.69E+05	3.36E+05	3.94E+06	7.40E+04	4.13E+06	3.79E+06	7.24E+06	8.09E+05	3.21E+08	8.27E+07	1.04E+06	1.11E+07	1.32E+07	9.21E+06	4.89E+06	4.05E+06	1.24
2.53E+06	6.71E+05	4.35E+07	5.03E+06	8.41E+06	2.60E+06	1.31E+08	5.21E+07	2.10E+05	6.94E+07	0.00E+00	2.57E+07	6.61E+07	7.95E+07	4.10E+06	7.50E+05	7.20E+06	1.56E+06	2.05E+08	6.08E+06	2.67E+07	3.91E+07	5.19E+05	6.99E+07	1.52E+07	4.02E+06	2.43E+08	2.29E+07	5.89
5.61E+07	1.60E+06	6.28E+07	1.92E+07	4.03E+06	8.10E+06	1.88E+09	9.32E+08	6.60E+06	9.85E+07	3.04E+06	0.00E+00	9.35E+06	1.20E+07	1.35E+08	3.62E+06	2.00E+07	5.92E+06	2.21E+08	1.64E+07	1.45E+09	2.92E+07	8.95E+06	2.65E+08	5.74E+07	7.92E+08	6.06E+07	8.44E+07	1.55
0.00E+00	4.40E+04	1.07E+06	1.06E+06	9.71E+06	4.48E+05	2.55E+06	1.07E+07	1.06E+04	1.85E+06	4.31E+05	6.11E+05	0.00E+00	4.49E+07	1.59E+05	1.10E+04	1.35E+05	4.09E+05	1.72E+06	7.70E+04	9.40E+04	1.03E+05	7.00E+03	9.29E+05	2.24E+06	2.18E+05	8.82E+05	4.59E+05	0.00
0.00E+00	2.60E+04	5.33E+05	1.31E+06	3.63E+06	2.45E+05	3.86E+06	8.48E+06	1.32E+04	1.05E+06	8.08E+05	7.22E+05	3.15E+07	0.00E+00	6.09E+05	0.00E+00	1.32E+05	1.03E+06	6.48E+06	9.50E+04	7.50E+04	8.60E+04	0.00E+00	5.00E+06	1.17E+06	1.61E+05	1.95E+06	1.62E+05	0.00
1.25E+06	1.39E+05	6.04E+06	1.20E+07	1.50E+06	3.21E+06	4.44E+08	5.38E+07	5.62E+05	8.59E+06	1.18E+06	6.19E+07	1.53E+06	1.29E+06	0.00E+00	5.04E+05	5.91E+06	5.70E+05	5.29E+06	2.15E+08	2.46E+06	2.44E+06	1.11E+06	3.32E+07	1.54E+07	2.19E+06	5.27E+06	3.41E+05	7.85
3.16E+05	1.18E+05	4.58E+05	4.23E+05	1.46E+04	1.47E+05	3.65E+06	4.30E+06	2.29E+04	2.97E+05	2.43E+05	4.87E+06	9.54E+04	5.50E+04	5.29E+04	0.00E+00	6.63E+05	1.29E+05	2.32E+05	6.00E+04	7.03E+05	3.17E+05	1.05E+05	6.65E+05	1.46E+06	4.29E+05	9.59E+06	2.16E+07	3.33
6.19E+05	1.11E+06	4.51E+07	1.74E+07	2.50E+06	7.45E+06	3.07E+08	5.13E+08	3.75E+06	9.09E+07	3.92E+06	7.11E+07	8.42E+06	8.19E+06	2.86E+07	6.45E+05	0.00E+00	8.26E+06	1.43E+08	3.75E+07	2.01E+07	1.27E+07	2.47E+05	1.93E+08	3.53E+07	2.61E+07	4.19E+07	4.17E+07	2.59
8.52E+06	3.94E+05	1.44E+07	1.26E+08	1.48E+07	1.80E+07	7.93E+07	1.16E+08	6.36E+05	3.05E+07	8.38E+05	1.16E+07	3.02E+07	7.65E+07	3.47E+06	1.82E+05	1.20E+07	0.00E+00	1.39E+08	6.19E+06	1.56E+07	1.32E+07	8.01E+05	4.90E+07	3.96E+08	8.21E+06	1.65E+07	8.51E+06	2.16
2.12E+06	4.87E+05	3.26E+07	4.82E+06	6.08E+05	6.93E+05	3.58E+08	3.31E+08	1.01E+06	1.12E+07	6.31E+06	3.30E+07	5.12E+06	1.16E+08	6.56E+06	2.90E+04	3.91E+06	4.92E+06	0.00E+00	3.34E+05	3.68E+06	4.78E+06	3.79E+05	4.40E+07	1.11E+07	4.17E+06	3.11E+07	3.86E+06	1.81
2.19E+05	6.80E+04	1.73E+06	2.06E+06	3.77E+05	8.94E+05	1.20E+09	1.12E+08	5.97E+04	3.26E+06	1.25E+06	8.73E+06	6.65E+05	8.11E+05	1.07E+08	8.80E+04	5.76E+06	1.03E+06	1.69E+06	0.00E+00	3.29E+07	3.31E+05	1.36E+05	1.40E+08	6.61E+06	6.40E+07	1.59E+07	4.92E+06	2.66
3.65E+06	6.35E+05	3.93E+06	5.59E+05	1.42E+04	3.48E+05	4.44E+07	1.45E+07	1.84E+06	5.88E+07	7.39E+05	8.51E+07	1.84E+04	1.70E+04	6.35E+05	1.50E+04	6.56E+05	1.53E+05	8.10E+05	2.22E+06	0.00E+00	8.54E+05	2.03E+05	1.24E+08	1.52E+06	6.24E+05	3.23E+06	2.85E+05	2.11
1.67E+06	1.72E+05	5.83E+08	5.69E+05	9.14E+04	1.68E+05	2.94E+07	1.21E+07	7.20E+04	1.31E+08	6.04E+05	5.89E+06	1.72E+05	1.74E+05	1.59E+06	2.90E+04	6.29E+05	6.91E+05	7.72E+06	1.59E+05	7.42E+06	0.00E+00	4.99E+05	4.69E+06	1.13E+06	2.34E+06	4.11E+06	1.01E+06	1.75
1.79E+08	7.00E+04	4.70E+06	4.08E+05	1.10E+05	1.57E+05	5.07E+07	6.21E+07	5.31E+04	5.58E+06	6.98E+04	2.90E+07	1.48E+05	1.52E+05	2.20E+06	2.50E+04	8.50E+05	1.41E+05	1.09E+06	1.70E+05	8.93E+05	3.36E+06	0.00E+00	7.02E+06	5.27E+06	1.56E+07	1.75E+06	8.27E+06	1.62
4.12E+06	7.05E+05	6.22E+07	6.14E+07	4.76E+06	3.38E+07	2.83E+09	9.51E+08	1.30E+06	7.35E+07	1.32E+07	2.95E+08	1.20E+07	4.34E+07	3.82E+07	5.78E+05	7.20E+07	5.58E+07	1.26E+08	3.12E+08	1.14E+09	2.69E+07	2.86E+06	0.00E+00	1.77E+08	2.39E+08	3.22E+08	2.16E+07	2.16
1.81E+07	1.51E+06	1.12E+07	2.18E+08	3.07E+07	4.22E+08	1.13E+08	1.98E+08	4.64E+06	1.33E+08	1.81E+06	2.97E+07	2.01E+07	2.18E+07	7.75E+06	3.12E+05	1.38E+07	1.28E+08	1.38E+08	7.93E+06	3.45E+07	4.98E+06	2.73E+06	7.60E+07	0.00E+00	1.27E+07	2.00E+07	1.48E+07	1.43
5.94E+07	8.78E+05	1.01E+08	3.05E+07	1.80E+06	1.47E+07	2.00E+09	1.48E+09	3.04E+06	1.48E+08	2.82E+06	8.51E+08	5.58E+06	2.89E+06	6.29E+07	5.95E+05	3.44E+07	7.26E+06	4.72E+07	4.99E+08	2.23E+07	4.58E+07	9.56E+06	5.59E+08	8.19E+07	0.00E+00	4.14E+07	2.45E+07	4.75
2.39E+07	1.51E+08	2.84E+08	1.11E+08	2.77E+07	3.77E+07	1.78E+09	1.26E+09	1.24E+07	4.18E+08	3.20E+08	4.28E+08	2.28E+08	2.97E+08	0.00E+00	5.66E+07	8.50E+07	5.13E+07	1.15E+09	2.13E+08	1.50E+08	2.23E+08	0.00E+00	7.38E+08	2.57E+08	6.56E+07	0.00E+00	4.46E+08	4.69
1.95E+08	5.09E+07	1.05E+08	5.94E+07	9.47E+06	2.68E+07	4.24E+08	5.56E+08	4.38E+07	2.00E+08	6.01E+07	7.34E+08	1.99E+07	7.63E+06	6.51E+06	1.03E+08	1.33E+08	1.47E+07	1.10E+08	4.72E+07	2.66E+07	2.11E+07	1.91E+07	1.47E+08	9.19E+07	6.06E+07	1.08E+09	0.00E+00	6.09
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E+07	0.00E+00	0.00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.88E+06	3.70E+06	4.41
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.60E+06	1.62E+05	0.00E+00	0.00E+00	0.00E+00	4.96E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.89E+04	4.71E+05	0.00
3.35E+05	0.00E+00	2.42E+06	8.86E+06	0.00E+00	3.48E+06	1.93E+08	5.84E+07	1.12E+05	2.94E+06	7.52E+05	1.85E+07	3.07E+05	2.14E+05	0.00E+00	0.00E+00	4.75E+06	2.56E+06	1.31E+06	8.52E+05	6.23E+05	6.99E+05	0.00E+00	2.92E+07	2.04E+07	5.16E+06	1.06E+07	5.26E+07	9.26
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E+07	8.84E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.61E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.16E+06	2.68E+06	4.03
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.54E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.29E+07	3.75E+07	0.00
0.00E+00	0.00E+00	0.00E+00	3.26E+06	0.00E+00	1.79E+06	1.22E+08	2.70E+07	0.00E+00	0.00E+00	9.99E+05	8.33E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E+06	1.37E+06	1.98E+06	1.14E+06	0.00E+00	0.00E+00	0.00E+00	1.66E+07	1.25E+07	4.54E+06	1.75E+07	5.29E+07	2.61
0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.51E+06	0.00E+00	0.00E+00	3.87E+08	7.68E+05	0.00E+00	0.00E+00	0.00E+00	8.10E+06	7.23E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.53E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E+07	7.81E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.32E+06	2.13E+07	2.15
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.73E+04	0.00
0.00E+00	0.00E+00	7.15E+05	1.84E+06	0.00E+00	0.00E+00	4.02E+07	5.29E+06	0.00E+00	0.00E+00	9.30E+05	1.67E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E+06	9.11E+05	0.00E+00	8.86E+05	0.00E+00	0.00E+00	0.00E+00	1.96E+05	0.00E+00	3.37E+05	6.72E+06	1.39E+07	2.08
0.00E+00	0.00E+00	1.08E+05	0.00E+00	0.00E+00	8.00E+03	9.21E+05	6.47E+05	0.00E+00	8.50E+04	7.00E+03	5.89E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+04	0.00E+00	0.00E+00	0.00E+00	1.00E+04	0.00E+00	0.00E+00	6.89E+04	7.21E+04	8.11E+05	0.00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87
4.50E+06	0.00E+00	8.84E+06	7.10E+06	0.00E+00	0.00E+00	4.81E+07	5.23E+07	0.00E+00	1.11E+07	7.02E+06	6.10E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E+07	0.00E+00	3.34E+06	0.00E+00	3.20E+06	0.00E+00	0.00E+00	0.00E+00	1.07E+07	1.17E+07	2.15E+08	2.48E+08	2.78
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27
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7.65E+05	1.52E+06	7.35E+07	1.13E+06	1.62E+08	5.52E+06	3.18E+07	5.56E+08	5.73E+05	1.26E+08	1.32E+05	5.70E+06	2.65E+08	1.47E+08	9.26E+05	9.90E+04	7.48E+05	2.04E+06	4.67E+07	5.13E+05	5.13E+06	6.11E+06	7.83E+05	1.15E+07	3.67E+06	2.16E+06	1.42E+06	2.08E+06	7.40
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.89E+07	1.91
0.00E+00	0.00E+00	0.00E+00	1.90E+07	0.00E+00	5.82E+06	2.88E+08	9.85E+07	0.00E+00	0.00E+00	0.00E+00	2.44E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.90E+06	1.14E+07	0.00E+00	1.38E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.12E+07	2.45E+07	7.20E+07	4.47E+07	1.15
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.21E+05	0.00E+00	0.00E+00	0.00E+00	3.47E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.09E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+06	8.11E+05	8.99


hello!

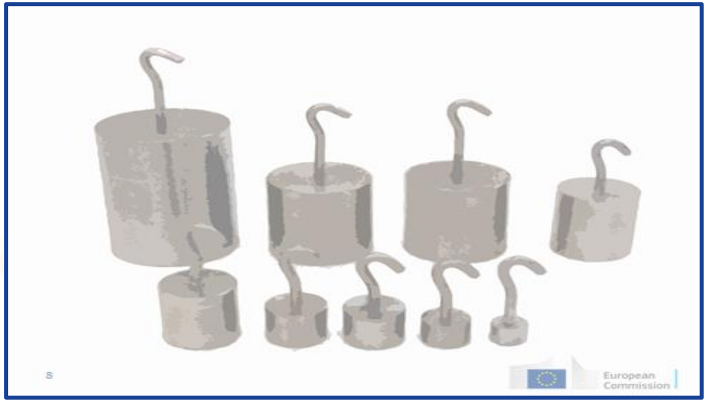
What do we want to achieve by weighting?

- Equal weighting: indicators should be equally important/influential
- Principle component analysis: let the data speak! (clue: data doesn’t speak on its own)
- Data envelopment analysis: give the benefit of the doubt – let units maximise their scores

For methods with only one set of weights, there are at least two differing objectives:

- Balance indicators (or make indicators agree with pre-specified importance)
- Maximise information transfer/compression (PCA)

Weights are typically assigned to reflect importance, but…



≠

weights do not equal measures

Weights are typically assigned to reflect importance, but...

≠

weights do not equal measures

A composite indicator to rank teachers…

A composite indicator to rank teachers…

A composite indicator to rank teachers…

x_1=number of publications
x_2=teaching feedback
x_3=hours of teaching and office work

$$\boxed{y = \frac{1}{3}(x_1 + x_2 + x_3)}$$

All have been standardised to have unit variance, *but* x_2 and x_3 have a correlation of 0.7. After calculating the values of the composite indicator, R^2 is used to check influence:

$$\boxed{R_i^2 := \mathrm{corr}^2(y, x_i)} \longrightarrow$$

R_1^2=0.227
R_2^2=0.657
R_3^2=0.657

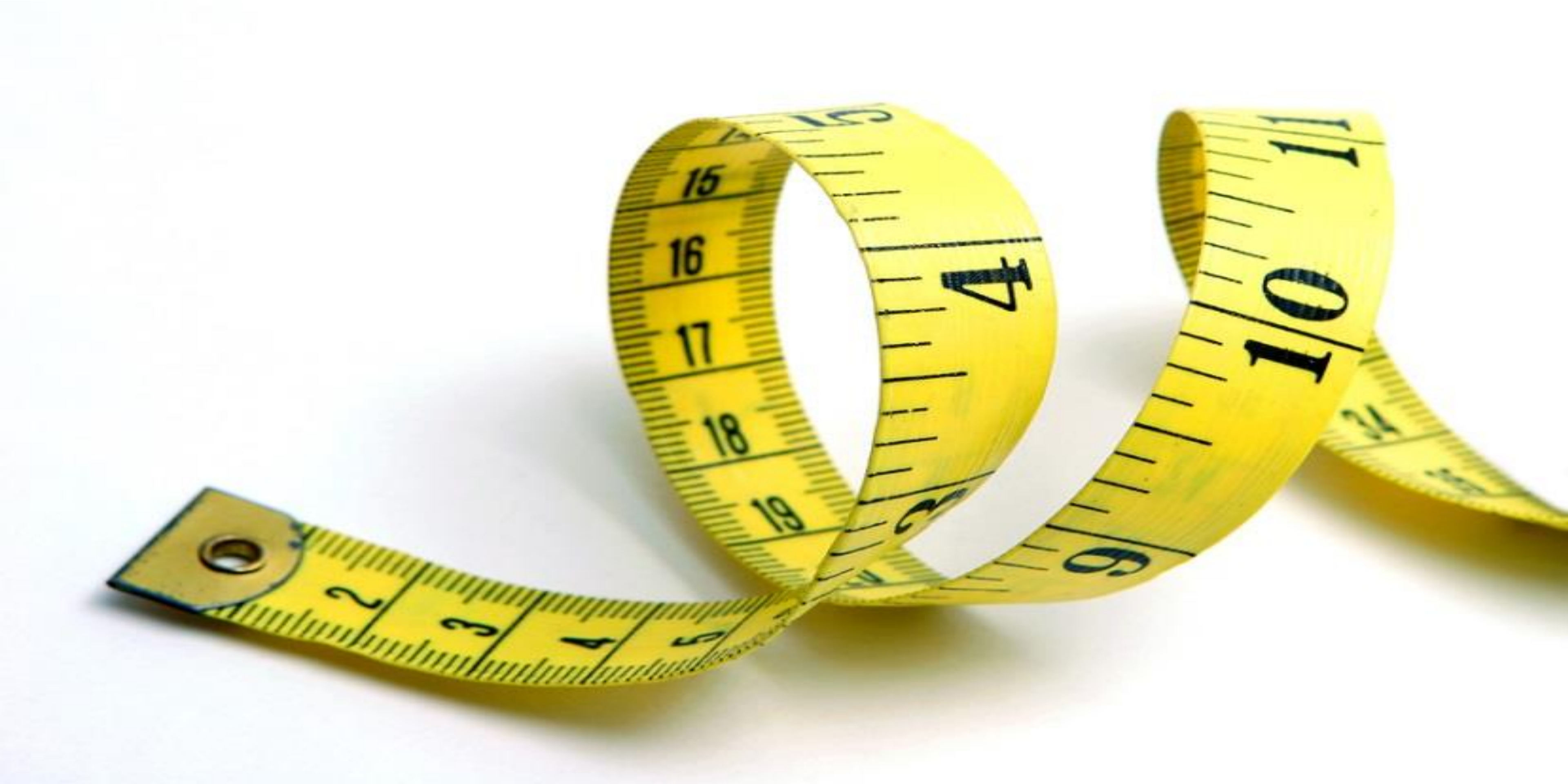
Increase the weight of x_1? Teachers will complain that the index unfairly favours publications!

Correlations are very common in composite indicators.

