Spatial Dispersion Index (SDI)

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SDI Background

- A large scale, Turkish Development Agency funded study to explore relational structure of towns & cities (Gençer et al. 2020).
- Analysis of permanent or temporary human movements (migration or travels for education, health, and leisure), goods (cargo and trade), communication (GSM records).
- The study employed network analysis alongside traditional urban planning methodologies.
- Turkish Development Agency provides outputs of the study to the general public and state agencies as a base plate (e.g. for regional office & service area planning): https://yersis.gov.tr/web

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SDI Conception

- The study called for a comparison of Turkish cities in terms of the “spatial extent” of inter-city socio-economic flows.
- Existing network metrics could not provide an answer.
- Spatial studies, mostly the urban planning literature, have no generalized measures to evaluate the quality in question.

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Meet SDI

- Spatial Dispersion Index (SDI) is a weighted average of distances between towns, weighted on the amount of flows between them.
- In a network $N = (V, E)$, let δ_{ij}, denote spatial distance between two vertices, and let $w_{i \to j}$ denote the amount of flow between them, e.g. number of people who migrated from town i to town j.
- The *generic* form of SDI captures the weighted average of how far the flows are dispersed in space/geography:

$$\text{SDI} = \frac{\sum_{i,j} (w_{i \to j} \cdot \delta_{ij})}{\sum_{i,j} w_{i \to j}} \tag{1}$$

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Variants

- The generic form is specialized by deciding on **level**, use of edge **direction** and **strength**:
- Level: **n**etwork or **v**ertex
- Use of direction: use **i**n-flows only, use **o**ut-flows only, or **u**ndirected (use all edges in an undirected graph or use both in and out flows in a directed graph),
- Use of strength: **w**eighted, **u**nweighted, or **g**eneralized (combination of weighted and unweighted with alpha parameter, see (Opsahl, Agneessens, and Skvoretz 2010)).

Variant examples

- Network level & weighted SDI

$$\mathrm{SDI}^{w}(N) = \frac{\sum_{i \to j \in E} (w_{i \to j} \cdot \delta_{ij})}{\sum_{i \to j \in E} w_{i \to j}} \tag{2}$$

- Vertex level, unweighted, out-flows only SDI (all weights taken as 1):

$$\mathrm{SDI}^{u}_{+}(i) = \frac{\sum_{i \to j \in E} (1 \cdot \delta_{ij})}{\sum_{i \to j \in E} 1} \tag{3}$$

- Full definition and details in (Gençer 2023)

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Example: Comparing different flows by dispersion at network level

- In this example SDI facilitates quantitative comparison of geographic outreach of different socio-economic activities between Turkish cities/provinces. Source: Gençer et al. (2020).

Network.Flow	Weighted.SDI
Secondary Education	300
Higher Education	374
Health Service Visits	471
Transportation	379
Trade	401
Cargo (state company only)	479
Communication (GSM calls)	419
Migration	485

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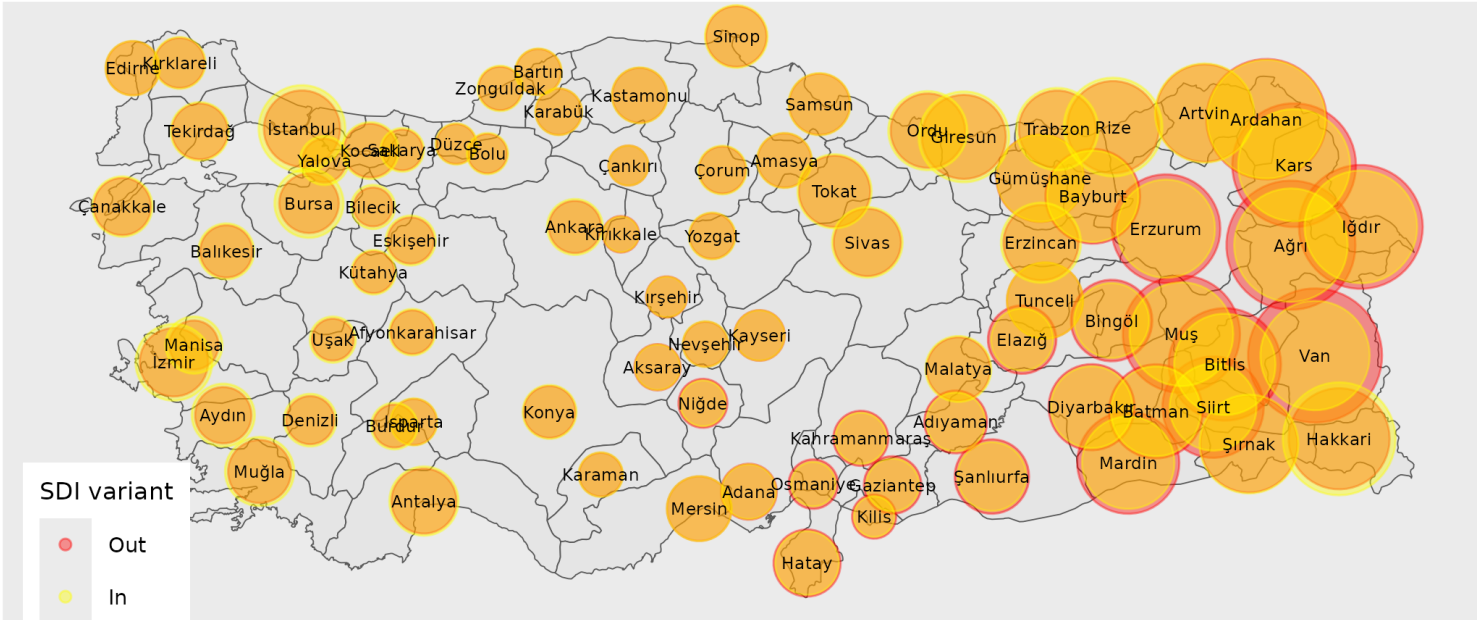
Example: Comparing cities' level dispersion in the migration network

- Vertex level, weighted & unweighted SDI in Turkey's migration network (2016-2018).
- Correlation analysis revealed suppressing effect of 'socio-economic development index' on outward SDI (Gençer 2023).



