Measuring structural resilience of economies Globalization or deglobalization?

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Agenda

Motivation

Highly globalized international trade vs self-sufficiency

- To make production processes more efficient: specialization, division of labor
- The role of intermediate goods in trade (Johnson and Noguera, 2012; Baldwin and Lopez Gonzales, 2015) and the length of GVC's has increased (Wang et al., 2017)
- The high level of interconnectedness between countries goes hand in hand with the rapid spread of shocks (Fang et al., 2020; Iloskics et al., 2021) in which the structural properties of international linkages have a huge impact (Barrot et al., 2020; Guan et al., 2020)
- The exposure to foreign trade relations carries a high risk (Barrot et al., 2020; Bonadio et al., 2021; Fang et al., 2020; Guan et al., 2020) and the need for self-sufficiency increases (Braun et al., 2021)
- However, backshoring, nearshoring (Piatanesi and Arauzo-Carod, 2019) and for example, in the case of COVID, "renationalizing" (Barrot et al., 2020) do not necessarily make economies less vulnerable

Trade-off

There is an obvious trade-off between efficiency gains from openness (highly globalzed international trade) and high risks from dependence on global value chains (self-sufficiency).

Resilience

The responsiveness of countries to shocks might depend on the resilience of the countries

- Resilience could mean the ability to react to shocks (Reggiani et al., 2002; Annarelli and Nonino, 2016)
- Ecological Network Analysis (ENA) contributo to resilience research (Ulanowicz, 2009) - can also be applied to economic IO data (Kharrazi et al., 2013; Fath, 2015; Chatterjee and Layton, 2020)
- A system's (economy's) resilience level derives from the two structural properties: efficiency and redundancy
  - None of the full efficiency and full redundancy is a good solution
  - An efficient system has only a few mutual relationships, which indicates strong specialized trade flows and corresponds to highly globalized production processes
  - A redundant system has many more similarly weak connections signaling a less specialized and embedded position of elements within the system, corresponding to a lower level of involvement within the international division of labor

The IO network

The IO system

	w_1	w_2	...	w_i	E_i	O_i
w_1	$w_{1,1}$	$w_{2,2}$	...	$w_{i,1}$	e_1	o_1
w_2	$w_{1,2}$	$w_{2,2}$	...	$w_{i,2}$	e_2	o_2
...	...	...	...	...	...	...
w_j	$w_{1,j}$	$w_{2,j}$	...	$w_{i,j}$	e_j	o_j
M_j	m_1	m_2	...	m_j	0	0
I_j	I_1	I_2	...	I_j	0	0

- The rows and columns are the economic sectors
- $w_{i,j}$ shows the trade flow from sector i to sector j
- E_i is the export of sector i
- O_i is the out of sector i
- M_j is the import of sector j
- I_j is the other input of sector j
- $i, j = 1, 2, ...n$

Measuring structural resilience

Based on Ulanowicz (2009) & Chatterjee and Layton (2020)

- Total System Throughput (TST)

$$TST = \sum_{i=0}^{n+2} \sum_{j=0}^{n+2} T_{i,j} \tag{1}$$

- Average Mutual Information (AMI)

$$AMI = \sum_{i=0}^{n+2} \sum_{j=0}^{n+2} \frac{T_{i,j}}{TST} \log_2 \left(\frac{T_{i,j} * TST}{T_{i.} * T_{.j}} \right) \tag{2}$$

where

$$T_{i.} = \sum_{j=0}^{n+2} T_{i,j} \text{ and } T_{.j} = \sum_{i=0}^{n+2} T_{i,j}$$

- Shannon Index (H)

$$H = -\sum_{i=0}^{n+2} \sum_{j=0}^{n+2} \frac{T_{i,j}}{TST} \log_2 \left(\frac{T_{i,j}}{TST} \right) \tag{3}$$

Measuring structural resilience (2)

- Degree of System Order, i.e. structural resilience indicator (α)

$$\alpha = \frac{AMI}{H} \tag{4}$$

- Ecological Fitness Function (R_{eco})

$$R_{eco} = -\left(\frac{AMI}{H}\right) ln\left(\frac{AMI}{H}\right) \tag{5}$$

and the maximum of $R_{eco} = 1/e = 0.368$ ($e = 2.7183$, Euler's Number)