≠

≠

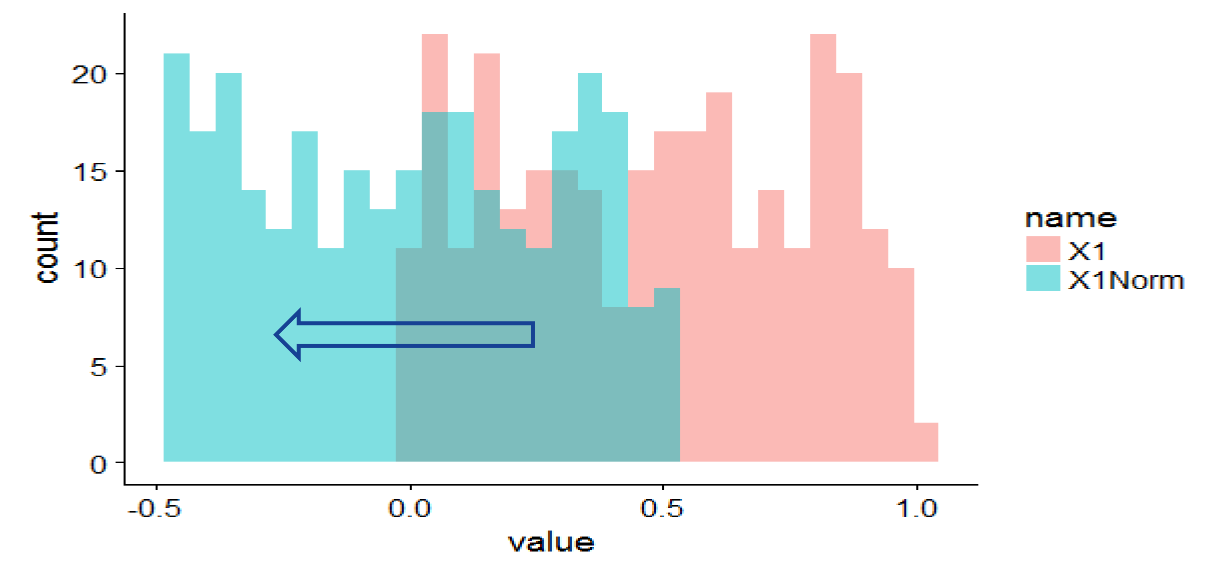
How can we measure importance?



Measures of dependence

Fundamentally, we are interested in how the random variable y depends on the random variable x.

1. Covariance: $\mathrm{cov}(y, x_i) := \mathrm{E}[(y-\mu_y)(x_i-\mu_i)]$ $\mu_i = E(x_i)$



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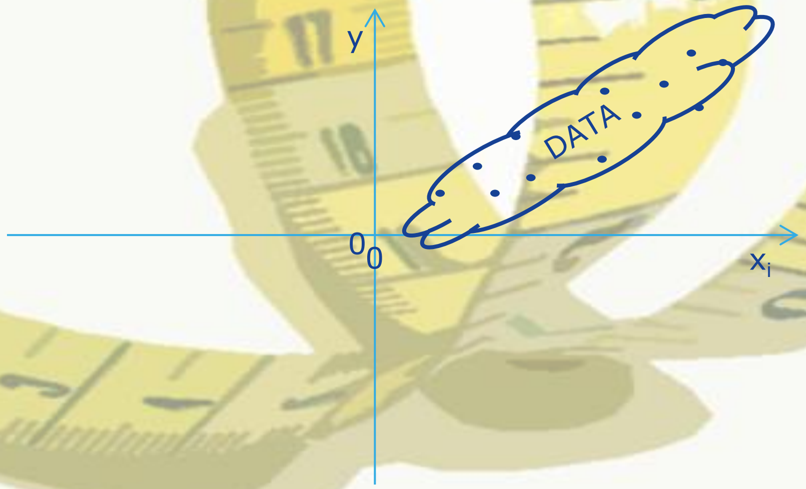

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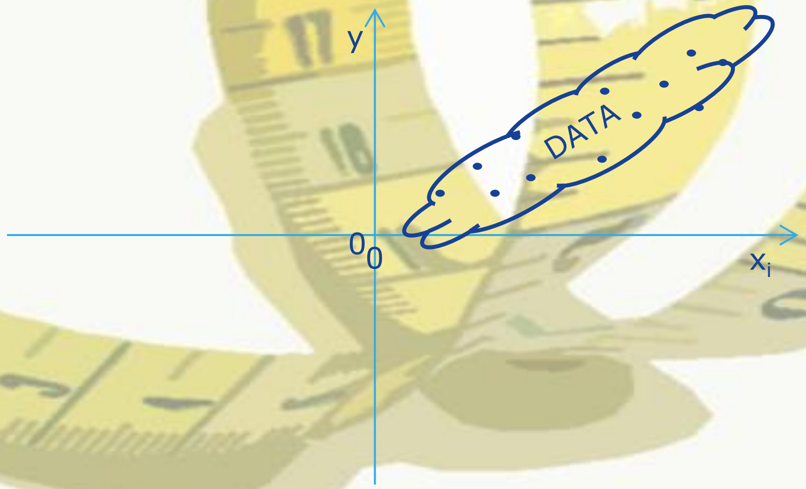

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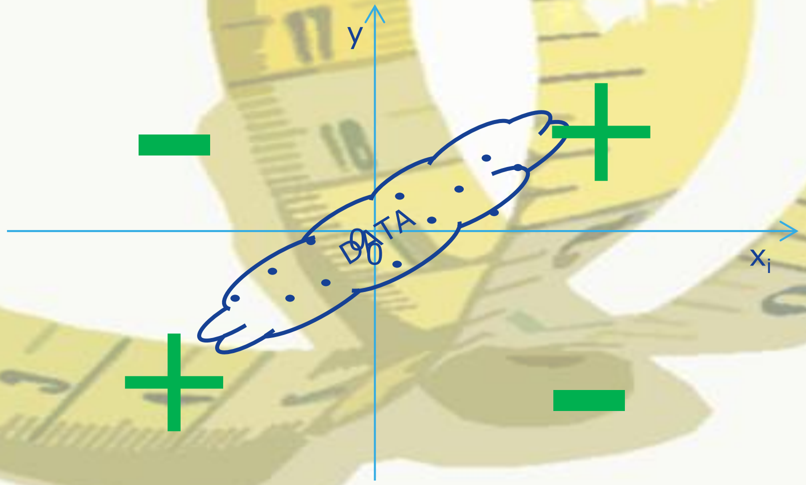

2+

European Commission

interlude

Measures of dependence

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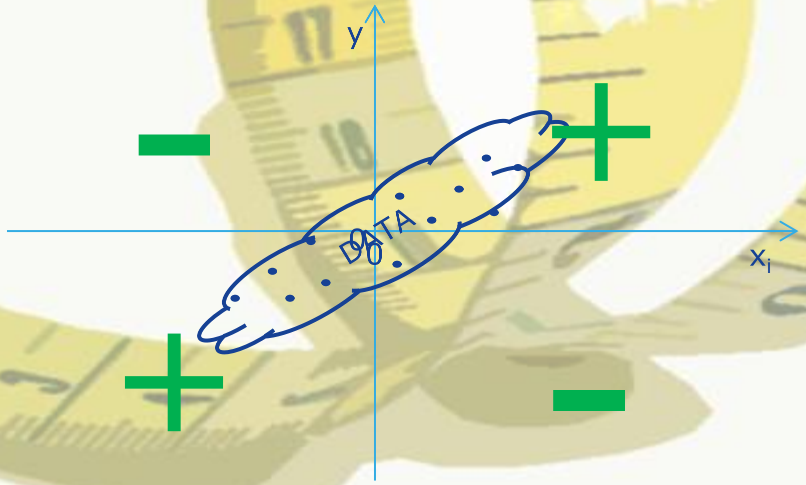

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European Commission

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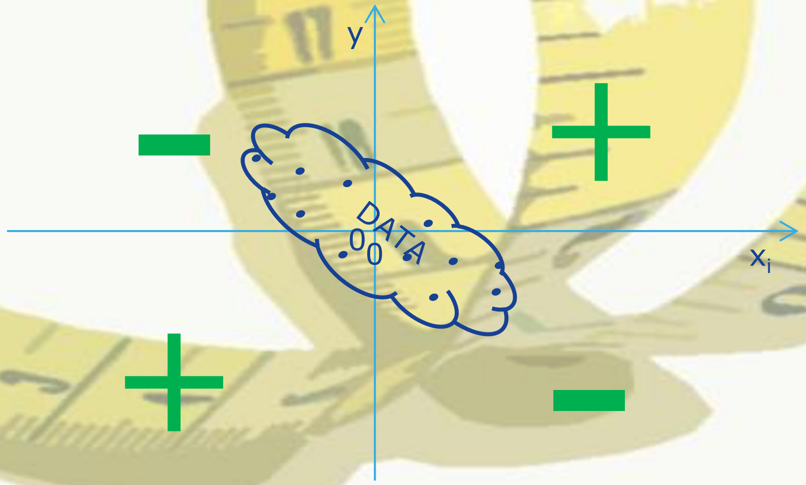

2-

interlude

Measures of dependence

Fundamentally, we are interested in how the random variable y depends on the random variable x.

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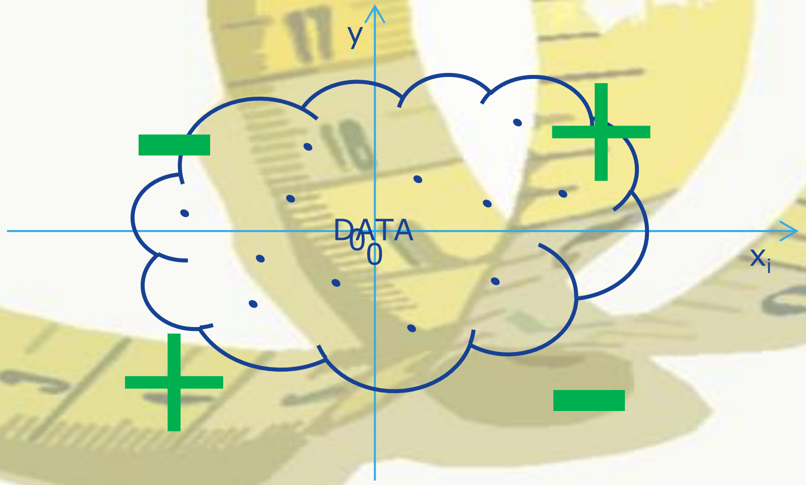


(2+)+(2-)=0

interlude

Measures of dependence

Fundamentally, we are interested in how the random variable y depends on the random variable x.

1. Covariance: $\operatorname{cov}(y, x_i) := \mathrm{E}[(y - \mu_y)(x_i - \mu_i)]$

2. Pearson correlation coefficient: $R_i := \operatorname{corr}(y, x_i) := \dfrac{\operatorname{cov}(y, x_i)}{\sigma_y \sigma_i}$

Correlation coefficients are equal to the **standardised regression coefficients**

->Standardises covariance so that $R \in [-1,1]$: 1 or -1 is perfect correlation, 0 is no correlation. Allows comparability.

3. Coefficient of determination: R_i^2

R_i^2 is a measure of linear dependence

$R_i^2 \in [0,1]$: higher values indicate stronger dependence.

More generally, R_i^2 can be defined as $\dfrac{\text{variance explained by regression}}{\text{total variance}}$

Measuring the importance of indicators

Correlation coefficient

$$R_i := \mathrm{corr}(y, x_i) := \frac{\mathrm{cov}(y, x_i)}{\sigma_y \sigma_i}.$$

$$R_i^2 := \mathrm{corr}^2(y, x_i),$$

Ok but only measures linear dependence.
Not always the case.

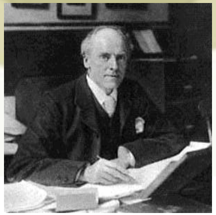
Correlation ratio*

$$S_i \equiv \eta_i^2 := \frac{\mathrm{V}_{x_i}\left(\mathrm{E}_{\mathbf{x}_{\sim i}}\left(y \mid x_i\right)\right)}{\mathrm{V}\left(y\right)},$$

Also known as "main effect index", "first-order sensitivity index", "nonlinear R^2"…

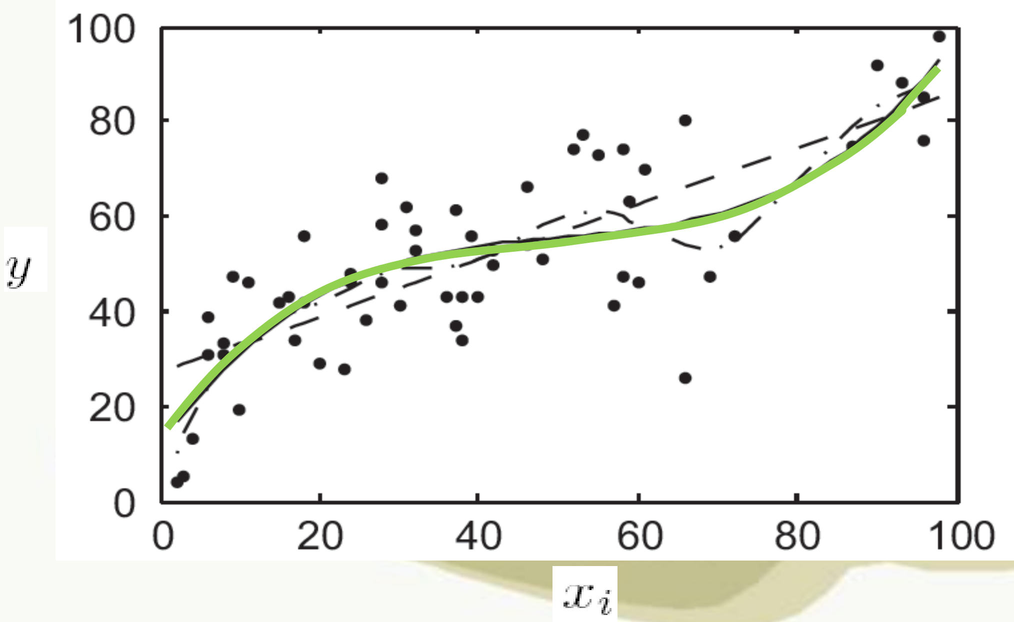
- Allows for nonlinear dependence
- Easily estimated by regression

*First conceived by Karl Pearson in 1905



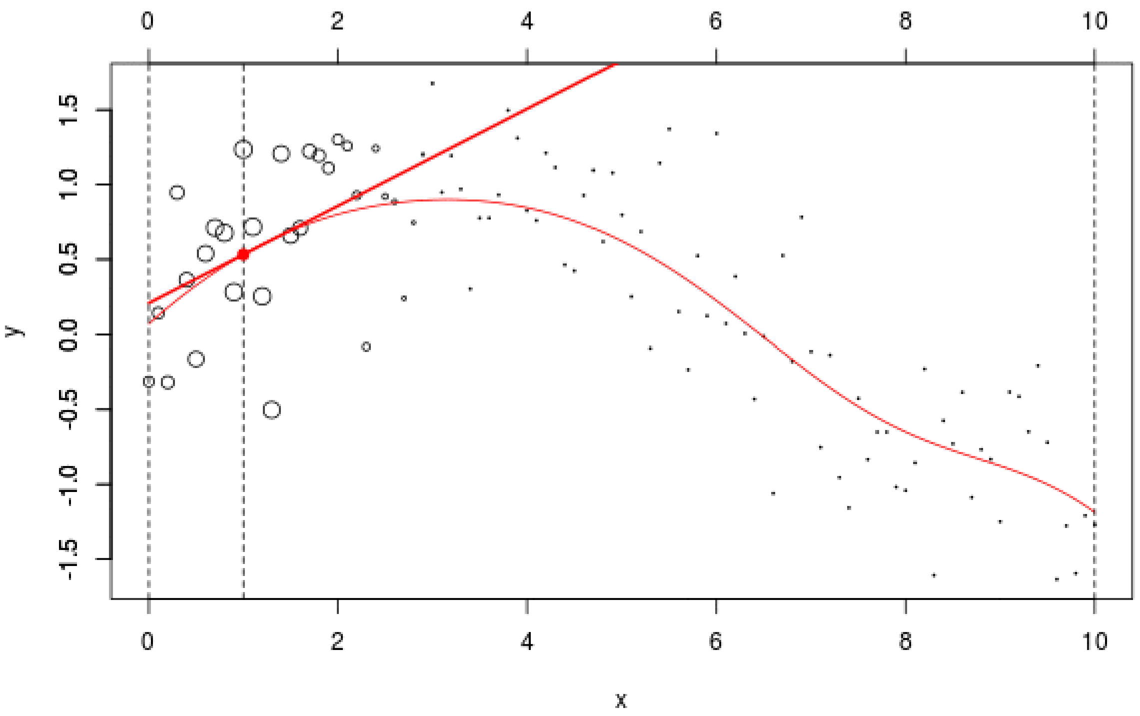
$$S_i \equiv \eta_i^2 := \frac{V_{x_i}\left(\boxed{E_{\mathbf{x}_{\sim i}}(y \mid x_i)}\right)}{V(y)},$$

Nonlinearity in the main effect



Nonlinear regression approaches required

Local linear regression



Weighted polynomial regression.

$$\hat{m}(x_i) = \frac{\sum_{j=1}^{n} w(x_{ji} - x_i; h) y_j}{\sum_{j=1}^{n} w(x_{ji} - x_i; h)}$$

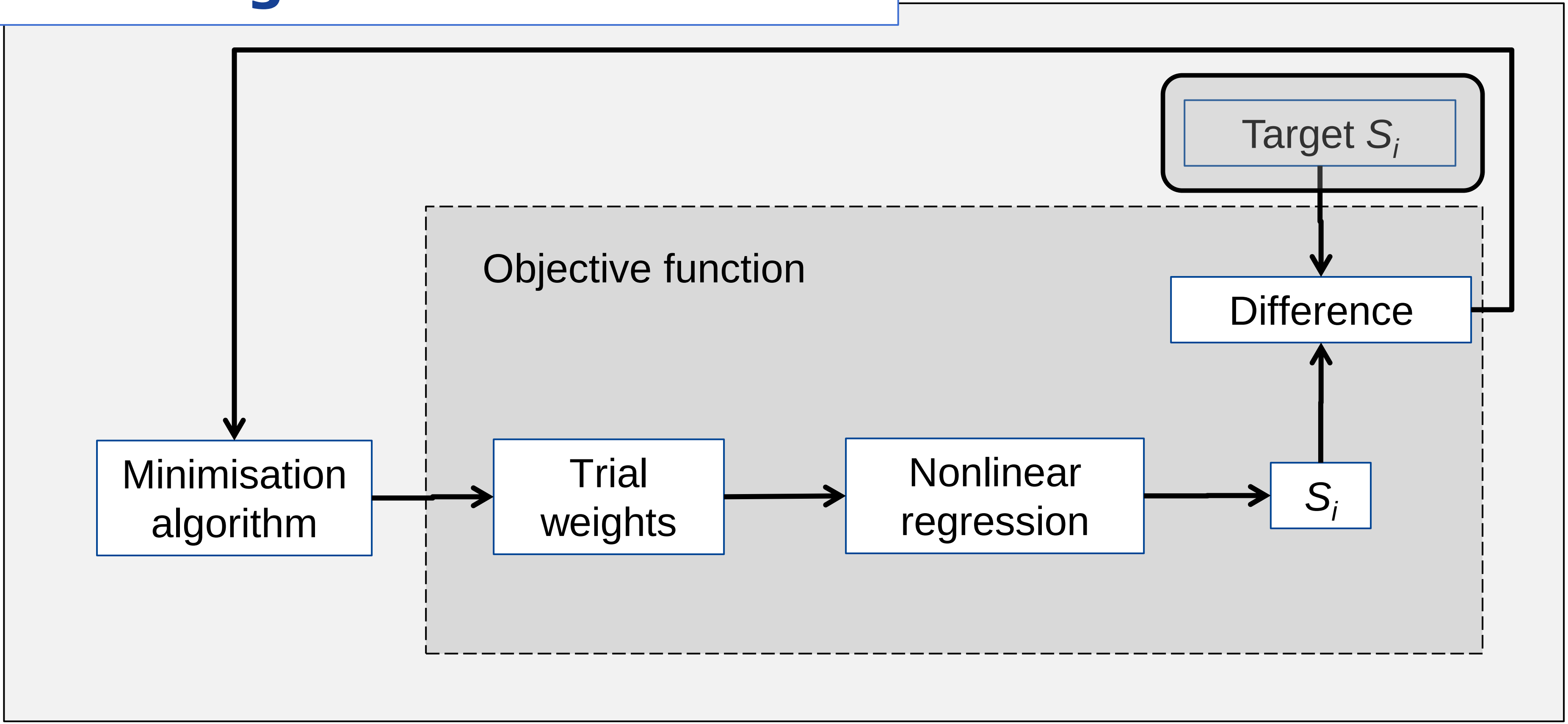
Source: https://www.r-bloggers.com/some-heuristics-about-local-regression-and-kernel-smoothing/

Can we tune the weights?

