Didelės apimties Lietuvos švietimo duomenų analizė

Doktorantė Dovilė Stumbrienė

Doktorantūros pradžios ir pabaigos metai: 2014 – 2018

Darbo vadovė: Dr. Audronė Jakaitienė

Tyrimo objektas

Švietimo duomenų tyryba

Stebėsenos indekso konstravimas

Darbo planas ir ataskaita: treti metai (I)

Planas	Atlikta
Pranešimas tarptautinėje konferencijoje.	Stumbriene, D., Camanho, A. S., Jakaitiene, A. 2017. **Data Envelopment Analysis in Construction a Composite Indicator for Education Monitoring**. *6th Workshop on Efficiency and productivity Analysis.* 2017 birželio 9 d. Porto, Portugalija. Stumbrienė, D., Jakaitienė, A., Želvys, R. 2016. **Principal Component versus Data Envelopment analysis in Construction a Composite Indicator for Education Monitoring**. *DAMSS 2016 (Data Analysis Methtods for Software Systems),* stendinis pranešimas 2016 gruodžio 1–3 d., Druskininkai, Lietuva.

Darbo planas ir ataskaita: treti metai (II)

Planas	Atlikta
Publikuoti straipsnį recenzuojamame periodiniame mokslo leidinyje.	Publikuotas straipsnis: Želvys R., Jakaitienė A., Stumbrienė D. 2017. **Link skirtingų gerovės valstybių švietimo modelių: Baltijos šalių švietimo sistemų palyginimas**. *Filosofija. Sociologija.* ISSN 0235-7186, Nr. 2 (WoS). Straipsnis priimtas publikavimui: Stumbrienė D., Jakaitienė A., Želvys R. 2017. **Švietimo sistemos stebėsenos indeksas: išteklių ir rezultatų sąveika.** *Lietuvos statistikos darbai.* Parengtas straipsnis: Stumbrienė D., Jakaitienė A., Želvys R. **Educational Systems and Inequalities in European countries from PISA 2015.**

Darbo planas ir ataskaita: treti metai (III)

Planas	Atlikta
Atlikti empirinį tyrimą, gautų duomenų analizę ir apibendrinimą bei parengti disertacijos dalį „Tyrimų apžvalga ir analizė“.	Atliktas empirinis tyrimas: algoritmo pritaikymas Europos Sąjungos švietimo duomenims ir tobulinimas. Gautų duomenų analizė ir apibendrinimas: algoritmo tikslumo įvertinimas ir palyginimas su kitais metodais. Parengta disertacijos dalis „Tyrimų apžvalga ir analizė“ *(anglų kalba).*

Darbo planas ir ataskaita: treti metai (IV)

Planas	Atlikta
Atlikti stažuotę užsienio mokslo ir studijų institucijoje	ERASMUS+ programa, University of Porto, Portugalijoje. 5 mėnesiai (2017.02.02 - 2017.06.30). Doktorantų mokykla „Chipset training school 2017 - Big data processing in the internet of everything era“ 2017 rugsėjo 20-22 d., Novi Sad, Serbija.

Dirbta Mokslininkų grupių projekte **„Lietuvos švietimo sistemos būklės ir jos įtakos veiksnių modeliavimas“**, projekto vykdymo laikotarpis: 2015 – 2017 m.

Duomenų apgaubties metodas:

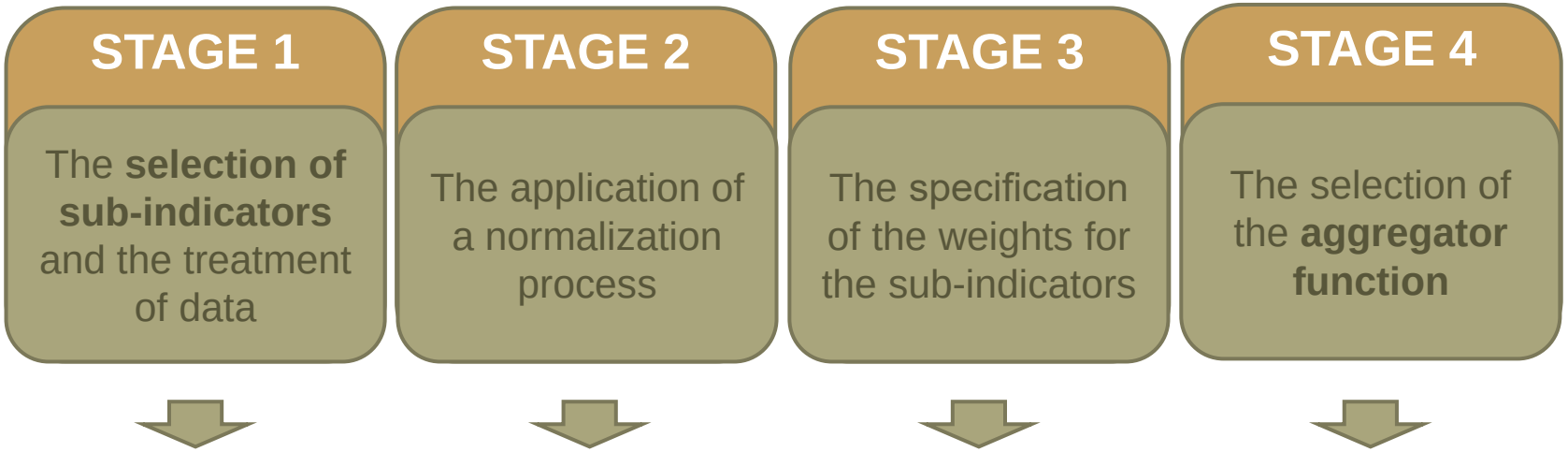
perėjimas nuo sistemos vertinimo (kontrolės) į sistemos valdymą (tobulinimą).

The purpose of our research

The research focuses on the exploring the advantages and disadvantages of different modelling alternatives in the context of the education systems monitoring.

- To identify the impact of different type of weight restrictions.
- To compare the traditional formulation of CIs (fixed weighting) with DEA CIs (flexible weighting: DMU-specific).

Stages of the construction of CI



Education and training (ET2020) targets

Sub-indicators were standardized:

$$z = \frac{x - \bar{x}}{s_x} + x_{min} + \varepsilon;$$

$$\varepsilon = 0.001$$

A fixed and flexible weighting systems

Additive aggregation

Weighting systems

- **A fixed weighting system** implies the assignment of weights that are uniform across all units under assessment.
  - The Simple Additive Weighted (SAW) method: $$CI_j^{SAW} = \sum_{r=1}^{s} u_r \cdot y_{rj}$$
- **A flexible weighting system** includes the possibility of specifying weights for each indicator that are different across individual providers. The flexibility in choosing the weights assigned to each indicator allows maximising the performance score of the country under assessment.
  - Data envelopment analysis

Flexible weighting system – DEA model (input-oriented model)

$$Max \sum_{r=1}^{s} u_r y_{rj_0}$$

$$\text{s.t.} \sum_{i=1}^{m} v_i x_{ij_0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \qquad j = 1,\dots, n$$

$$u_r \ge 0, \qquad r = 1,\dots, s$$

$$v_i \ge 0, \qquad i = 1,\dots, m$$

Benefit of the Doubt model with “dummy input”

$$\text{Max} \sum_{r=1}^{s} u_r y_{rj_0}$$

$$\text{s.t.}$$

$$\sum_{r=1}^{s} u_r y_{rj} \le 1,$$

$$u_r \ge 0,$$

Flexible weighting system – DEA model (output-oriented model)

$$Min \sum_{i=1}^{m} v_i x_{ij0}$$

$$s.t \sum_{r=1}^{s} u_r y_{rj0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj0} - \sum_{i=1}^{m} v_i x_{ij0} \leq 0, \quad j = 1, \dots, n$$

$$u_r \geq \varepsilon, \quad r = 1, \dots, s$$

$$v_i \geq \varepsilon, \quad i = 1, \dots, m$$

$$\frac{1}{CI^{DEA}} = Min\, v$$

$$s.t \sum_{r=1}^{s} u_r y_{rj0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj0} - v \leq 0, \quad j = 1, \dots, n$$

$$u_r \geq \varepsilon, \quad r = 1, \dots, s$$

$$v \geq \varepsilon$$

Weight restrictions in DEA

Restrictions to pure weights:

- Absolute weight restriction:

$$a_r \leq u_r \leq b_r$$

Restrictions to virtual weights:

- Virtual weight restrictions:

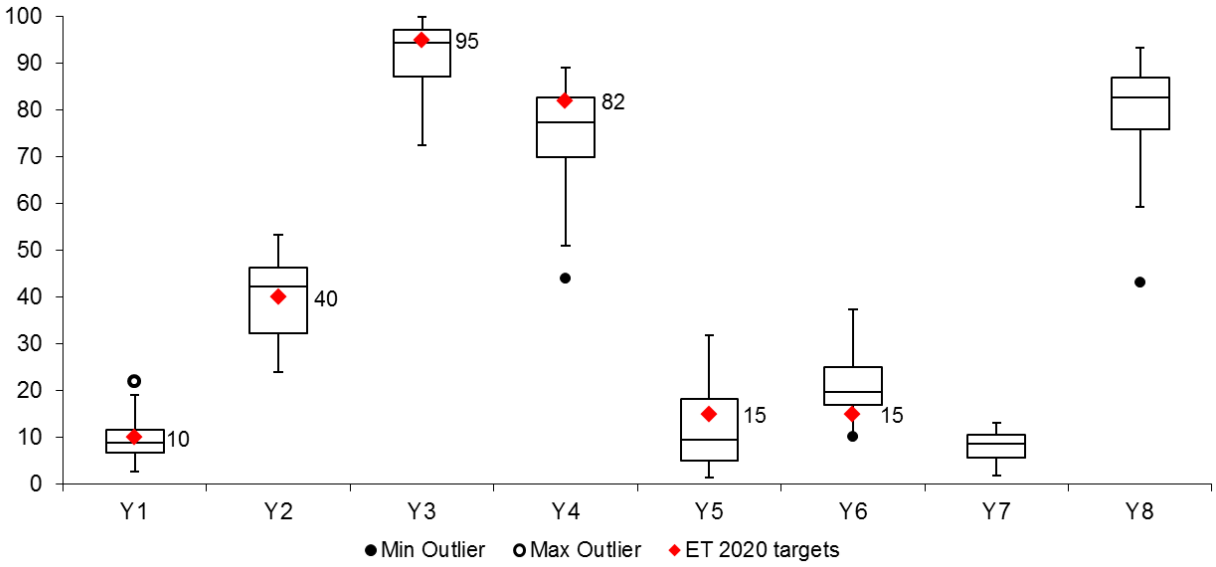
$$\gamma_r \leq \frac{u_r y_{rj}}{\sum_{r=1}^{s} u_r y_{rj}} \leq \delta_r$$

- ARI restrictions:

$$\phi_r \leq \frac{u_r \bar{y}_r}{\sum_{r=1}^{s} u_r \bar{y}_r} \leq \psi_r$$

Sub-indicators for education monitoring

Var.	Sub-indicator	Source	Year
Y1	Early leavers from education and training	EUROSTAT	2014
Y2	Tertiary educational attainment	EUROSTAT	2014
Y3	Early childhood education	EUROSTAT	2014
Y4	Employment rates of recent graduates	EUROSTAT	2014
Y5	Adult participation in learning	EUROSTAT	2014
Y6	Avarege of PISA Low achievers	OECD	2015
Y7	Average of PISA Top achievers	OECD	2015
Y8	Upper sec. or tertiary educational attainment	EUROSTAT	2014



Note that variables Y1 and Y6 represented are measured in such a way that lower values represent better performance.