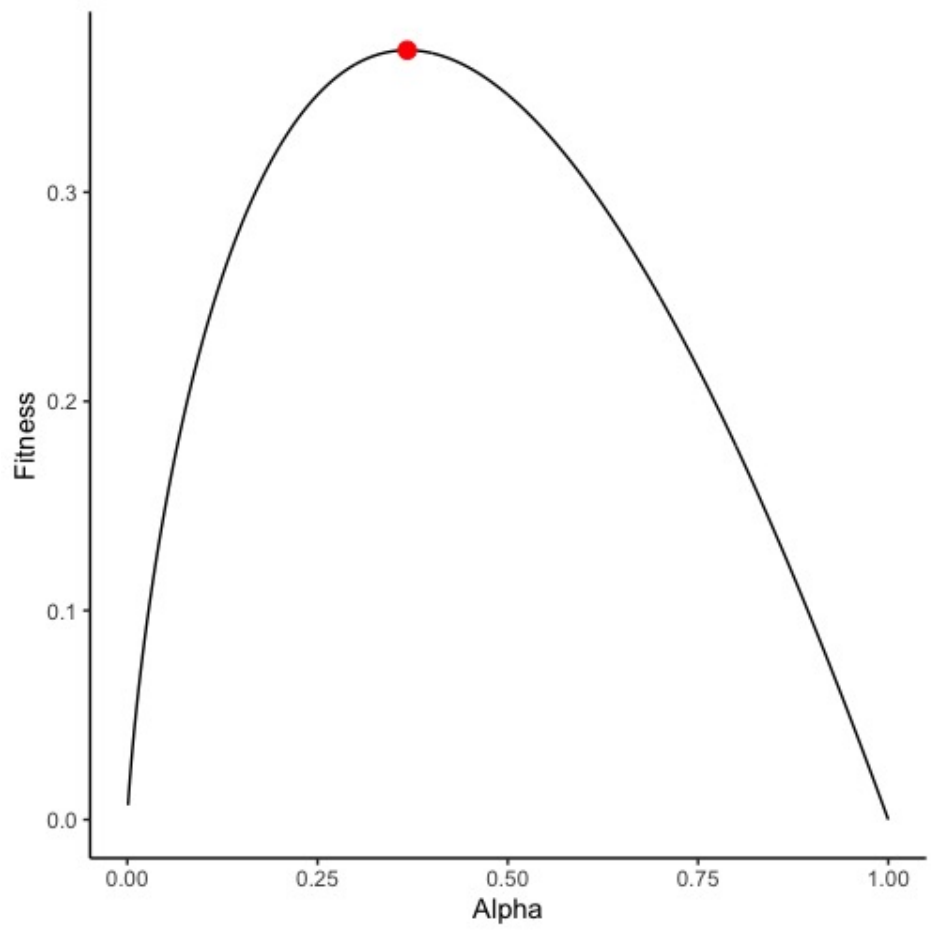
- Fitness for Evolution (F_s)