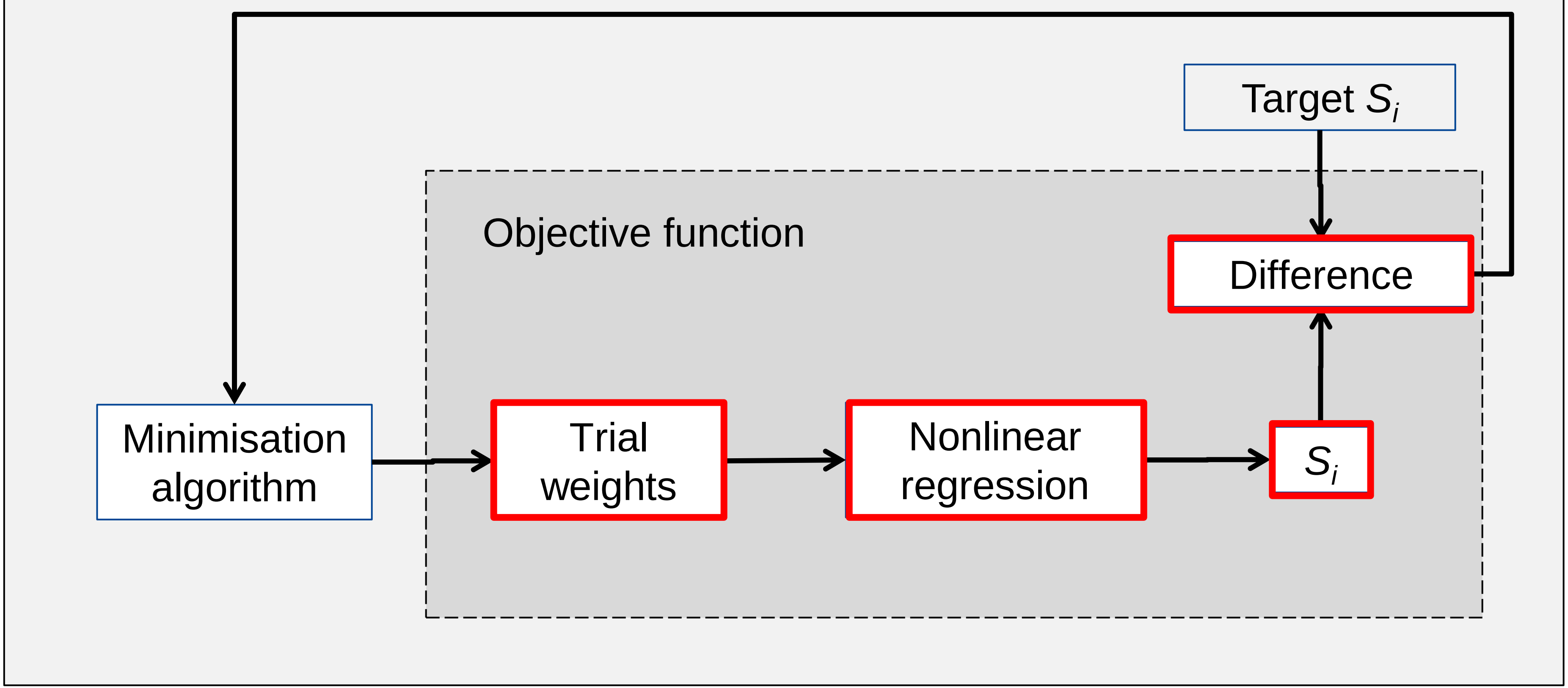
yes

(Optimisation approach)

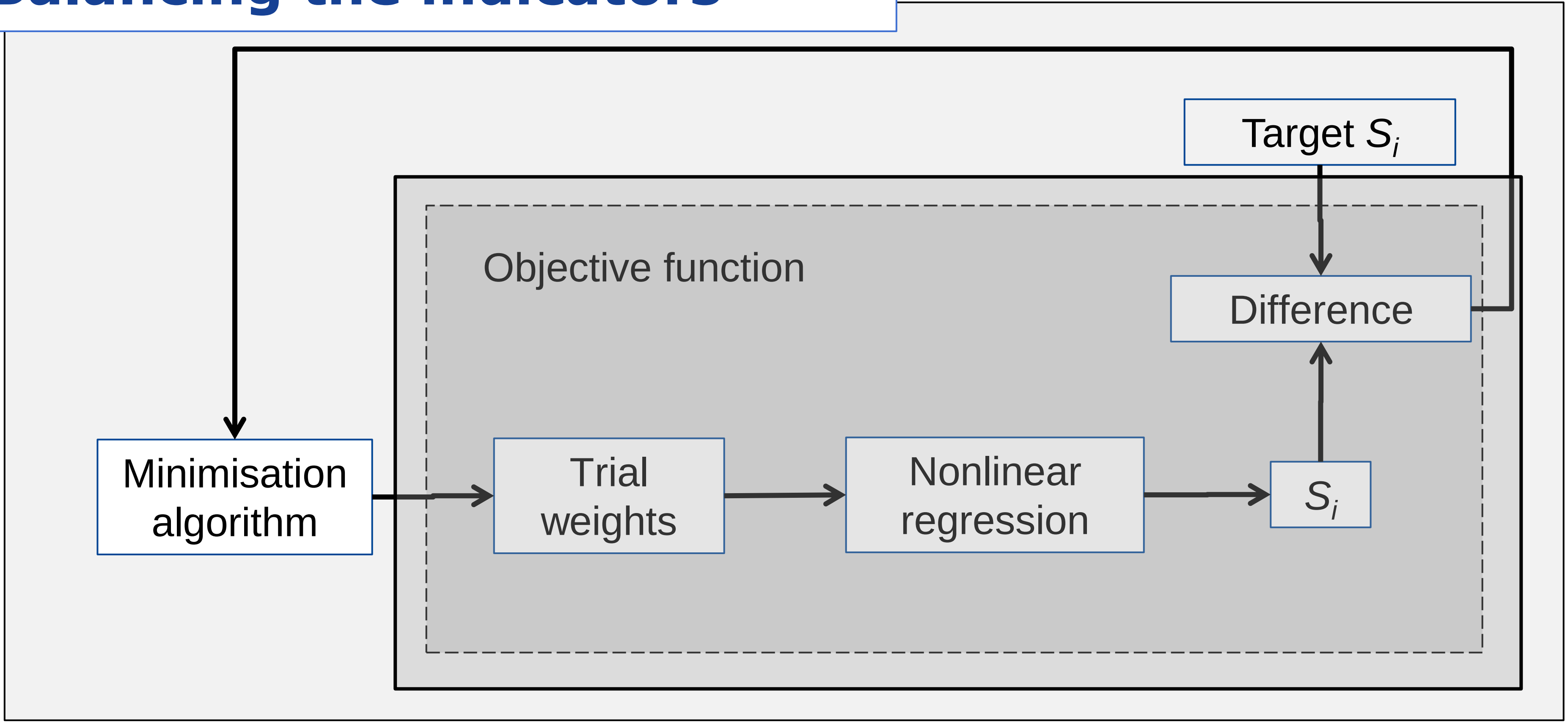
Balancing the indicators



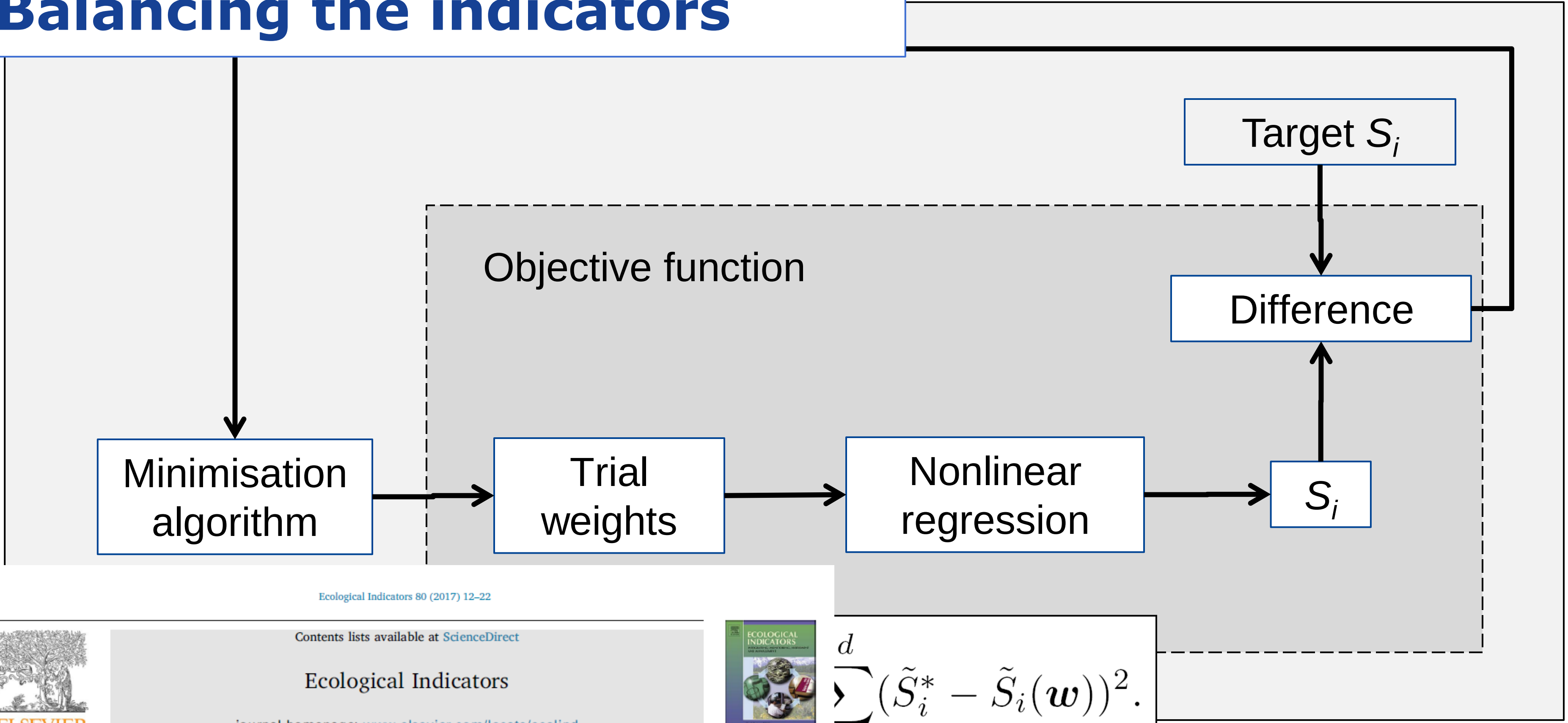
Balancing the indicators



Balancing the indicators



Balancing the indicators



$$\sum_{=1}^{d} (\tilde{S}_i^* - \tilde{S}_i(\boldsymbol{w}))^2 .$$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Weights and importance in composite indicators: Closing the gap

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European Commission, Joint Research Centre, Via Enrico Fermi, 2749, 21027 Ispra VA, Italy

What about information?

Fundamentally, we want y to contain as much information from the x_i as possible. One way to measure this is through *mutual information* (a measure from information theory).

MI requires knowledge of joint and marginal distributions. But has a link with (linear) correlation:

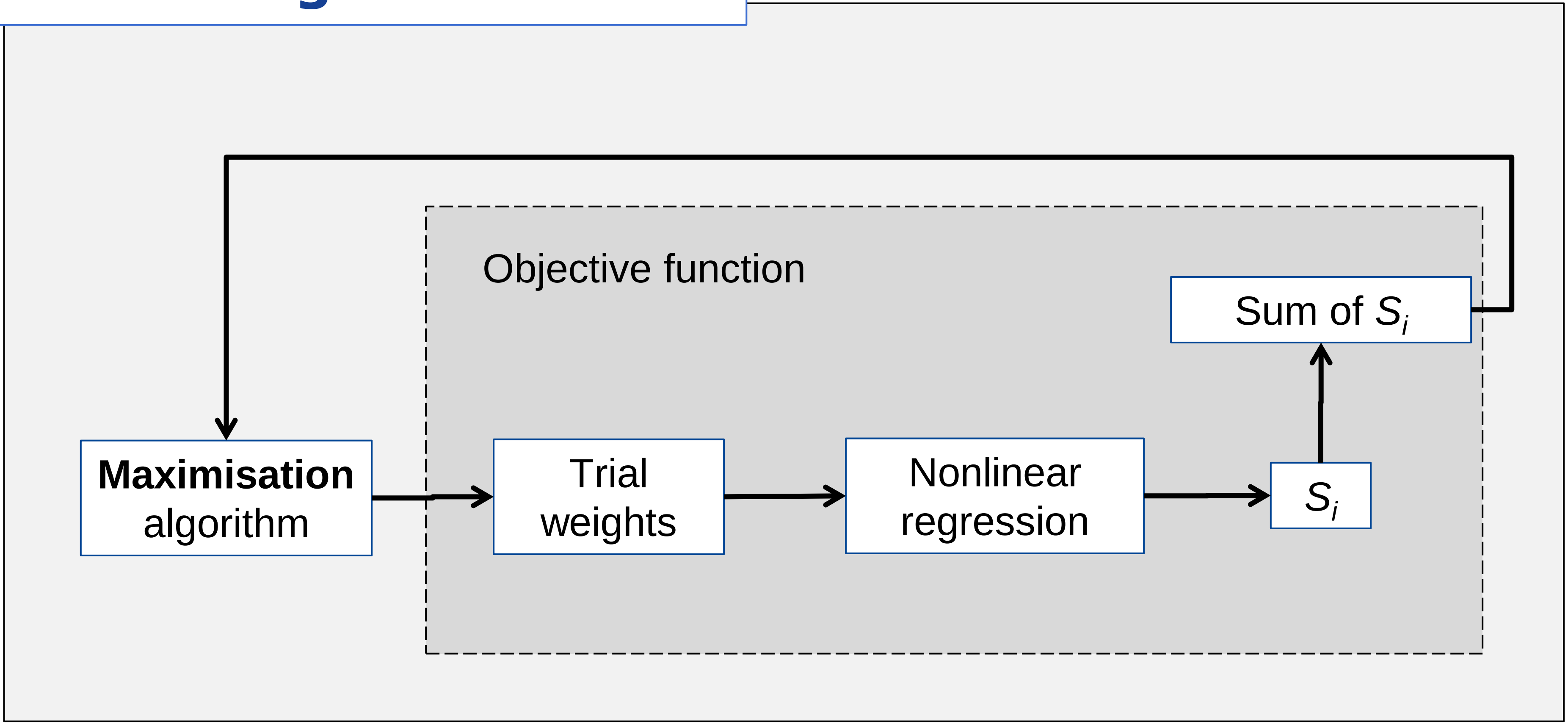
$$I(y, x_i) = -\frac{1}{2}\ln\left(1 - R_i^2\right)$$

With S_i we can generalise this to nonlinear dependence.

Implication: we can use S_i to measure the **mutual information** between each x_i and y.

We can also use this to try to tune the weights to maximise the information.

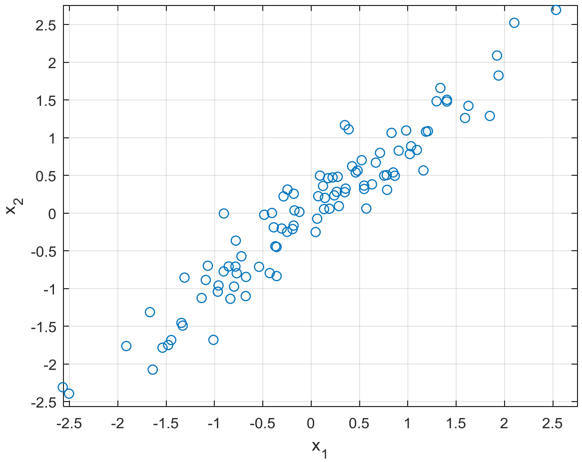
Maximising information



Actually this is almost the same as PCA

PCA weighting rests on the idea that there is one or more “latent phenomena” which is driving the indicators (i.e. much in the spirit of composite indicators). [The ideal case is that we find just one]

PCA finds the linear combination of the indicators which explains the most variance of the indicators.