Data sets of sub-indicators

	NORMALISED DATA							
	Dataset 2: with normalisation							
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**
Belgium	2.576	2.265	3.641	2.892	0.638	2.895	3.009	2.650
Bulgaria	1.916	0.797	2.395	1.853	0.066	0.001	0.529	3.306
Cz. Republic	3.491	0.490	1.984	3.229	0.876	2.662	2.089	4.364
Denmark	3.001	2.390	3.641	3.316	3.285	3.593	2.048	3.175
Germany	2.640	0.854	3.542	3.844	0.703	3.314	3.118	3.813
Estonia	2.235	2.197	2.735	3.056	1.092	4.236	3.496	4.189
Ireland	3.193	3.221	3.344	2.554	0.584	3.776	2.308	3.105
Greece	2.746	1.514	1.644	0.001	0.185	1.197	0.444	2.195
Spain	0.001	2.094	3.500	1.481	0.930	3.019	1.259	1.164
France	2.746	2.254	3.911	2.511	1.827	2.539	2.771	2.921
Croatia	4.086	0.945	0.001	1.559	0.141	2.094	1.008	3.463
Italy	1.469	0.001	3.415	0.070	0.714	2.519	1.527	1.400
Latvia	2.852	1.821	3.117	2.823	0.444	3.036	0.786	4.040
Lithuania	3.406	3.346	2.324	3.125	0.390	2.155	1.026	4.372
Luxembourg	3.363	3.278	3.684	3.351	1.406	2.058	2.035	3.384
Hungary	2.235	1.161	3.160	2.944	0.195	1.866	1.180	3.481
Netherlands	2.810	2.379	3.571	3.402	1.816	3.177	3.363	2.851
Austria	3.172	1.833	3.061	3.714	1.384	2.627	2.290	3.550
Poland	3.512	2.072	2.083	2.701	0.271	3.433	2.324	4.127
Portugal	0.959	0.843	2.990	1.966	0.876	2.942	2.179	0.001
Romania	0.810	0.126	1.984	1.896	0.001	0.197	0.001	2.580
Slovenia	3.725	1.946	2.409	2.251	1.146	3.508	2.884	3.708
Slovakia	3.235	0.342	0.709	2.485	0.174	1.442	0.955	4.171
Finland	2.640	2.436	1.587	2.857	2.551	3.981	3.599	3.778
Sweden	3.235	2.959	3.330	3.506	2.994	2.824	2.443	3.533
UK	2.150	2.709	3.656	3.316	1.600	2.999	2.638	3.140
Iceland	0.597	2.561	3.443	3.896	2.680	2.351	1.573	2.650
Norway	2.171	3.209	3.514	3.645	2.011	3.301	2.656	3.446
Switzerland	3.512	2.879	1.163	3.749	3.264	3.136	3.289	3.909
Mean	*2.6*	*1.9*	*2.7*	*2.7*	*1.2*	*2.7*	*2.0*	*3.2*
St. Deviation	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
Max	*4.1*	*3.3*	*3.9*	*3.9*	*3.3*	*4.2*	*3.6*	*4.4*
Min	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*

RQ: The impact of restrictions in DEA CI models

The imposed restrictions were as follows:

- Restriction imposing **equal pure weights:**

$$u_r = \frac{1}{8} \quad (r = 1, \dots, 8)$$

- Restriction imposing **equal virtual weights (DMU-specific):**

$$u_r y_{rj0} = \frac{1}{8}$$

- Restriction imposing **equal virtual weights (formulated as AR type I):**

$$\frac{u_r \bar{y}_r}{\sum_{r=1}^{8} u_r \bar{y}_r} = \frac{1}{8}$$

The impact of restrictions in DEA CI models

1. The unrestricted DEA model has limited discrimination power.
   - For a sample of 29 countries, with 8 key performance indicators, 20 countries obtain the CI score equal to 1.
2. The SAW model and the DEA model with equal pure weights **have the same results** (the only exception is a draw on the first two countries in the DEA assessment).