$$F_s = -e\alpha^{\beta} log\left(\alpha^{\beta}\right) \tag{6}$$

where β is a coefficient, which serves to adjust the optimal α value

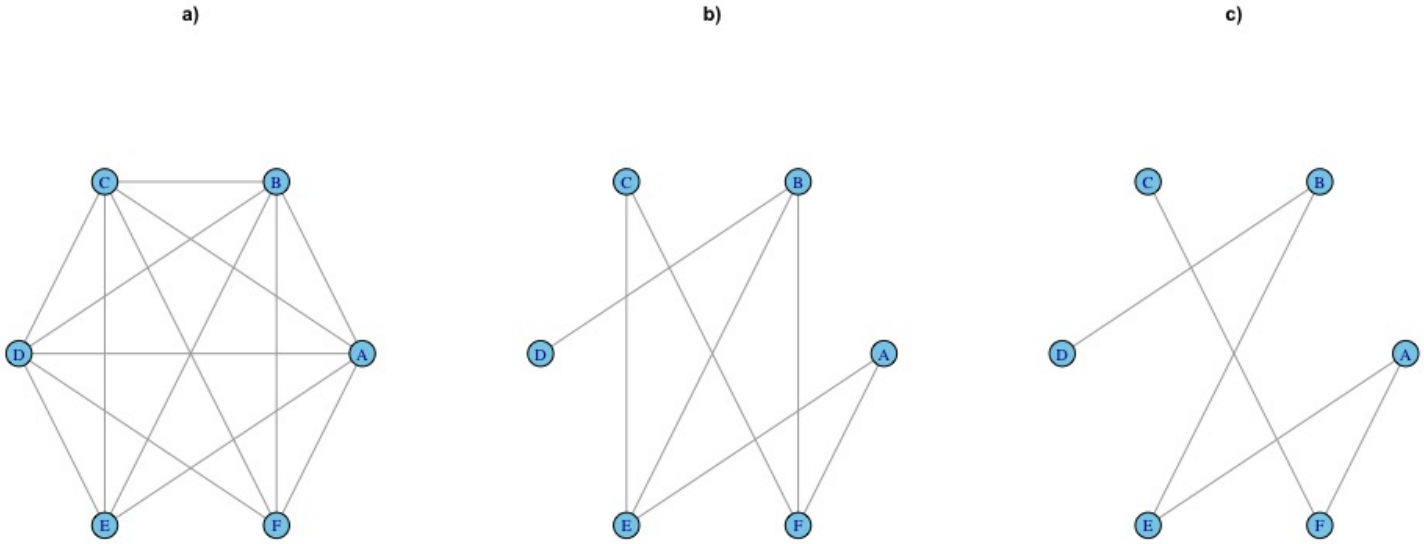
Ecological optimum for resilience on redundany-efficiency scale

Figure 1: Resilience and redundancy-efficiency structure



An example

Figure 2: Network illustration for resilience



	Network a)	Network b)	Network c)
α	0.0722	0.3147	0.5183
Fitness	0.1899	0.3638	0.3406

Self-organization

Based on Finn (1976)

- Construct Leontief-inverse matrix (**L**), where **I** is the identity matrix

$$\mathbf{L} = (\mathbf{I} - \mathbf{W})^{-1} \tag{7}$$

- The sectoral-level cycling index (FCI_i)

$$\hat{l}_i = \frac{l_{ii} - 1}{l_{ii}} \tag{8}$$

$$FCI_i = \hat{l}_i \frac{T_{.i}}{\sum_i T_{.i}} \tag{9}$$

- The country-level cycling index (FCI)