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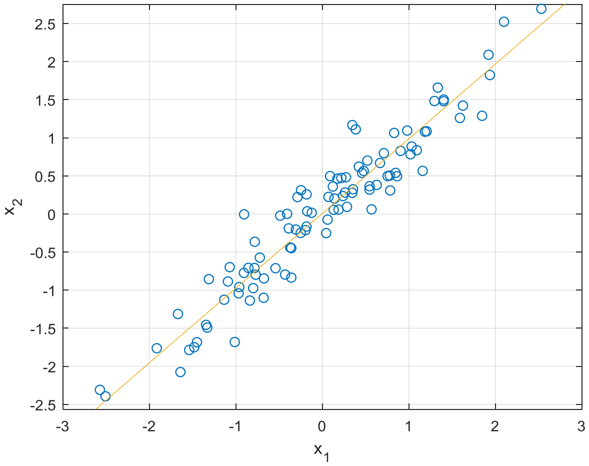

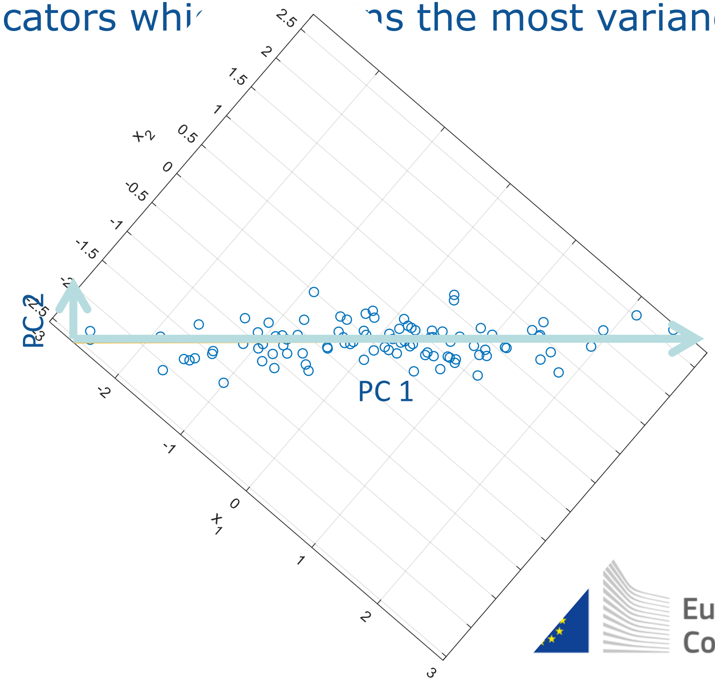

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Information and number of indicators

What happens when we add more indicators?

$$\lim_{n\to\infty} I(x_i, y) = -\frac{1}{2}\ln(1-\rho)$$

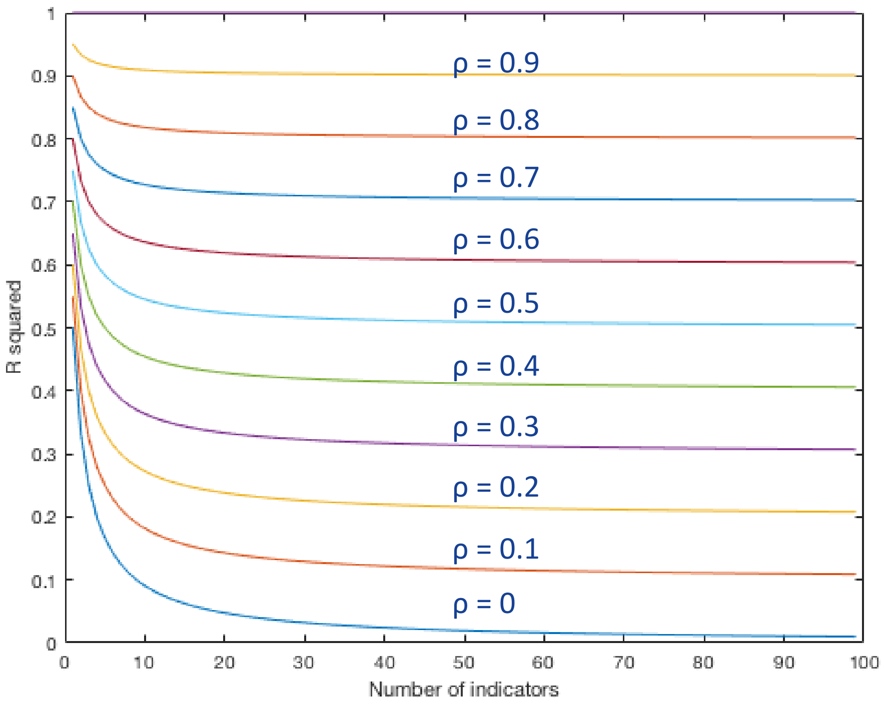
$$\lim_{n\to\infty} R^2 = \rho$$

The average MI tends to a limit which is defined by the *average correlation between the indicators*.

[in linear/Gaussian case… should roughly hold in practice]

Implications:

- Large frameworks can still work from an information perspective
- Size of framework should be (in part) determined from an information PoV



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    - Staff-student ratio
    - Doctorates
    - Institutional income
2. **Research**
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    - Research income
    - Research productivity
3. **Citations**
4. **International outlook**
    - Percentage international students and staff
    - Institutional collaboration
5. **Industry Income**

https://www.mentimeter.com/app

European Commission

QS WORLD UNIVERSITY RANKINGS®

Academic Reputation	Employer Reputation	Faculty/ Student Ratio	Citations per Faculty	International Faculty	International Students
40%	10%	20%	20%	5%	5%
Opinion-based survey	Opinion-based survey	Teacher/ student ratio	Citations divided by faculty	Proportion of international faculty members	Proportion of international students

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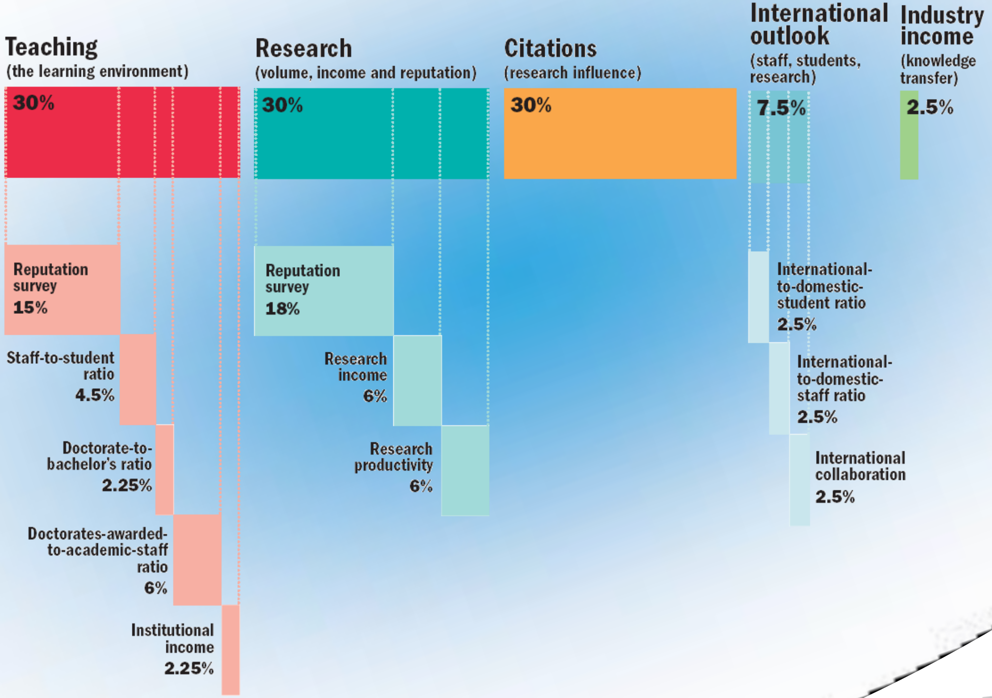
WORLD UNIVERSITY RANKINGS



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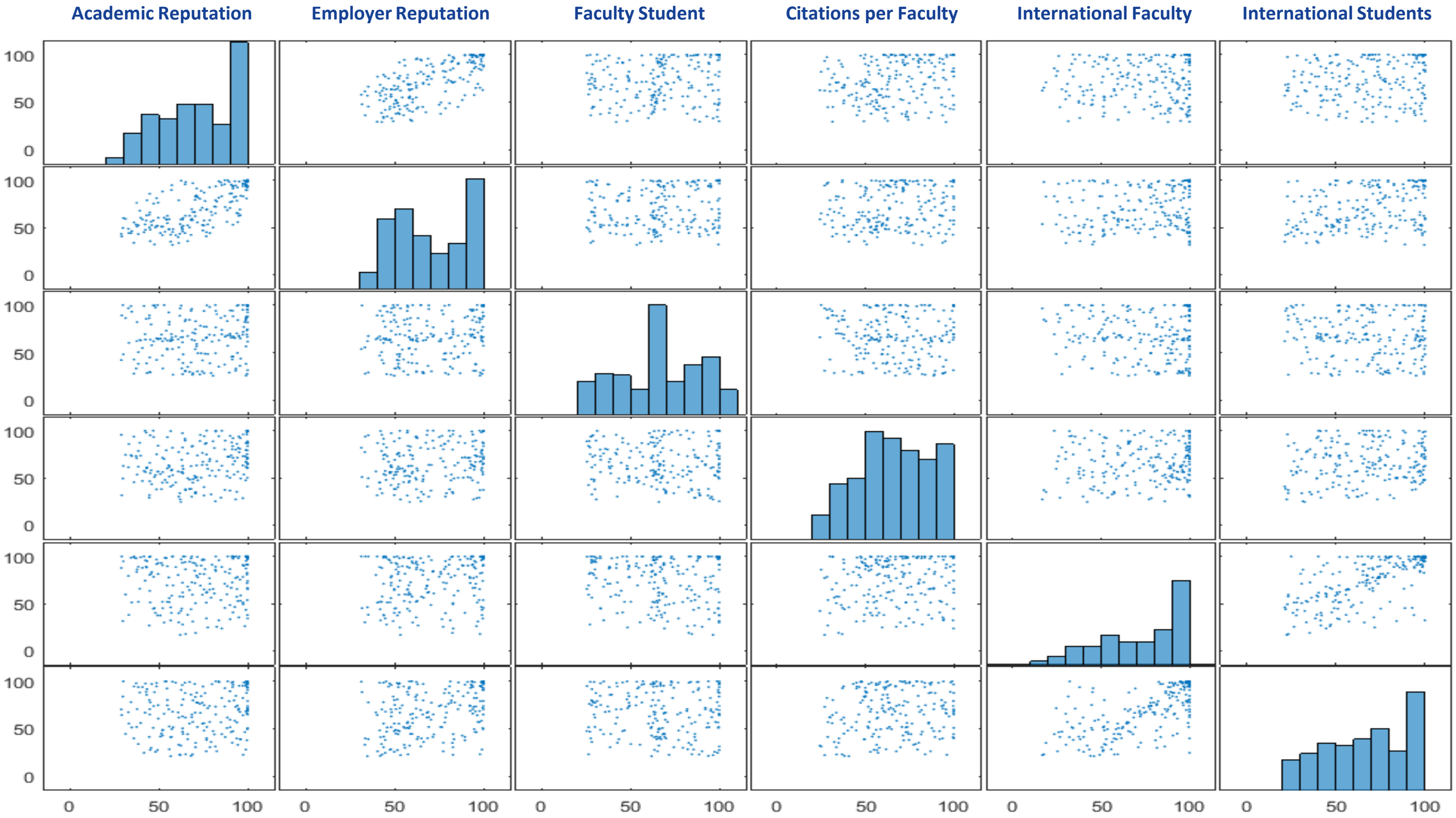
QS input data



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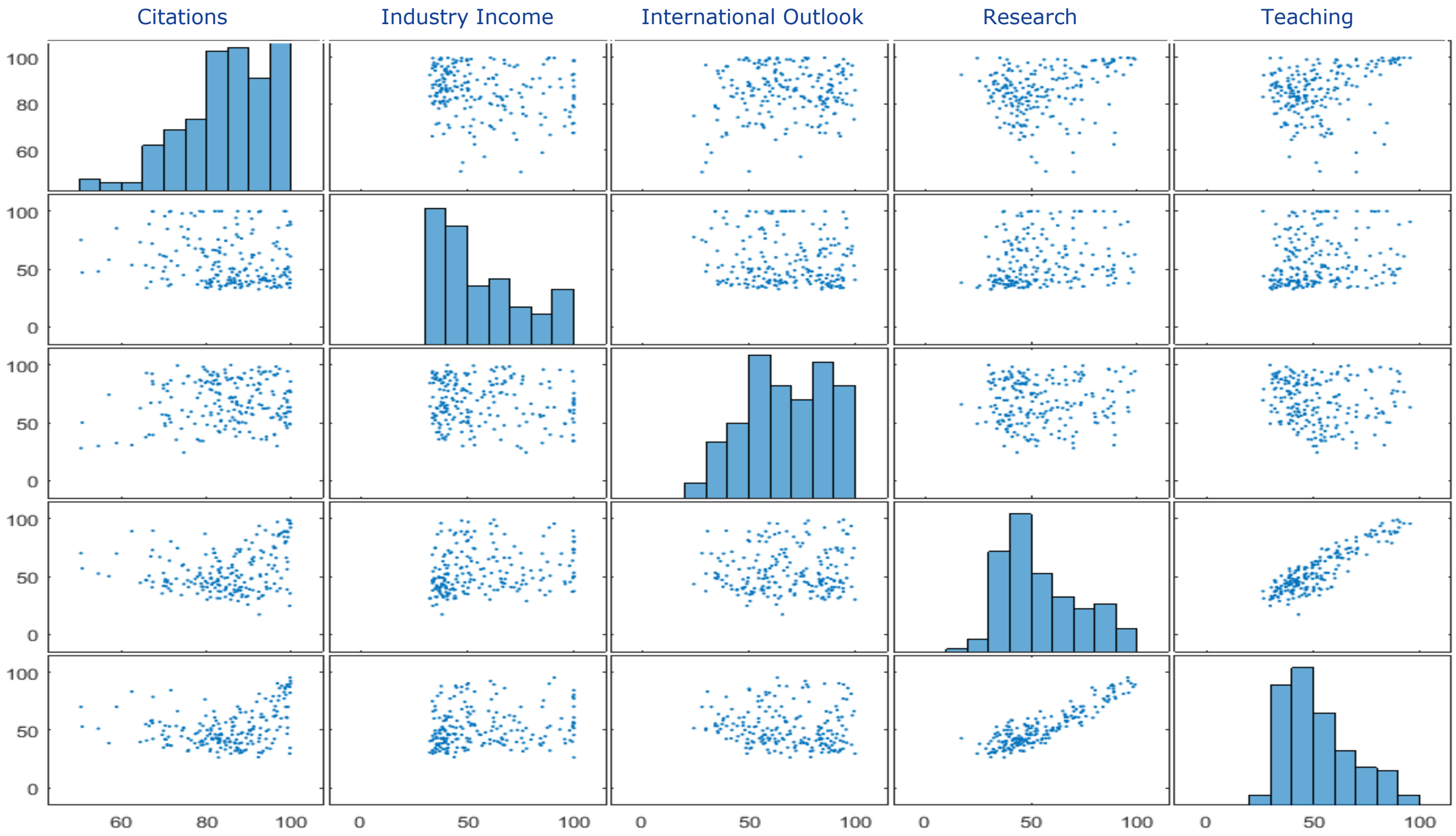
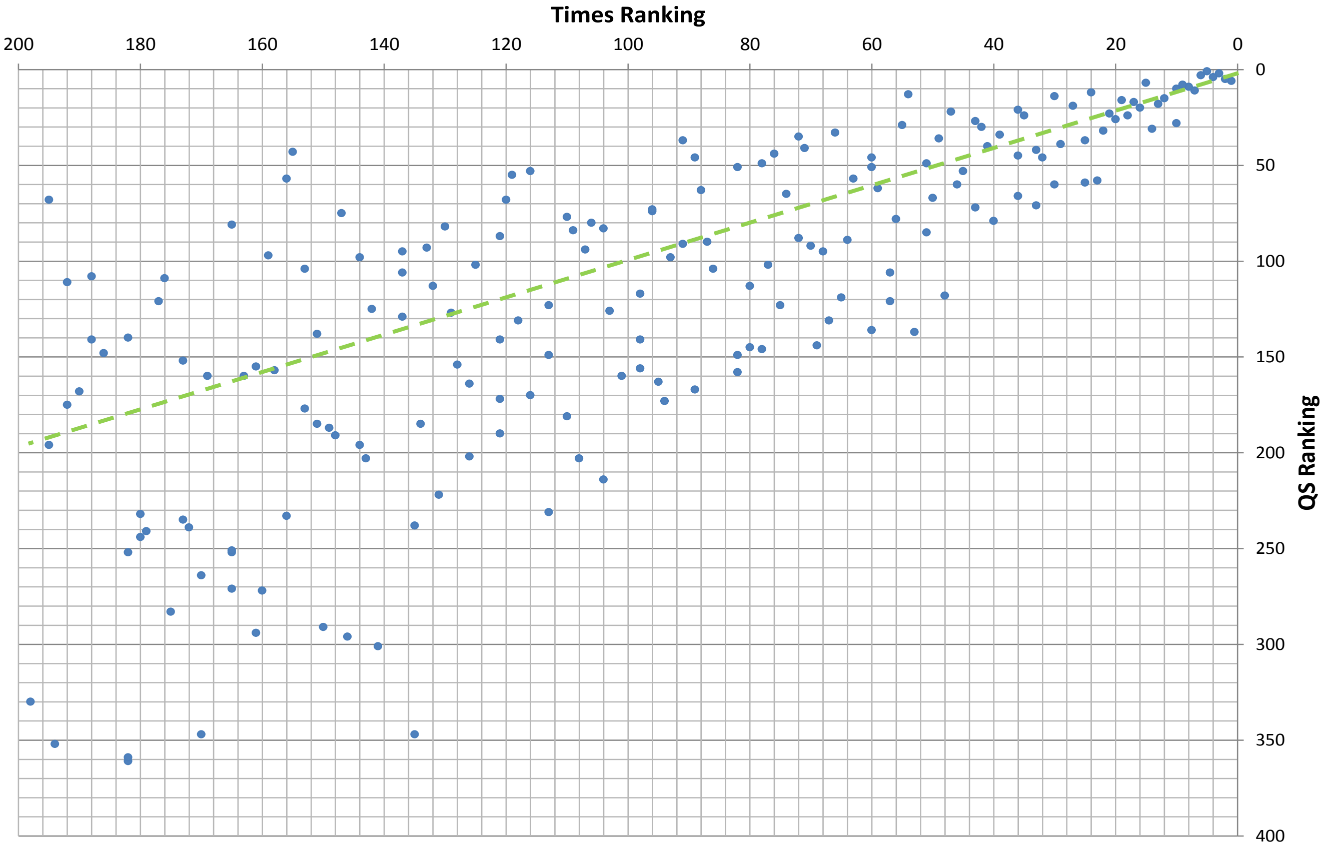
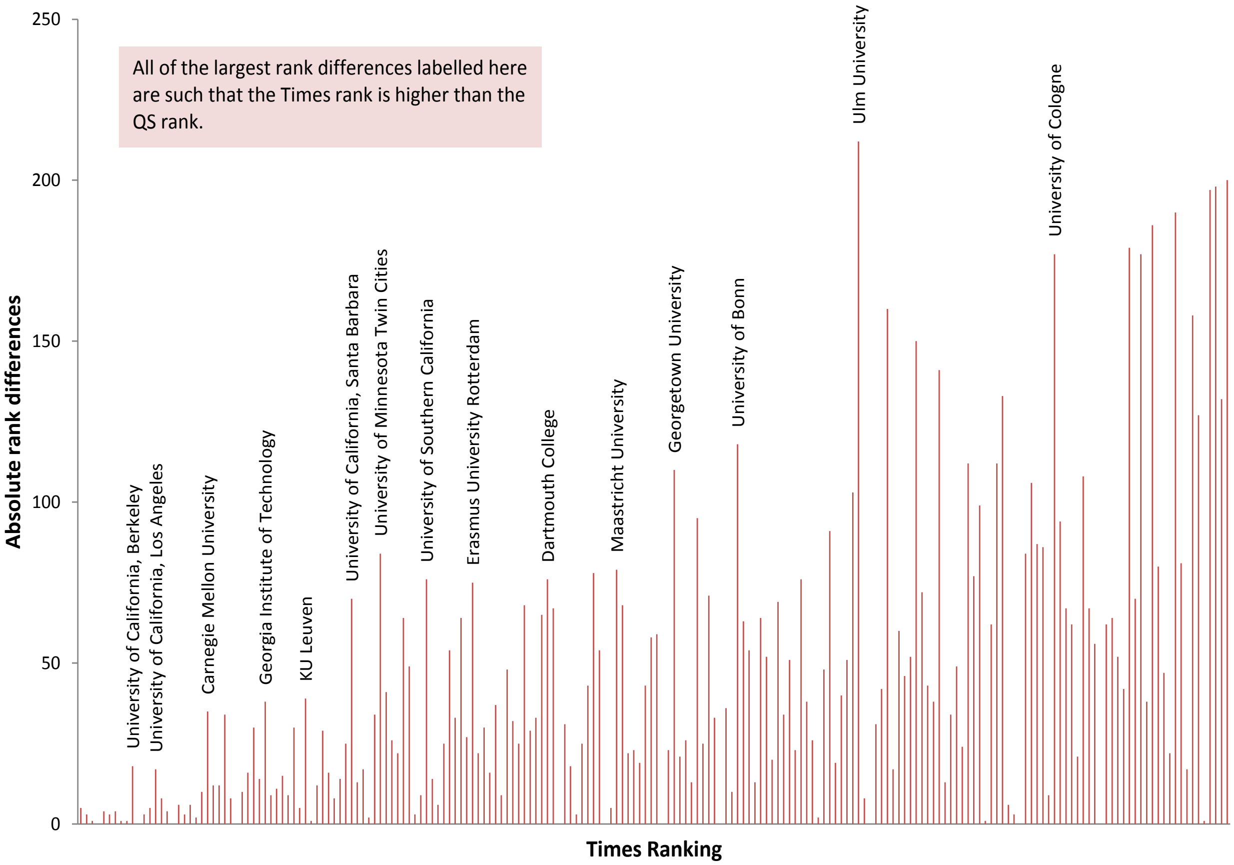
Times input data