A Global Example: Does distance matter for dispersion of scientific findings?

- Scientific works containing keyword “dijital transformation”
- Citation of B in A means importing of ideas from B to A
- A citation is translated into country level relation from country of first author of B to country of first author of A.
- 36,566 records from OpenAlex. Only 5,389 has first author country. 2,948 usable in-corpus citations.
- Distribution of missing information is assumed to be random.

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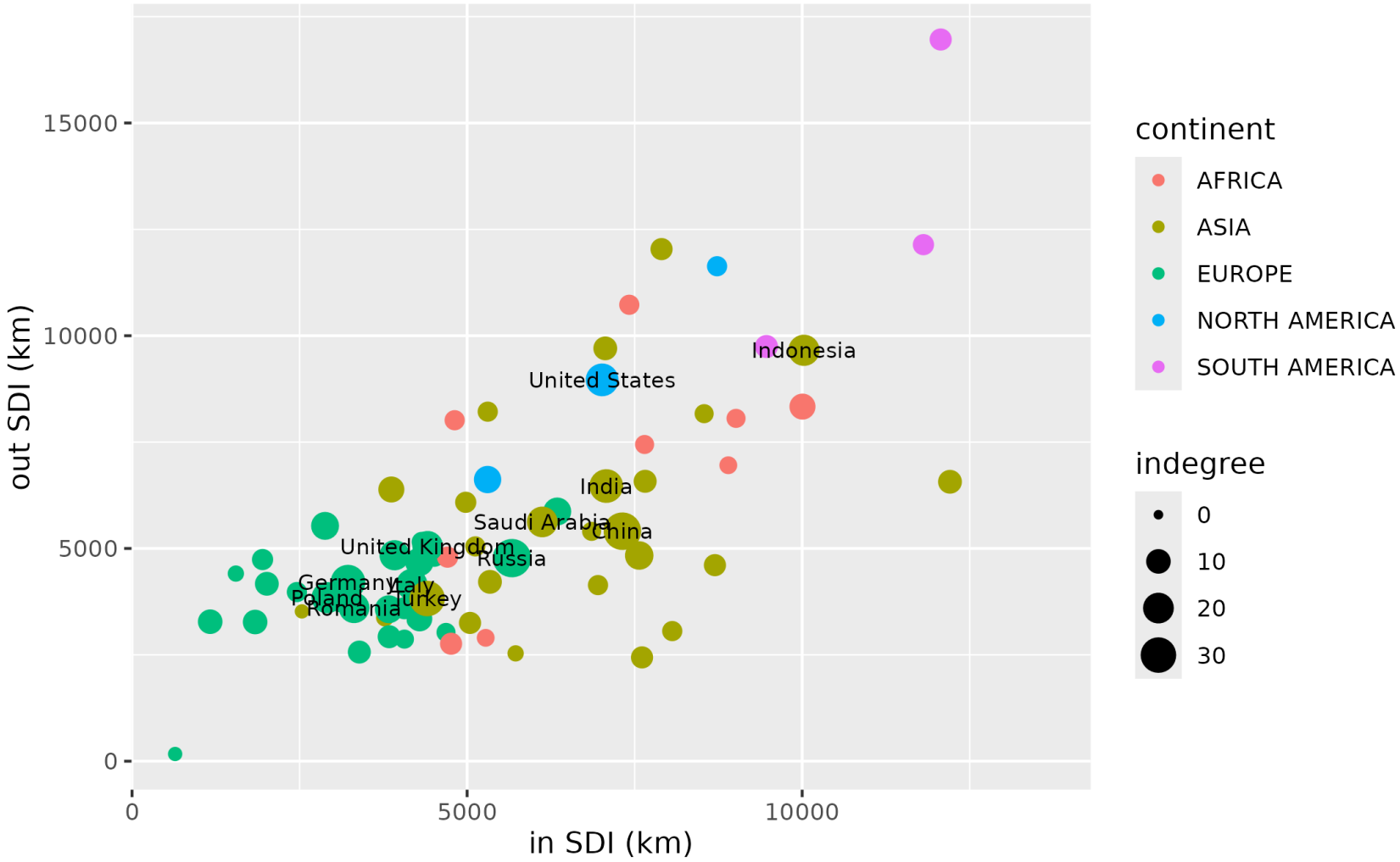
A Global Example: country level dispersion of scientific findings



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R package: rSDI

```
flows<-data.frame(from=c("A","B","A"), to=c("B","A","C"),
                  weight=c(10,20,5))
nodes<-data.frame(id=c("A","B","C","D"),
                  x=c(0,4,0,4),y=c(3,0,0,3))
library(igraph)
g <- graph_from_data_frame(flows, directed=TRUE,
                           vertices=nodes)
library(rSDI)
gout <- SDI(g, variant="nuw") # network/undir./weighted
graph_attr(gout,"SDI_nuw")
gout <- SDI(g, variant="vuw") # vertex/undir./weighted
vertex_attr(gout,"SDI_vuw")
```

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Thank you! Questions?

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References

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