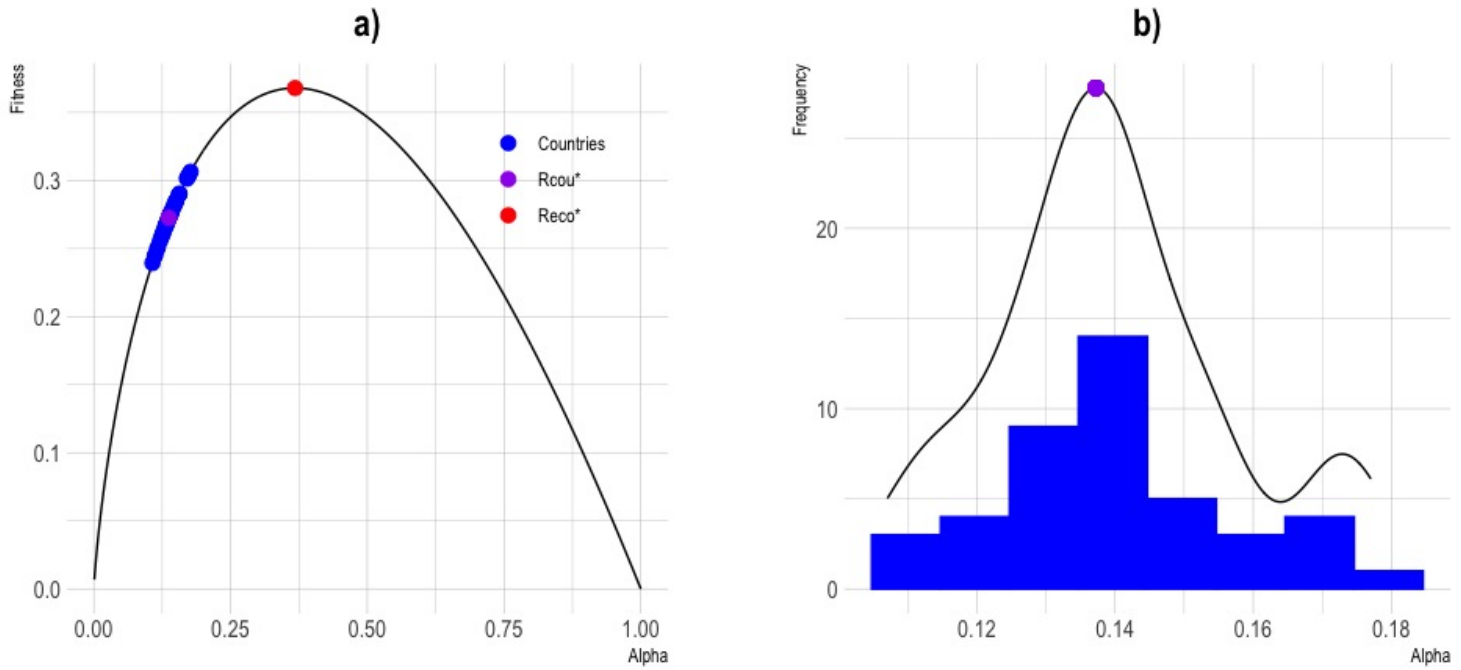
$$FCI = \sum_{i=0}^{n} FCI_i \tag{10}$$

Data

- Trade flows and IO data: WIOD (Release 2016)
  - 43 countries, 56 sectors per country
  - Years: 2000-2014
  - We create domestic IO tables and sum imports, exports, other inputs and outptus into one-one column
  - Openness: the imported inputs divided by the total input, weighted by the size (total output) of the sectors
- Macroeconomic data: Penn World Tables (9.1 version)
  - GDPPC: real GDP at chained PPPs (in thousands bil. 2011 US dollar, per capita)
  - EMP: employment (in millions)
  - CAPITAL: capital stock at current PPPs (in thousands bil. 2011 US dollar)

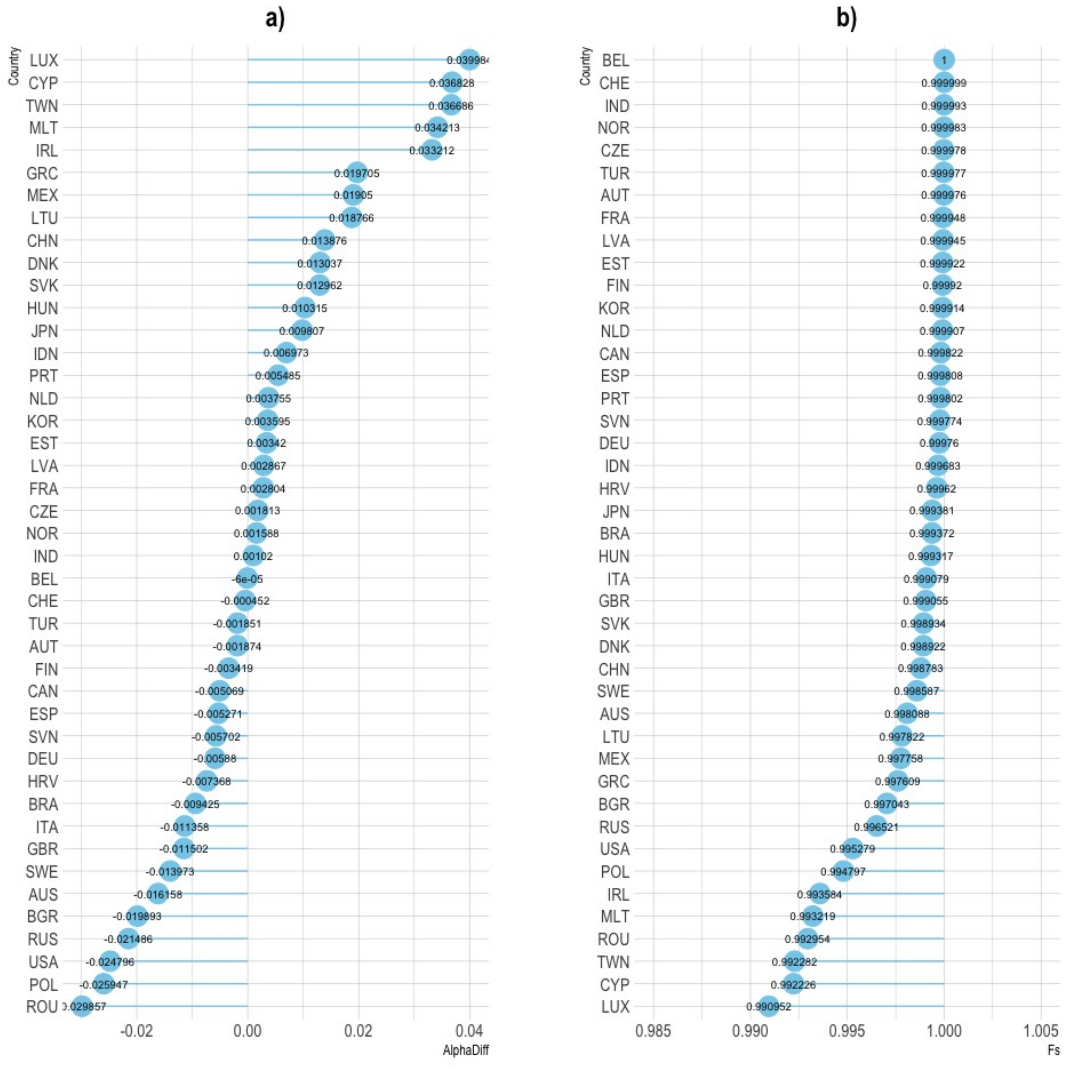
Ecological vs. experiential (economic) optimum