Times Ranking
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
QS Ranking



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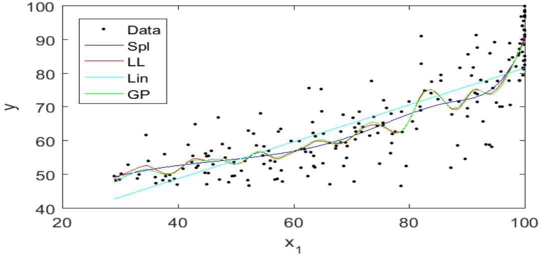
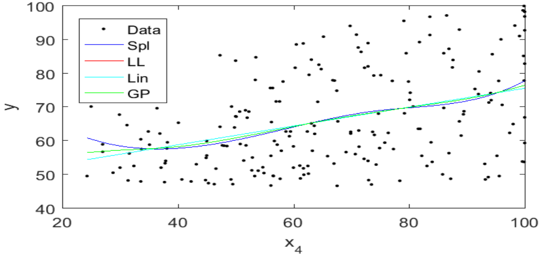
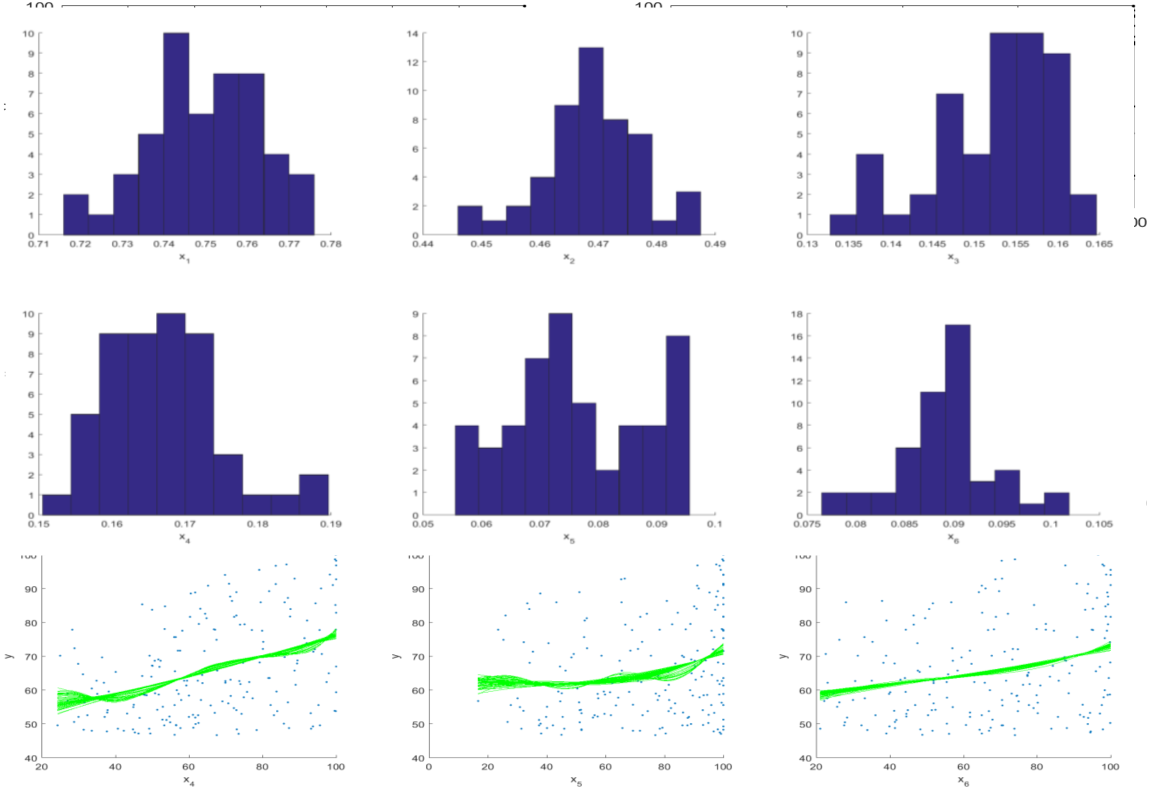
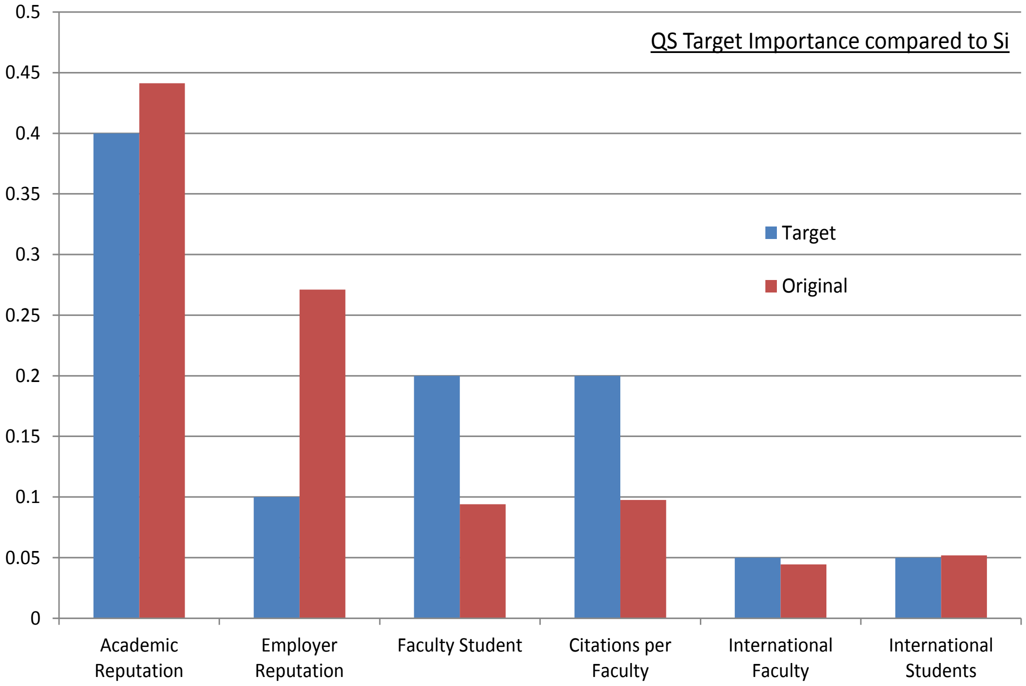
QS Regression



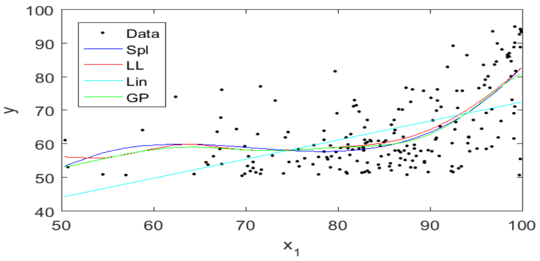


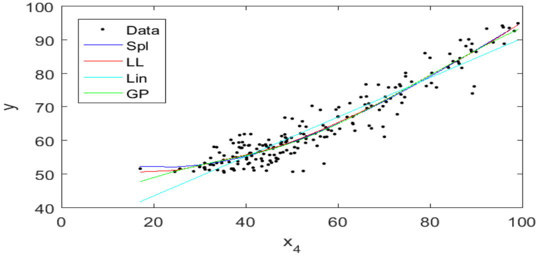


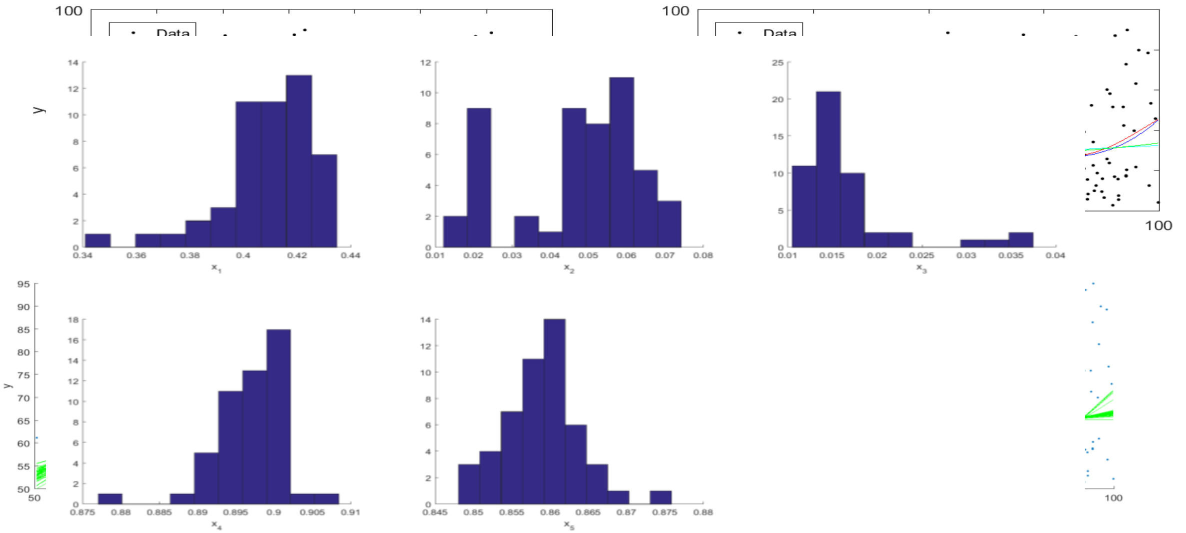
x1	Academic Reputation
x2	Employer Reputation
x3	Faculty Student
x4	Citations per Faculty
x5	International Faculty
x6	International Students

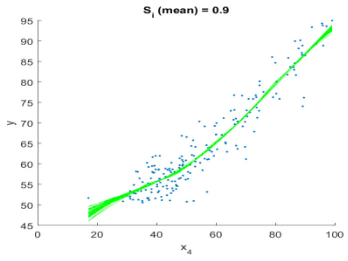

QS Target Importance compared to Si
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Target
Original
Academic Reputation
Employer Reputation
Faculty Student
Citations per Faculty
International Faculty
International Students

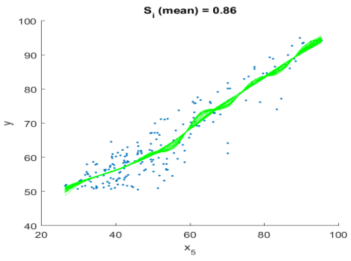
Times Regression



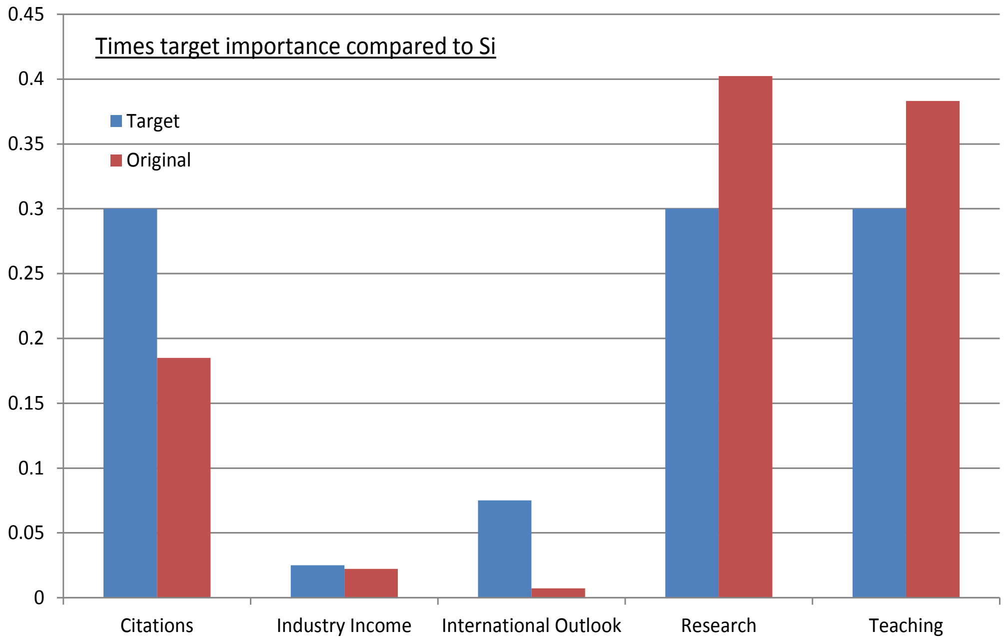




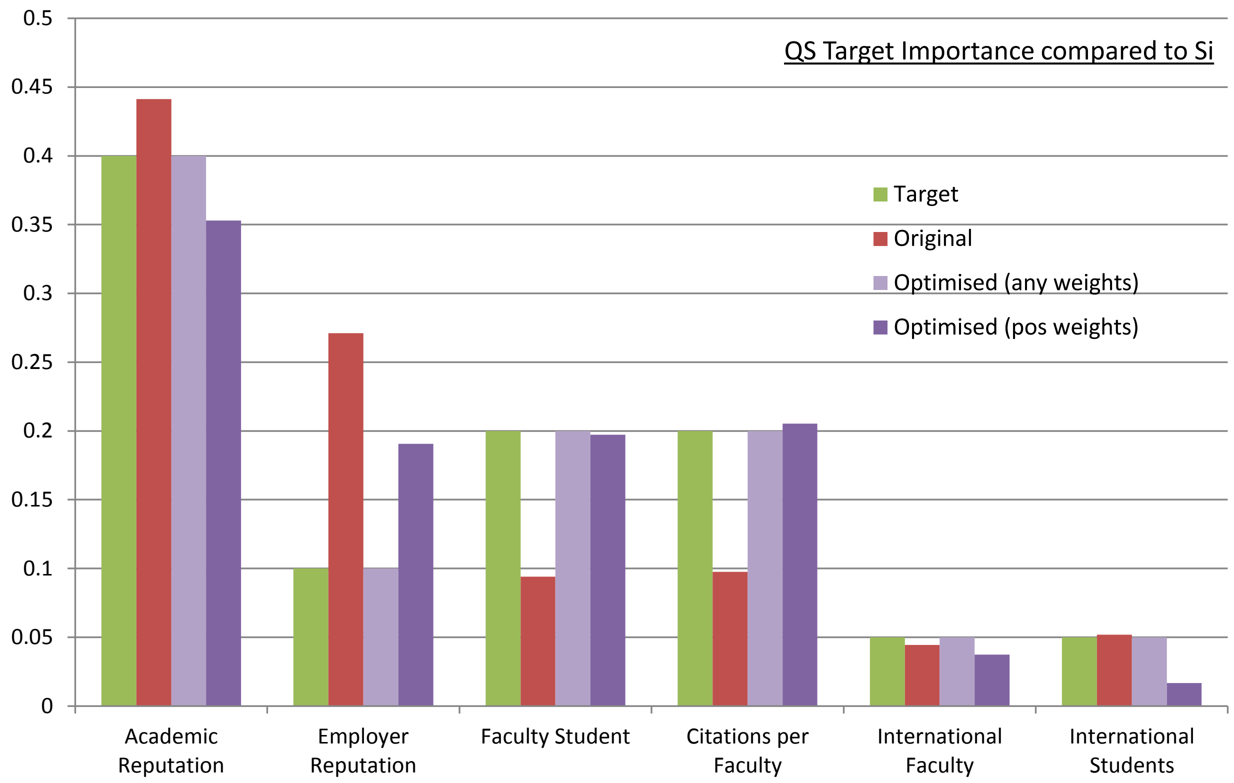




x1	Citations
x2	Industry Income
x3	International Outlook
x4	Research
x5	Teaching



Times target importance compared to Si
Target
Original
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Citations
Industry Income
International Outlook
Research
Teaching



Original	0.4	0.1	0.2	0.2	0.05	0.05
Optimised	0.60	-0.37	0.32	0.28	-0.03	0.20
Opt (+)	0.32	0.00	0.30	0.31	0.07	0.00