SAW model and DEA model with normalised data

	Normalised data (dataset 2)													
	SAW model		DEA model											
	Equal pure weights (17)		Unrestricted			Equal pure weights (17)			Equal Virtual weights (18)			ARI weights (19)		
	Score	Rank	Score	Rank	Diff rank	Score	Rank	Diff rank	Score	Rank	Diff rank	Score	Rank	Diff rank
Switzerland	3.11	**1**	1.00	1	0	1.00	1	0	0.86	6	-5	1.00	1	0
Sweden	3.10	**2**	1.00	1	+1	1.00	2	0	0.98	1	+1	0.98	2	0
Denmark	3.06	**3**	1.00	1	+2	0.98	3	0	0.94	2	+1	0.97	3	0
Norway	2.99	**4**	1.00	1	+3	0.96	4	0	0.91	3	+1	0.91	5	-1
Finland	2.93	**5**	1.00	1	+4	0.94	5	0	0.86	5	0	0.92	4	+1
Netherlands	2.92	**6**	1.00	1	+5	0.94	6	0	0.89	4	+2	0.89	6	0
Estonia	2.90	**7**	1.00	1	+6	0.93	7	0	0.79	10	-3	0.85	7	0
Luxembourg	2.82	**8**	1.00	1	+7	0.91	8	0	0.80	9	-1	0.84	8	0
UK	2.78	**9**	1.00	1	+8	0.89	9	0	0.82	7	+2	0.84	9	0
Ireland	2.76	**10**	1.00	1	+9	0.89	10	0	0.62	13	-3	0.80	11	-1
Germany	2.73	**11**	1.00	1	+10	0.88	11	0	0.59	15	-4	0.76	15	-4
Austria	2.70	**12**	1.00	1	+11	0.87	12	0	0.79	11	+1	0.79	12	0
Slovenia	2.70	**13**	1.00	1	+12	0.87	13	0	0.76	12	+1	0.79	13	0
France	2.68	**14**	1.00	1	+13	0.86	14	0	0.81	8	+6	0.82	10	+4
Belgium	2.57	**15**	0.98	21	-6	0.83	15	0	0.61	14	+1	0.74	16	-1
Poland	2.57	**16**	1.00	1	+15	0.82	16	0	0.40	20	-4	0.71	17	-1
Lithuania	2.52	**17**	1.00	1	+16	0.81	17	0	0.46	18	-1	0.71	18	-1
Iceland	2.47	**18**	1.00	1	+17	0.79	18	0	0.55	16	+2	0.79	14	+4
Cz. Republic	2.40	**19**	1.00	1	+18	0.77	19	0	0.49	17	+2	0.67	19	0
Latvia	2.36	**20**	1.00	1	+19	0.76	20	0	0.44	19	+1	0.65	20	0
Hungary	2.03	**21**	0.91	24	-3	0.65	21	0	0.29	21	0	0.55	21	0
Slovakia	1.69	**22**	0.95	22	0	0.54	22	0	0.21	22	0	0.44	25	-3
Spain	1.68	**23**	0.94	23	0	0.54	23	0	0.002	26	-3	0.51	22	+1
Croatia	1.66	**24**	1.00	1	+23	0.53	24	0	0.002	25	-1	0.45	24	0
Portugal	1.59	**25**	0.84	26	-1	0.51	25	0	0.002	28	-3	0.48	23	+2
Italy	1.39	**26**	0.89	25	+1	0.45	26	0	0.002	23	+3	0.40	26	0
Bulgaria	1.36	**27**	0.81	27	0	0.44	27	0	0.002	27	0	0.36	27	0
Greece	1.24	**28**	0.74	28	0	0.40	28	0	0.002	24	+4	0.35	28	0
Romania	0.95	**29**	0.64	29	0	0.31	29	0	0.001	29	0	0.23	29	0

The impact of restrictions in DEA CI models

When using equal virtual weights, the results of the DEA model with ARI virtual weights is more similar to the SAW results than the DEA with DMU-specific virtual weights. These models have more similar results when normalised data is used.

- DEA model with ARI weights (normalized data) has a correlation coefficient equal to 0.98 when compared to the SAW results, and the country rank is unchanged for 59% of the countries' analyzed. The correlation coefficient for the original data would be equal to 0.95 and the country rank would be unchanged for 10% of the countries'.
- DEA model with virtual DMU-specific weights (normalized data) has a correlation coefficient equal to 0.96 when compared to the SAW results, and the country rank is unchanged for 17% of the countries' analyzed. The correlation coefficient for the original data would be equal to 0.90 and the country rank would be unchanged for 3% of the countries'.

Conclusion: the use of DMU-specific virtual weights should be avoided. DEA with restrictions to pure weights or AR type I formulations (with normalized) are good alternatives to fixed weighting models.

Conclusions

1. DEA models without weights restrictions fail to discriminate countries.
2. The DEA model with equal pure weight restrictions returns a performance ranking of countries identical to the SAW model, both using original and normalised data.
   - However, if KPIs are measured in different scales, the imposition of equal pure weights does not reflect accurately the intention to give equal importance to all KPIs.
   - DEA models have advantages when original data (with different scales) is used, and in this case virtual restrictions (formulated as AR type I) have the best properties for conducting performance assessments.
3. Given that all results of SAW aggregations can be replicated by DEA, CIs can always be based on DEA.
   - This allows moving from performance assessment (control) to performance management (improvement), by proposing peers and targets, and enabling a more robust evaluation of performance changes over time (frontier shifts and changes in distance to the frontier).

Kitų metų darbo planas

Daktaro disertacijos parengimas ir gynimas.