Figure 3: The structural resilience of the IO economies (2014)



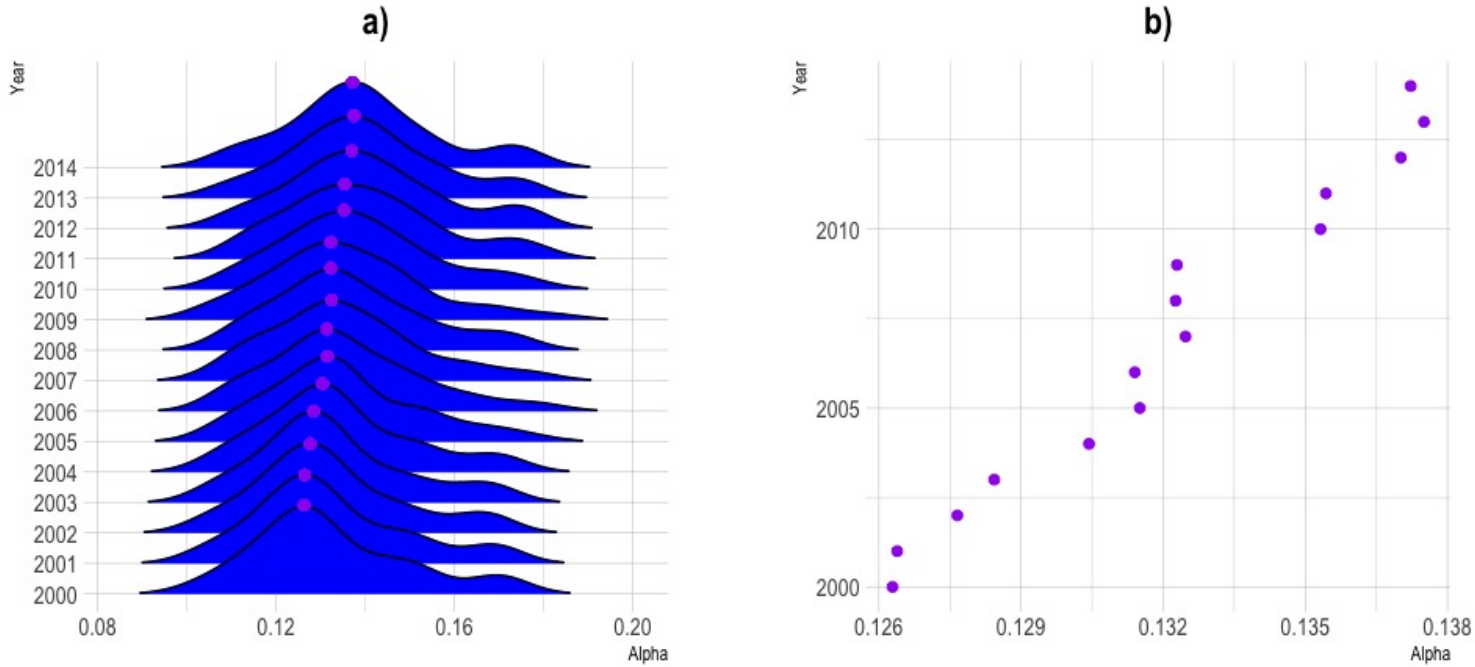
Structural properties of the IO economies