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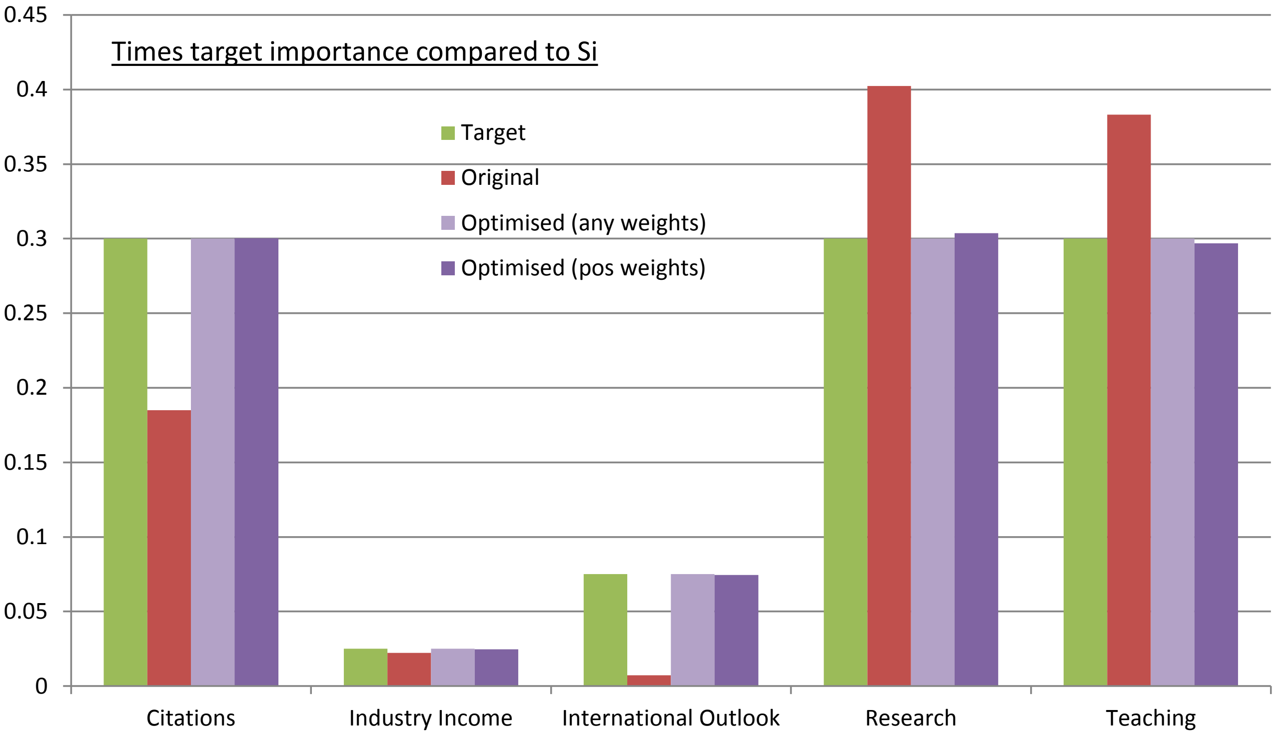


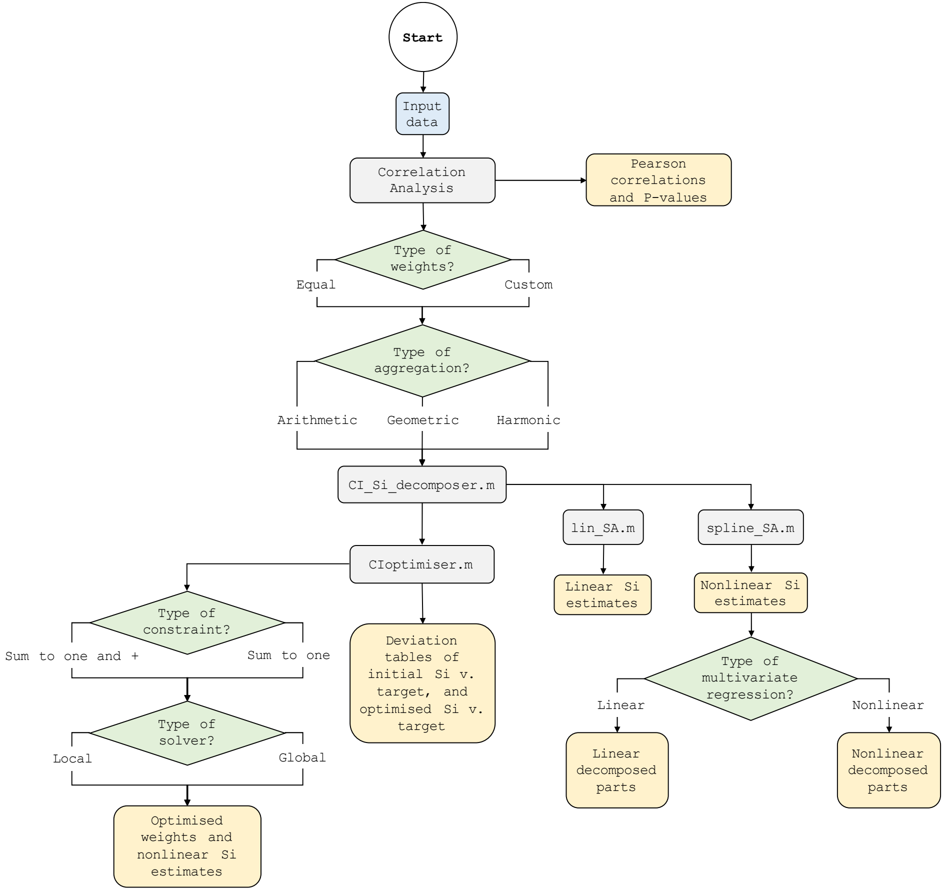
Original	0.30	0.03	0.08	0.30	0.30
Optimised	0.46	-0.08	0.19	0.03	0.39
Opt (+)	0.44	0.11	0.16	0.00	0.29

CIAO Toolbox

Composite
Indicator
Analysis and
Optimisation

- Optimisation of weights (balancing + [soon] infomax)
- Different types of aggregation
- Nonlinear dependence modelling

(very beta at the moment…)



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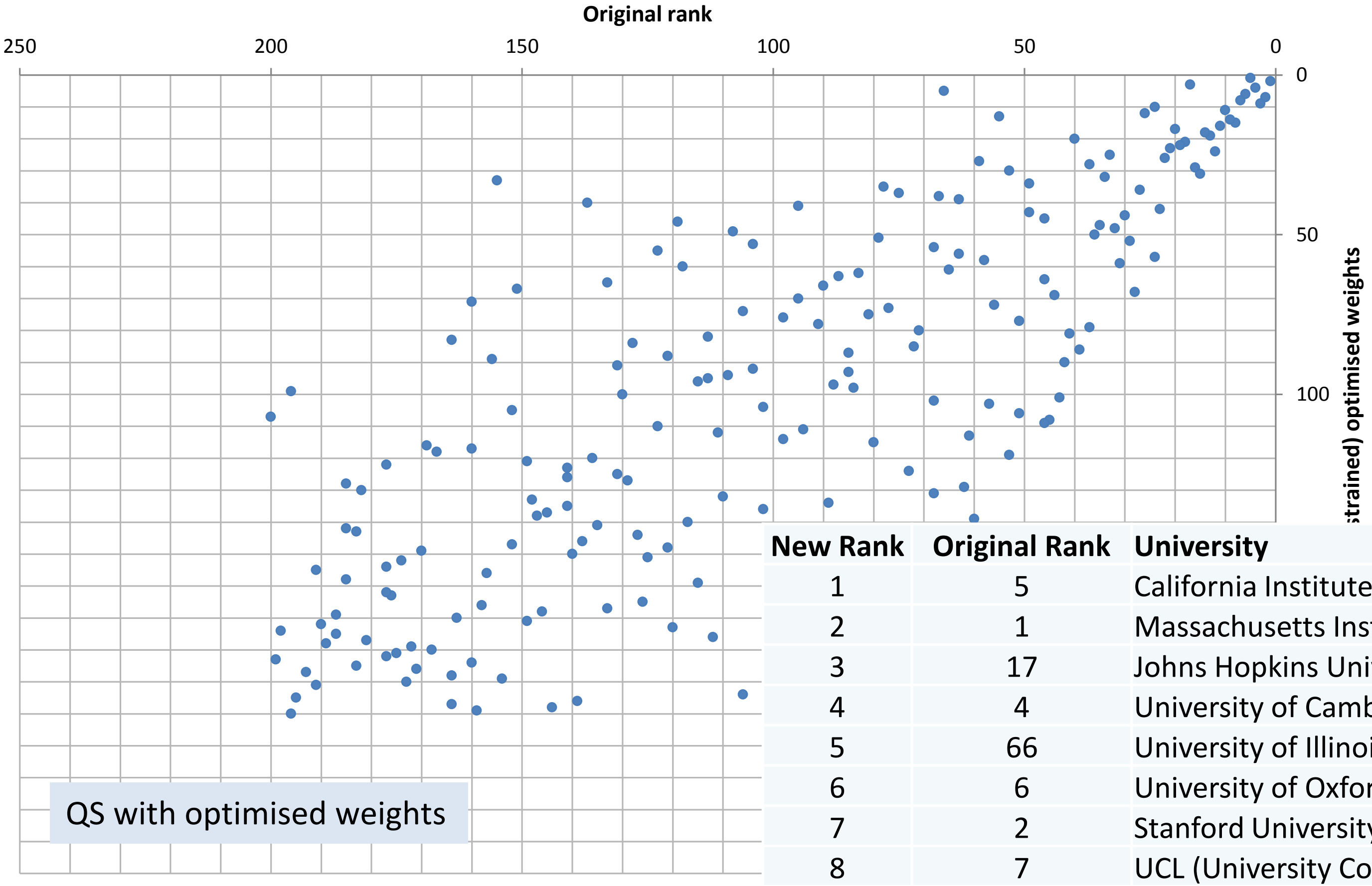
Can we tune the weights?

yes

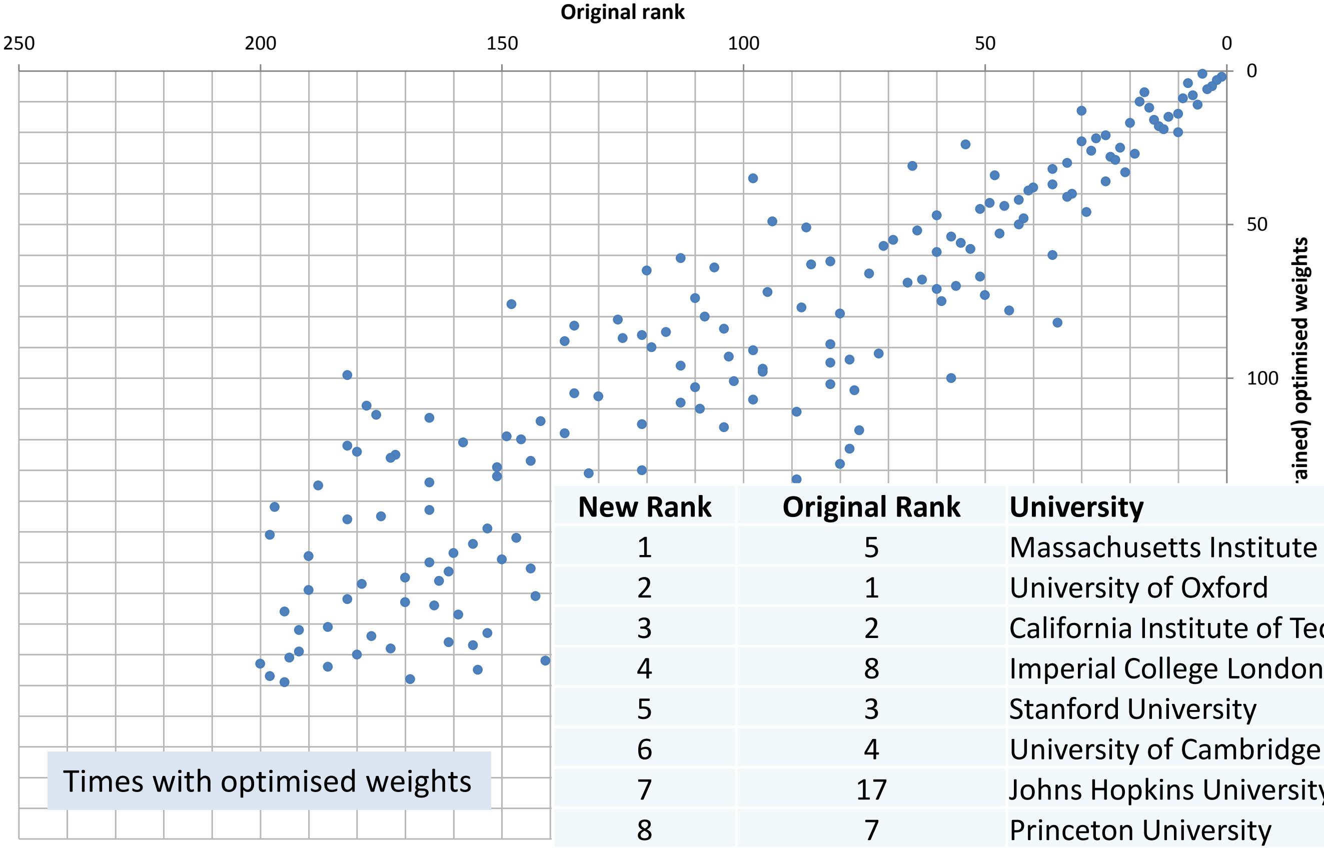
(Optimisation approach)

Should
~~Can~~ we tune the weights?

hmm

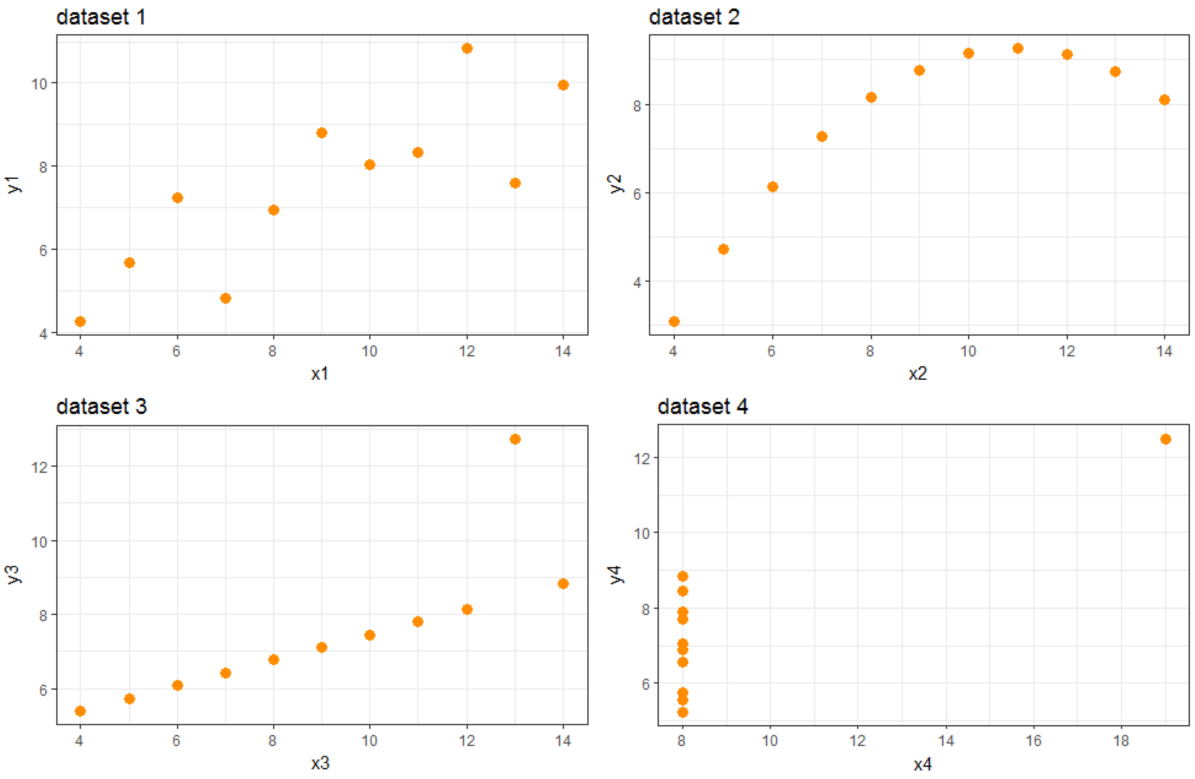


New Rank	Original Rank	University
1	5	California Institute of Technology (Caltech)
2	1	Massachusetts Institute of Technology (MIT)
3	17	Johns Hopkins University
4	4	University of Cambridge
5	66	University of Illinois at Urbana-Champaign
6	6	University of Oxford
7	2	Stanford University
8	7	UCL (University College London)
9	3	Harvard University
10	24	Duke University

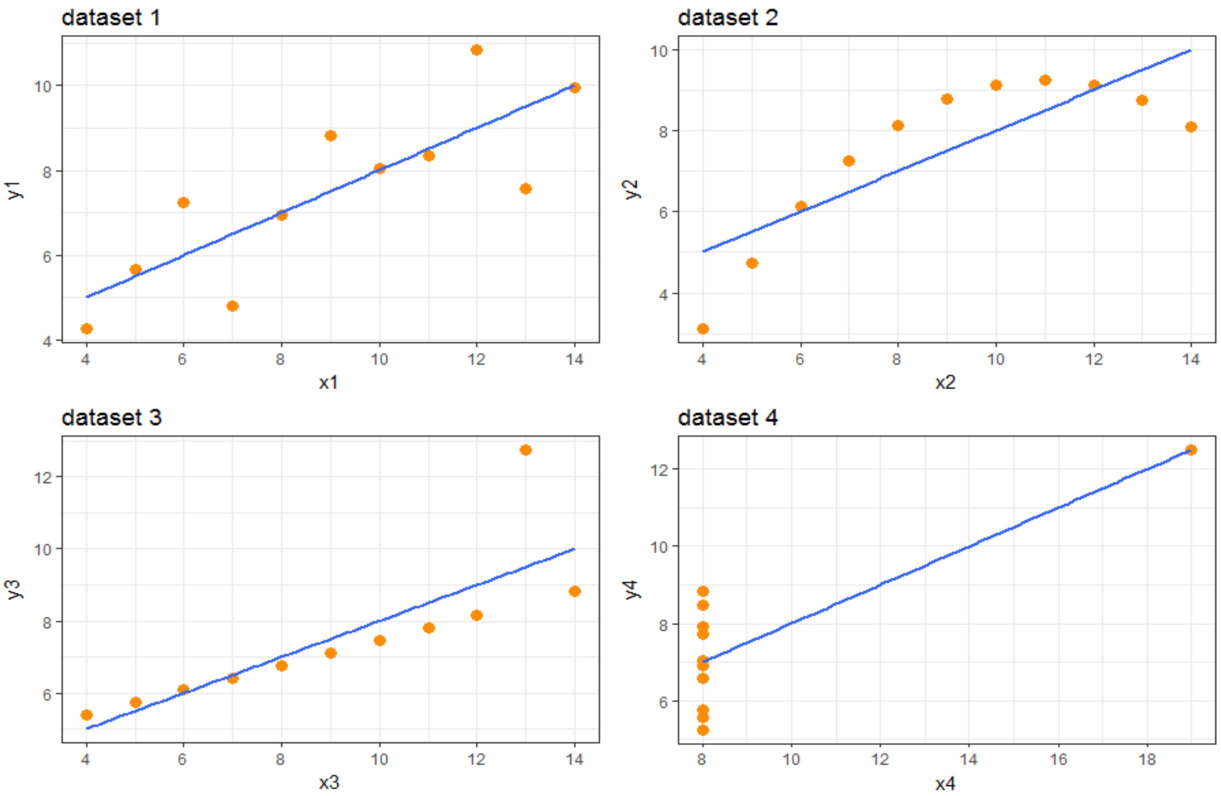


New Rank	Original Rank	University
1	5	Massachusetts Institute of Technology
2	1	University of Oxford
3	2	California Institute of Technology
4	8	Imperial College London
5	3	Stanford University
6	4	University of Cambridge
7	17	Johns Hopkins University
8	7	Princeton University
9	9	ETH Zurich
10	18	Duke University