Figure 4: Countries' redundancy and efficiency (2014)



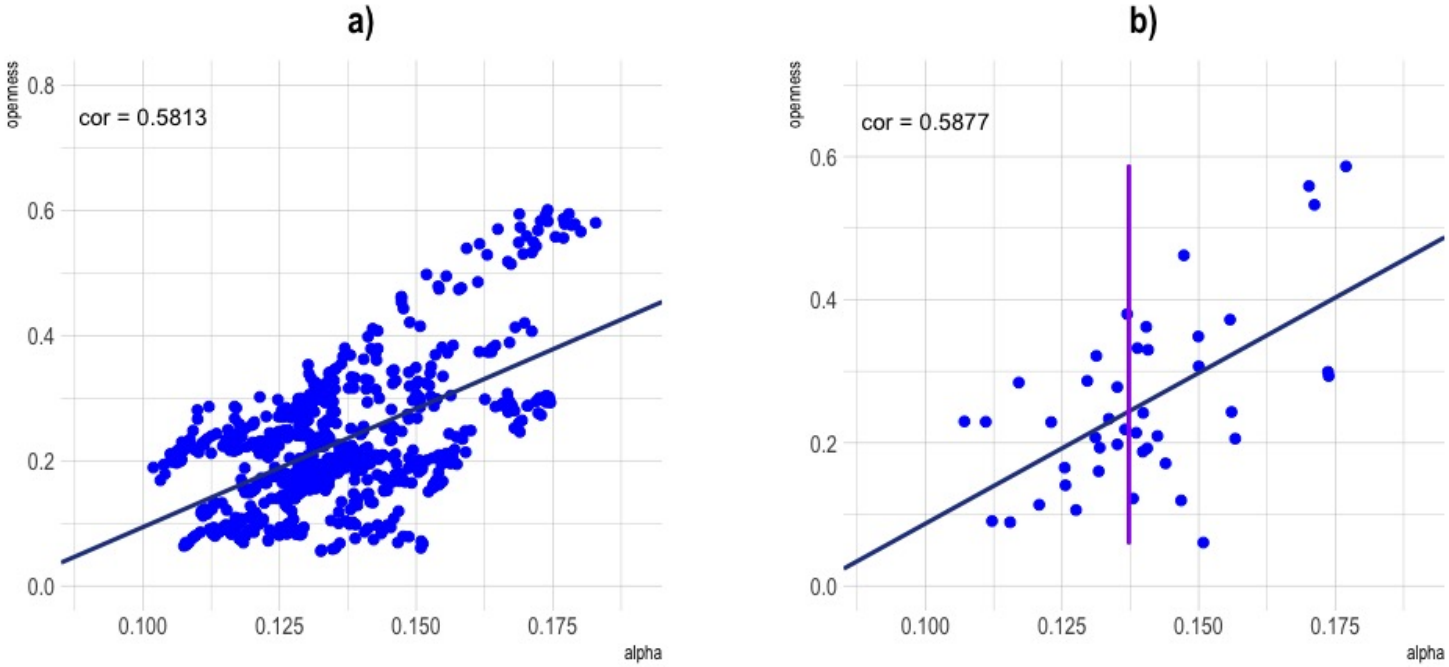
The dynamic of resilience indicators

Figure 5: The evaluation of experiential (economic) optimum (2000-2014)



Test the analogy

Figure 6: The correlation between resilience indicator and openness



Test the analogy (2)

Table 1: Regression table for the connection between structural properties (redundancy and efficiency) and openness (the level of self-sufficiency and international trade)