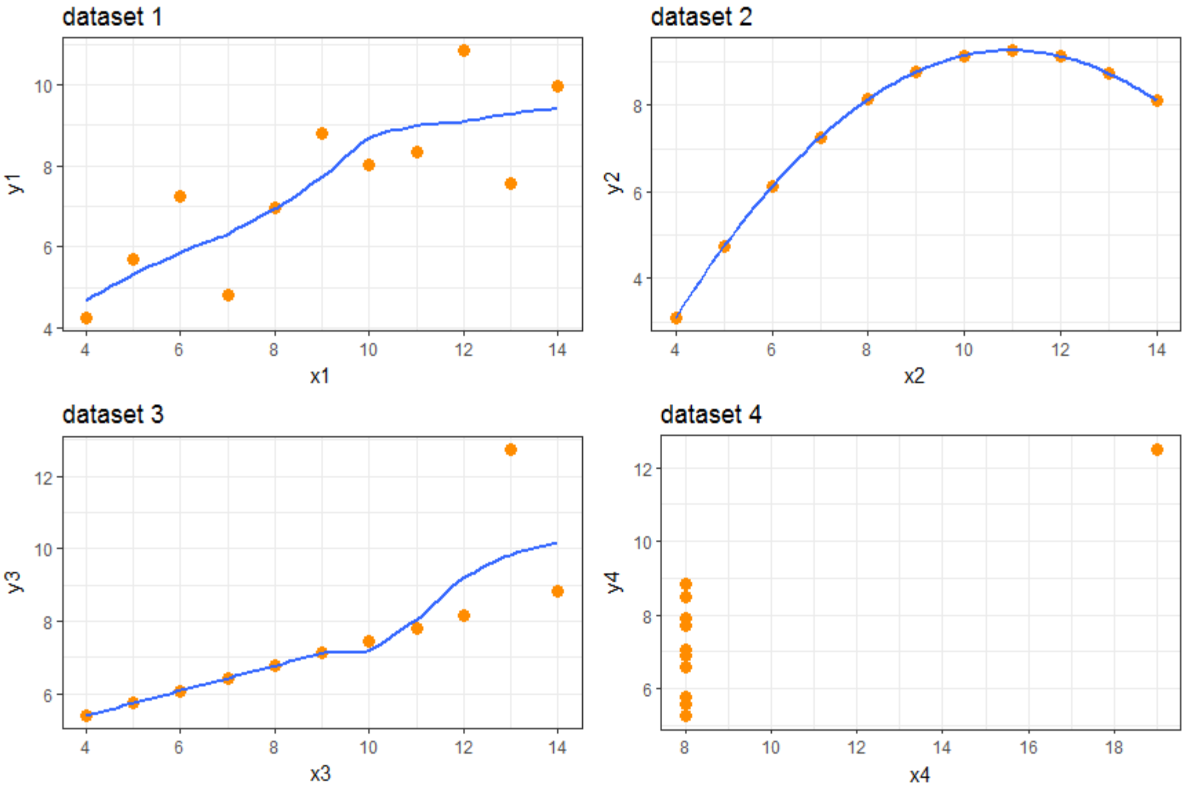
A final thought



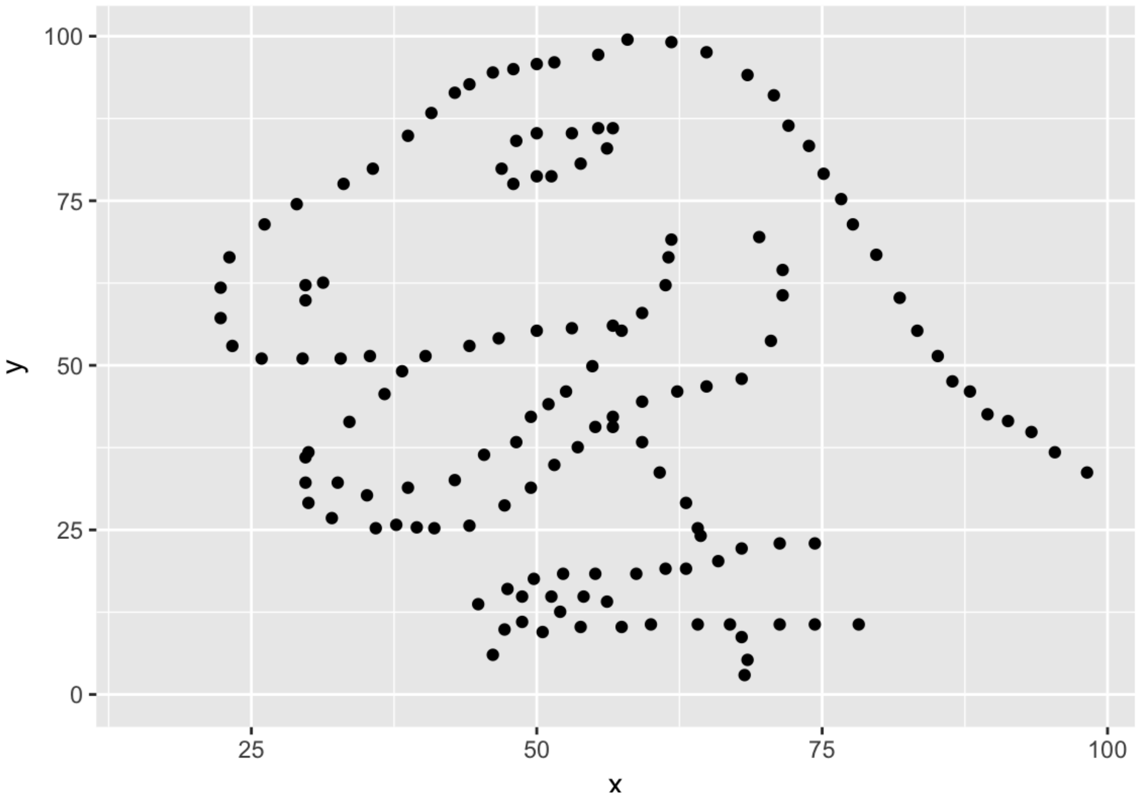
A final thought



A final thought



The Datasaurus Dozen



https://CRAN.R-project.org/package=datasauRus

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Summary

- Understand objective of weighting (esp. balancing vs. information objectives)
- Estimate S_i of indicators using nonlinear regression (allows for correlation)
- Optimise weights to agree with target “importance” using numerical algorithm
- CIAO toolbox if you want to really explore

All this can be found in recent paper:

Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological Indicators*, *80*, 12-22.

Takeaway

Weights don't equal importance in composite indicators.

Composite indicators often involve a **tradeoff** between statistics and communication.

Open Questions

Does importance = S_i?

When we assign "importances" to variables, are we implicitly taking some correlation into account?

Part 2: Robustness and uncertainty analysis

Which steps in the construction of a composite indicator are uncertain?

- Step 10. Presentation & dissemination
- Step 9. Association with other variables
- Step 8. Back to the indicators
- Step 7. Robustness & sensitivity
- Step 6. Weighting & aggregation
- Step 5. Normalisation of data
- Step 4. Multivariate analysis
- Step 3. Data treatment (missing, outliers)
- Step 2. Selection of indicators
- Step 1. Developing the framework

ALL OF THEM

Which steps in the construction of a composite indicator are uncertain?

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- Step 1. Developing the framework

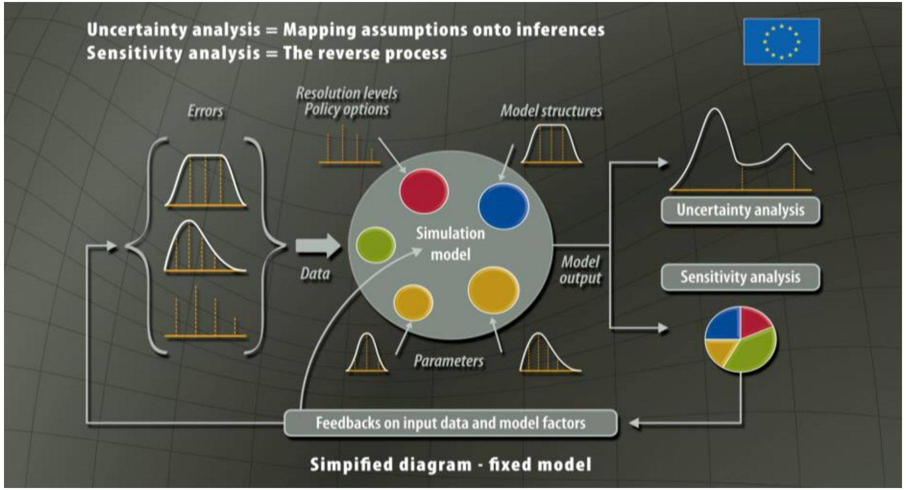
ALL OF THEM

Which steps in the construction of a composite indicator are uncertain?

Step 10. Presentation & dissemination	
Step 9. Association with other variables	
Step 8. Back to the indicators	
Step 7. Robustness & sensitivity	Even here: uncertain pdfs, limited exploration of assumptions…
Step 6. Weighting & aggregation	What weights? How to aggregate?
Step 5. Normalisation of data	How? Min/max, standarise, rank…
Step 4. Multivariate analysis	Which methods? Assume normality?
Step 3. Data treatment (missing, outliers)	How to impute? What is an outlier?
Step 2. Selection of indicators	The right ones? Irrelevant ones? Missing indicators?
Step 1. Developing the framework	What is the definition of "excellence"/"innovation"/etc…?

But, the same is true for any model.

Uncertainty and Sensitivity Analysis

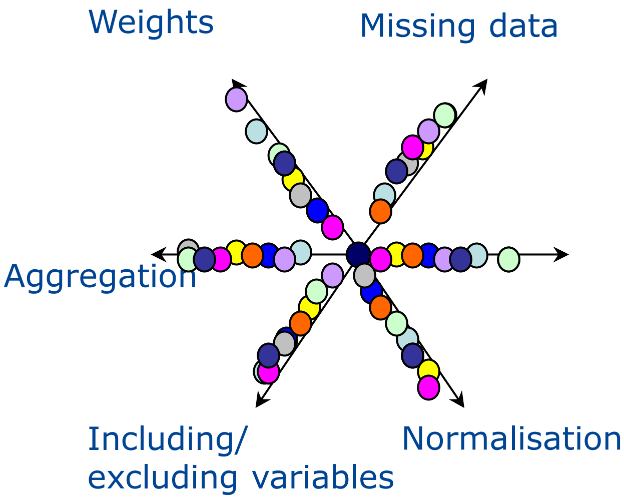


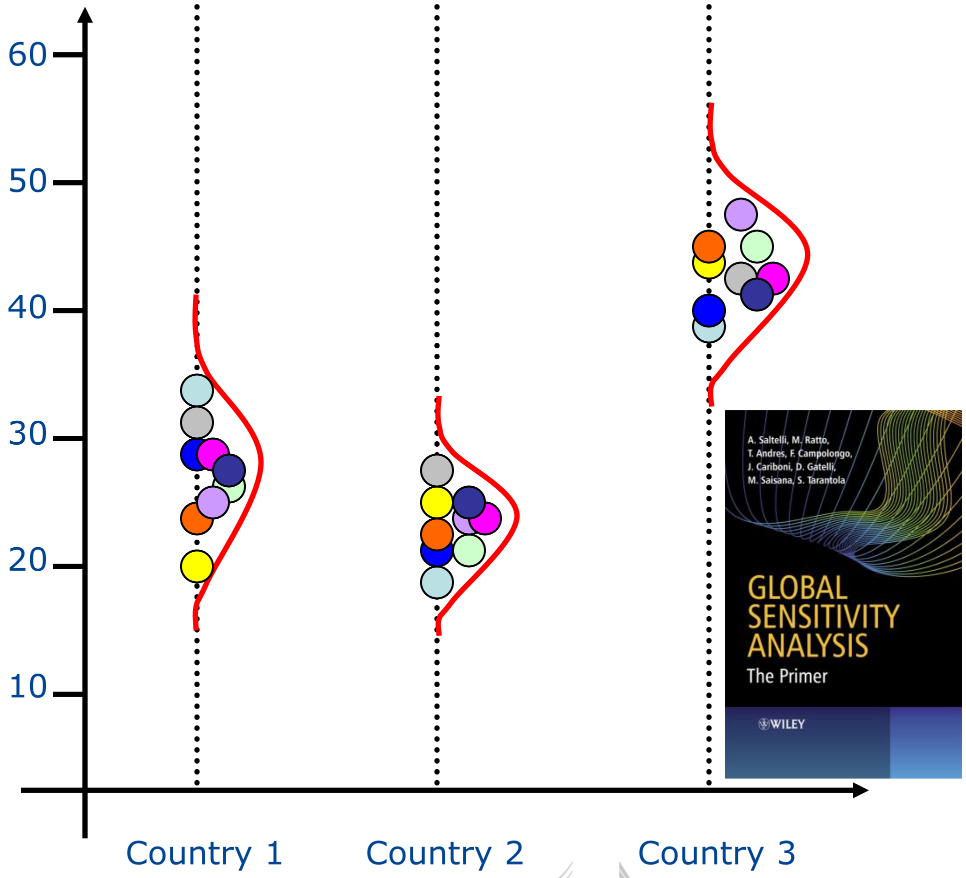
Uncertainty analysis
How uncertain is the output (CI scores) given the uncertainty in the input (assumptions made in it's construction)?

Sensitivity analysis
How much uncertainty is caused by each assumption?

We need:
- To quantify the uncertainty in our assumptions (assign probabilities to alternative assumptions)
- To propagate this through our composite indicator (Monte Carlo)
- To quantify/visualise uncertainty in the scores of our composite indicator (confidence intervals, pdfs, scatter plots, sensitivity analysis tools)

Space of alternatives





Model averaging: whenever a choice in the composite setting-up may not be strongly supported or if you may not trust one single model, we'll recommend you to use more models

it is essential to vary assumptions simultaneously to fully explore the “assumption space”.

C_1

Only child 1:

chaos = $f_1(C_1)$

C_2

Only child 2:

chaos = $f_2(C_2)$

Child 1 *plus* child 2:

Fighting, crying interactions, etc.

chaos = $f_1(C_1) + f_2(C_2) + f_{12}(C_1, C_2)$ $\boxed{\neq f_1(C_1) + f_2(C_2)}$

Testing the behaviour of one child at a time would not at all explore the full space of chaos.

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Uncertainty analysis of composite indicators requires some programming—currently using Matlab but moving to R.

Testable assumptions include:

- Normalisation method (A_1)
- Weighting method (A_2)
- Perturbations of weights (A_3)
- Set of indicators included (A_4)
- Data imputation method (…)
- Structure of composite (…)
- ++ anything you can program! (…)

$$\boxed{\text{scores} = CI(A_1, A_2, A_3, A_4,\ldots)}$$

Sample this function many times at random A_i values, and record the output each time

What do uncertainty and sensitivity analyses tell you?

→ *NOT to verify whether the two global university rankings are legitimate models to measure university performance*

→ *To test whether the rankings and/or their associated inferences are robust or volatile with respect to changes in selected methodological assumptions within a plausible and legitimate range.*

Source: Saisana, D'Hombres, Saltelli, 2011, Research Policy 40, 165–177

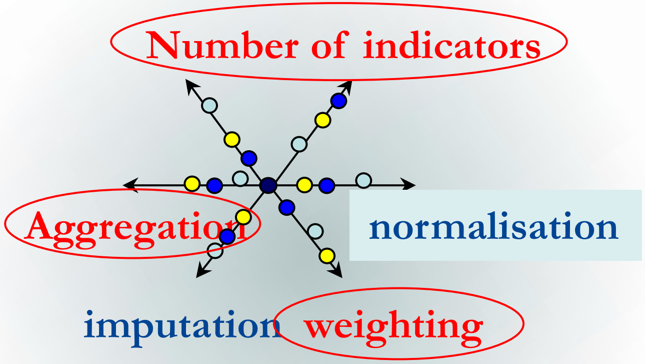
COIN Training 2017 University Rankings

Uncertainty analysis

- Normalisation
  - Min/max
  - Rank
- Aggregation
  - Arithmetic
  - Geometric
- Weights
  - +/-25% of nominal weight value

Back to university rankings

Activate simultaneously different sources of uncertainty that cover a wide spectrum of methodological assumptions



70 scenarios

Assumption	Alternatives
Number of indicators	▪ all six indicators included or one-at-time excluded (6 options)
Weighting method	▪ original set of weights, ▪ factor analysis, ▪ equal weighting, ▪ data envelopment analysis
Aggregation rule	▪ additive, ▪ multiplicative, ▪ Borda multi-criterion

Estimate the FREQUENCY of the university ranks obtained in the different simulations

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ARWU/SJTU

ACADEMIC RANKING OF WORLD UNIVERSITIES SINCE 2003

Legend:
Frequency lower 15%
Frequency between 15 and 30%
Frequency between 30 and 50%
Frequency greater than 50%
Note: Frequencies lower than 4% are not shown

Simulated rank range - SJTU 2008

	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	Original rank	
Harvard Univ	100																				1	USA
Stanford Univ	89	11																			2	USA
Univ California - Berkeley	97																				3	USA
Univ Cambridge	90	10																			4	UK
Massachusetts Inst Tech (MIT)	74	26																			5	USA
California Inst Tech	27	53	19																		6	USA
Columbia Univ	23	77																			7	USA
Princeton Univ		71	9	11	7																8	USA
Univ Chicago		51	34	13																	9	USA
Univ Oxford		99																			10	UK
Yale Univ		47	53																		11	USA
Cornell Univ		27	73																		12	USA
Univ California - Los Angeles		9	84	7																	13	USA
Univ California - San Diego			41	46	9																14	USA
Univ Pennsylvania		6	71	23																	15	USA
Univ Washington - Seattle			7	71	21																16	USA
Univ Wisconsin - Madison			27	70																	17	USA
Univ California - San Francisco			14	9	14		11		7	10						6				6	18	USA
Tokyo Univ			16	16	49	20															19	Japan
Johns Hopkins Univ			7	54	21	17															20	USA

- Harvard, Stanford, Berkley, Cambridge, MIT: top 5 in more than 75% of JRC simulations.
- Univ California: original rank 18th but could be ranked anywhere between the 6th and 100th position
- Impact of assumptions: much stronger for the middle ranked universities

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THE Ranking

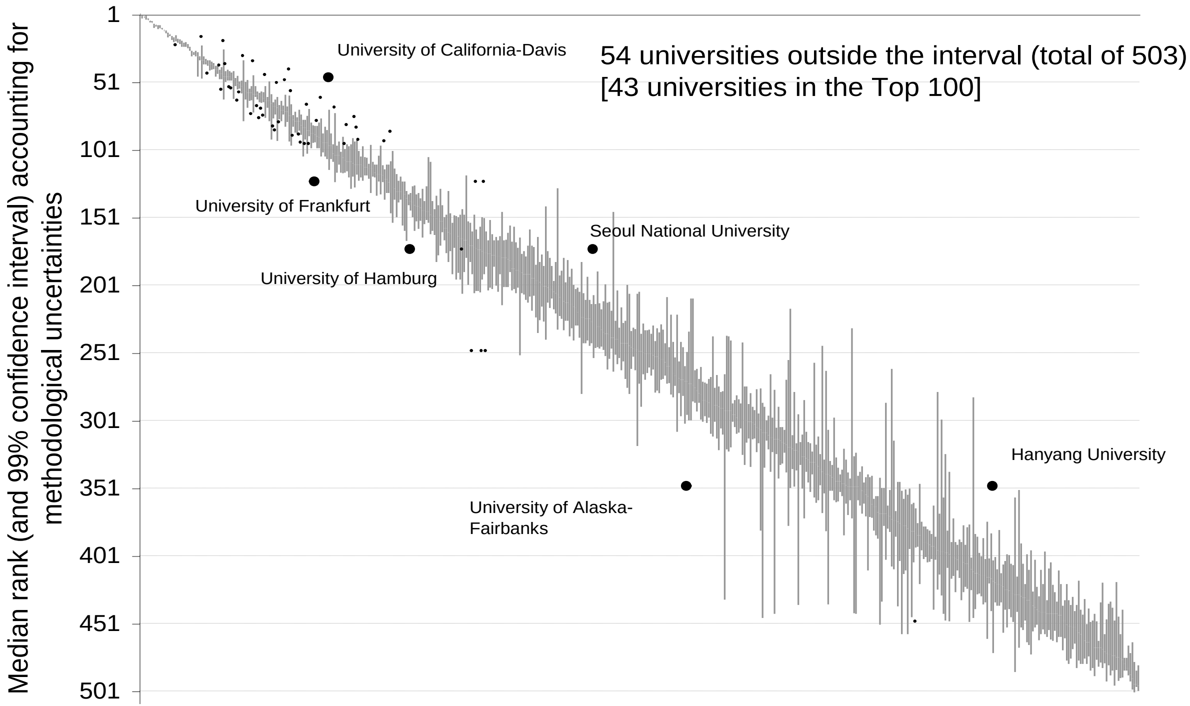
Legend:
Frequency lower 15%
Frequency between 15 and 30%
Frequency between 30 and 50%
Frequency greater than 50%
Note: Frequencies lower than 4% are not shown

Simulated rank range - THES 2008

	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100		
HARVARD University	44	56																			1	USA
YALE University	40	49	11																		2	USA
University of CAMBRIDGE	99																				3	UK
University of OXFORD	93	7																			4	UK
CALIFORNIA Institute of Technology	46	50																			5	USA
IMPERIAL College London	74	24																			6	UK
UCL (University College London)	73	23																			7	UK
University of CHICAGO		80	19																		8	USA
MASSACHUSETTS Institute of Technology	14	13	17	16	11	11	7														9	USA
COLUMBIA University	6	13	17	11	10	7	10	14													10	USA
University of PENNSYLVANIA		37	56	6																	11	USA
PRINCETON University	6	59	27	9																	12	USA
DUKE University			27	11	9		7		10	6	9		6								13	USA
JOHNS HOPKINS University			20	10	9	9	7		10		6	6	7			6					13	USA
CORNELL University		6	24	11		7	6	7	9	9		7									15	USA
AUSTRALIAN National University	10	30	29	31																	16	Australia
STANFORD University			10	14	7	10	9	10	6	6		7									17	USA
University of MICHIGAN			6	27	17	9	10	7	14	6											18	USA
University of TOKYO				16	7	13	7										6		6		19	Japan
MCGILL University			7	19	41	13	9	7													20	Canada

- Impact of uncertainties on the university ranks is even more apparent.
- M.I.T.: ranked 9th, but confirmed only in 13% of simulations (plausible range [4, 35])
- Very high volatility also for universities ranked 10th-20th position, e.g., Duke Univ, John Hopkins Univ, Cornell Univ.

Uncertainty analysis – ARWU results



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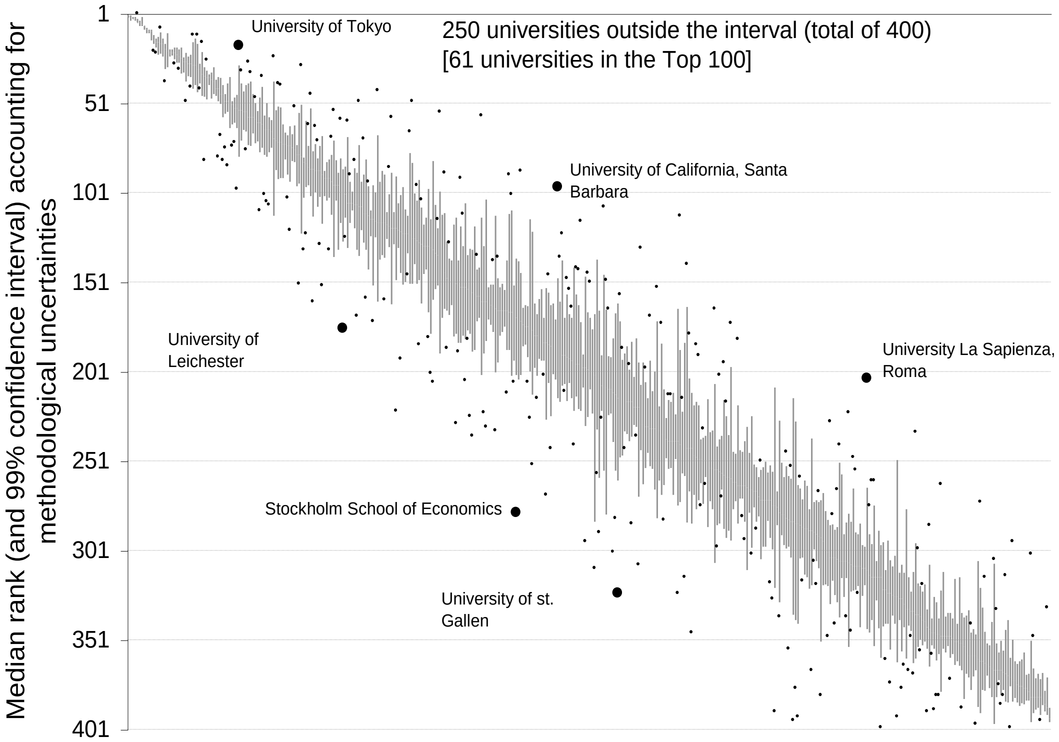
Uncertainty analysis – THE results



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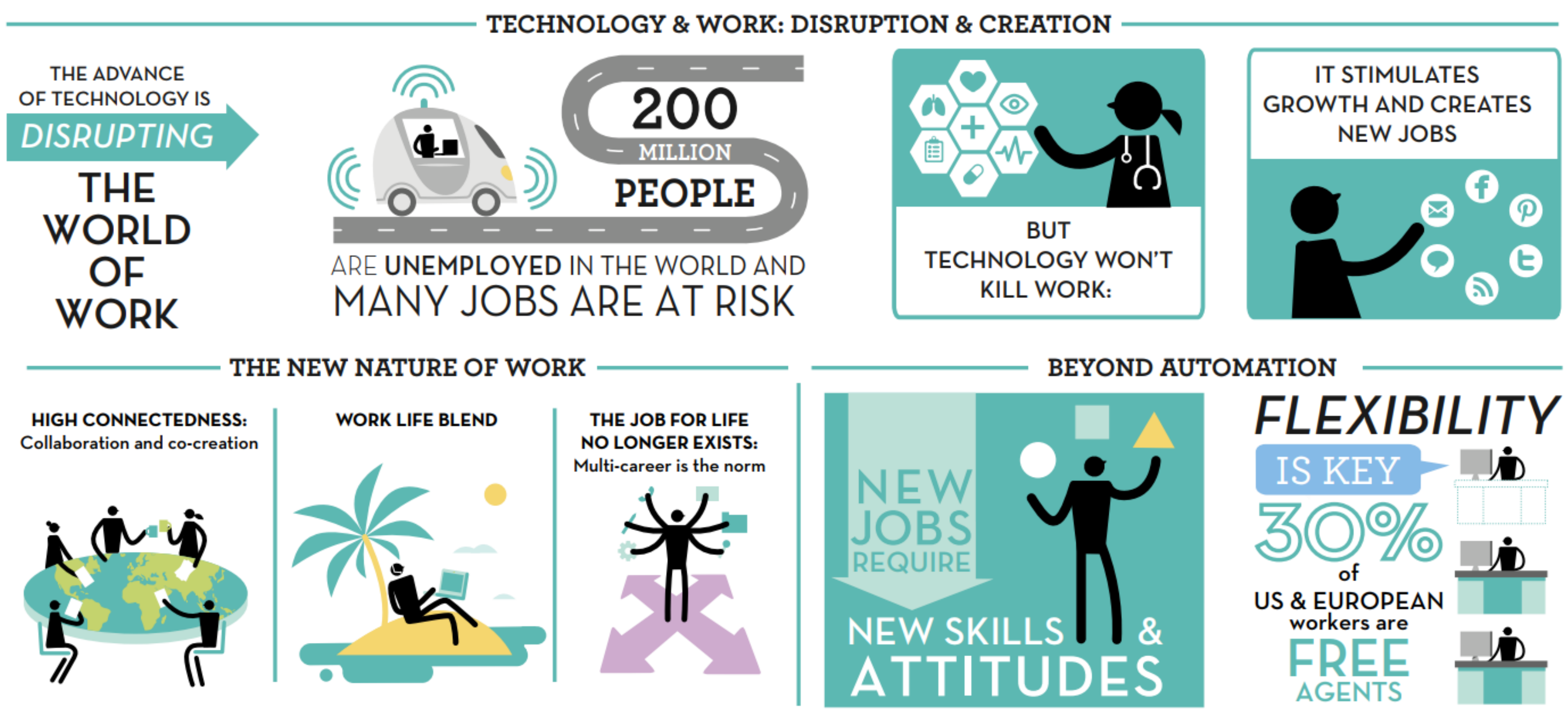
The Global Talent Competitiveness Index 2017 (GTCI)
Talent and Technology



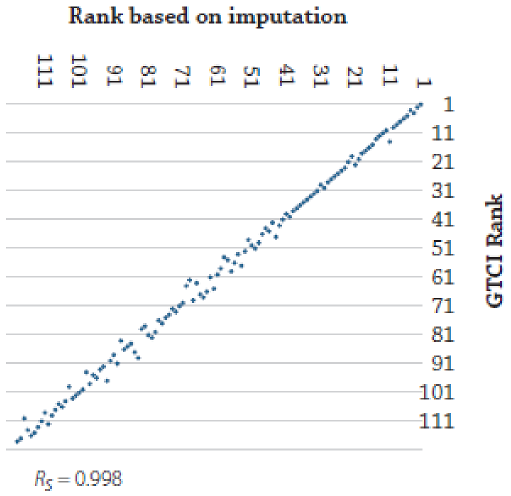
THE GTCI RANKS COUNTRIES BY THEIR ABILITY TO GROW, ATTRACT AND RETAIN TALENT

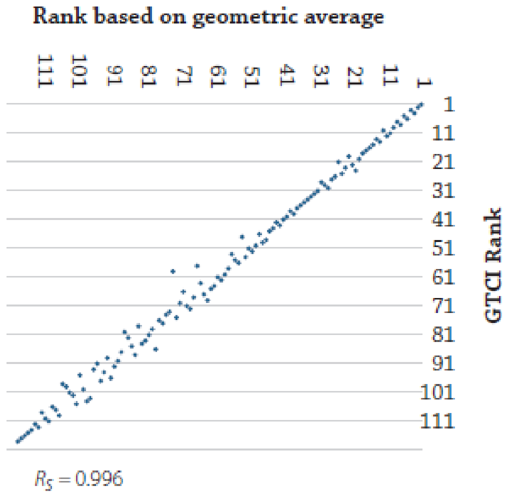
Uncertainty analysis for the GTCI 2017: Weights, missing data, aggregation, and normalisation

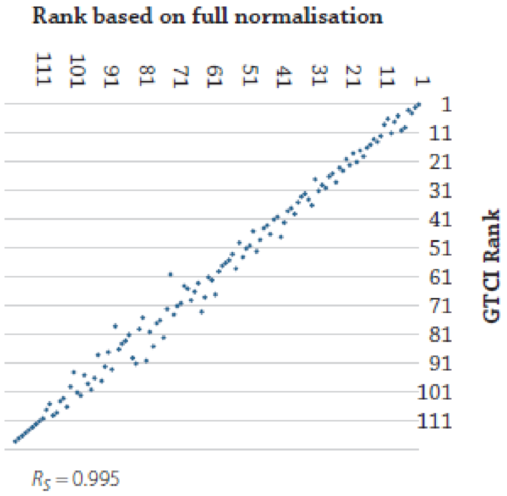
		REFERENCE	ALTERNATIVE
I. Uncertainty in the treatment of missing values		**No estimation of missing data**	**Expectation Maximisation (EM)**
II. Uncertainty in the aggregation formula at pillar level		**Arithmetic average**	**Geometric average**
III. Uncertainty in the method of normalisation		**Partial normalisation**	**Full normalisation**
IV. Uncertainty in the weights			
GTCI sub-index	Pillar	Reference value for the weight (within the sub-index)	Distribution assigned for robustness analysis (within the sub-index)
Input	Enable	0.25	U[0.15,0.35]
	Attract	0.25	U[0.15,0.35]
	Grow	0.25	U[0.15,0.35]
	Retain	0.25	U[0.15,0.35]
Output	Vocational and Technical Skills	0.50	U[0.40,0.60]
	Global Knowledge Skills	0.50	U[0.40,0.60]

Sensitivity Analysis

Which assumptions are driving the uncertainty in the rankings?

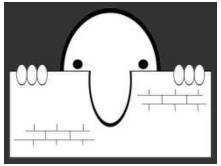






We can also go further and delve into the sensitivity analysis literature (variance-based SA, moment-independent measures, etc).

A brief glimpse of SA…



If we want to go a step further we can calculate formal sensitivity measures telling us, e.g:

"Of the assumptions tested, the uncertainty in the choice of normalisation method causes 40% of the uncertainty in rankings"

Let A_1, A_2, A_3,… be the assumptions used in the composite indicator construction, which result in a set of scores:

$$\boxed{\text{scores} = \text{CI}(A_1, A_2, A_3, A_4, \ldots)}$$

The uncertainty in the *scores*, as a result of uncertainty in the A_i, can be captured by var(scores). <u>Sensitivity analysis can decompose this variance into portions attributable to each assumption.</u>

$$\text{var}(\text{scores}) = \sum_{i=1}^{k} V_i + \sum_i \sum_{j<i} V_{i,j} + \cdots + V_{1,2,\ldots,k}$$

$$V_i = \text{var}_{A_i}[\text{E}_{A_{\sim i}}(\text{scores}|A_i)]$$

$$V_{i,j} = \text{var}_{A_i,A_j}\left[\text{E}_{A_{\sim i,j}}\left(\text{scores}\middle|A_i, A_j\right)\right] - \text{var}_{A_i}[\text{E}_{A_{\sim i}}(\text{scores}|A_i)] - \text{var}_{A_j}[\text{E}_{A_{\sim j}}(\text{scores}|A_j)]$$

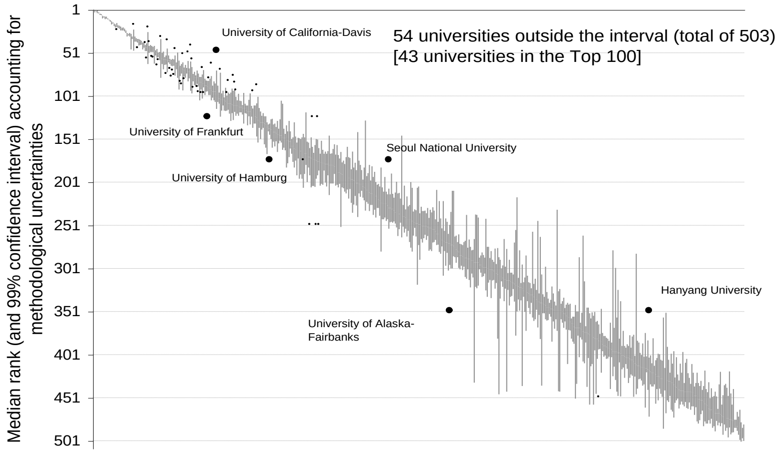
Requires a specific design.

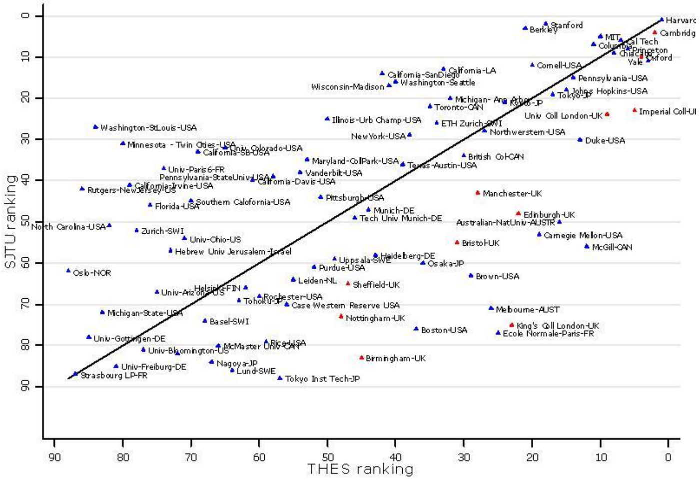
Very informative but perhaps hard to communicate…

Saisana M., Saltelli A., Tarantola S., 2005, Uncertainty and sensitivity analysis techniques as tools for the analysis and validation of composite indicators. *J Royal Statistical Society A* **168(2)**, 307-323

Uncertainty and validation

We cannot explore the full uncertainty of a composite indicator: we can only explore some of the assumptions.





"Given the assumptions that were tested, the outcome of the composite indicator is shown to vary in the following way…" [lower bound on uncertainty]

In general it is not possible to *validate* a composite indicator (build compelling evidence that it is an effective model).

(but, the same problems apply to some extent to any model)

European Commission

From irresponsible musings to serious efforts

Rankings range from irresponsible musings by self-appointed experts and money-making schemes by commercial organizations to, at their best, serious efforts by academic or research organizations. (Aitbach, 2015)

Composite indicators

- Are very widely used
- Fill a demand for which there is no other alternative

Therefore we should use available tools to **increase robustness and credibility**:

1. Transparency—detailed description of methodology, data sources, assumptions
2. Statistical soundness—analysis of correlations, data structure, effects of weights, etc.
3. Uncertainty and sensitivity analysis—check effect of alternative but plausible assumptions. Honestly acknowledge uncertainty.

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