	Pooled	Panel A1	Panel A2	Panel A3	Panel A4
Intercept	1.080E-01***				
	(1.662E-03)				
OPEN	9.414E-02***	7.383E-02***	7.612E-02***	7.965E-02***	9.169E-02***
	(5.844E-03)	(2.600E-02)	(2.627E-02)	(2.524E-02)	(2.605E-02)
GDPPC	1.670E-07***		-4.227E-07***	-3.930E-07***	-3.651E-07***
	(4.108E-08)		(1.349E-07)	(1.314E-07)	(1.284E-07)
EMP	3.842E-05***			7.277E-05	-1.544E-04**
	(5.538E-06)			(1.620E-04)	(7.421E-05)
CAPITAL	-1.015E-04				4.703E-04***
	(7.749E-05)				(6.554E-05)
Country FE	No	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Adj. R^2	0.3964	0.0405	0.0927	0.0984	0.1722
F-stat	106.7514	84.1537	61.9026	43.0833	48.4821

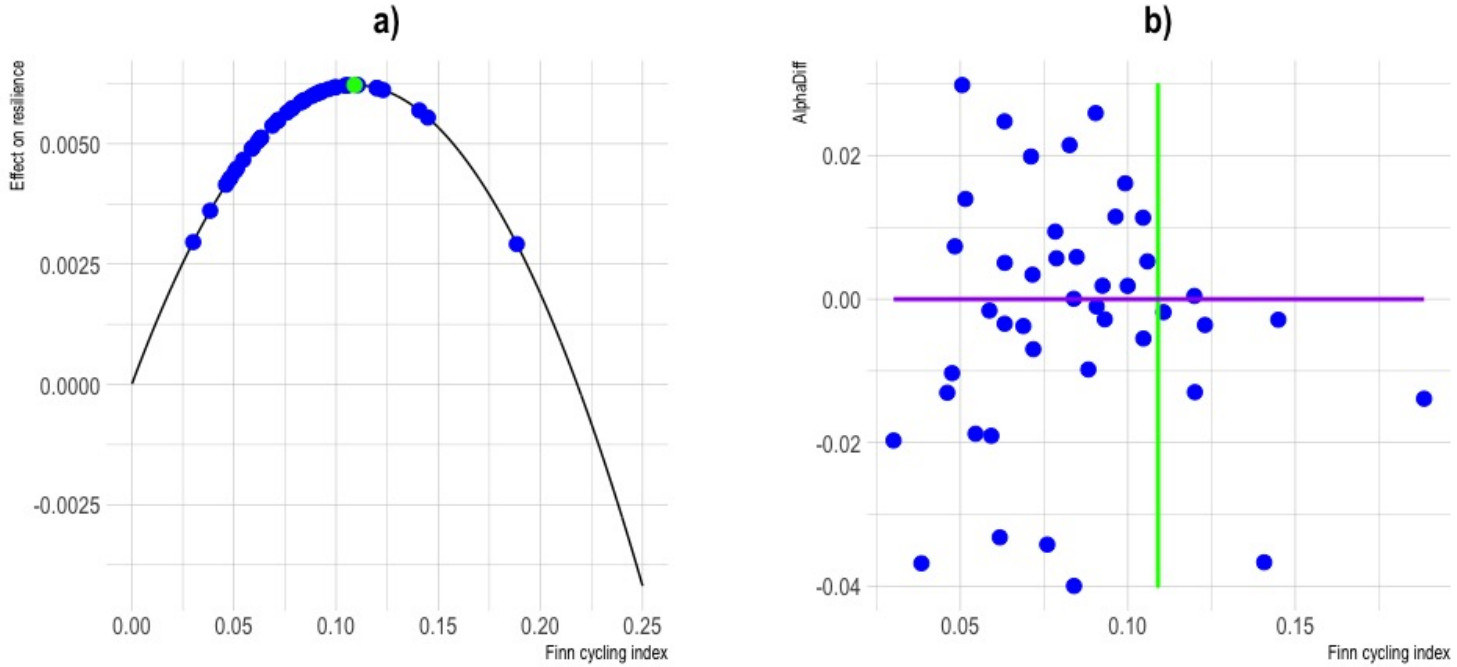
Resilience and self-organization

Table 2: Regression table for the connection between resilience and self-organization

	Pooled	Panel A1	Panel A2	Panel A3	Panel A4
Intercept	9.980E-01***				
	(7.524E-04)				
FCI	1.296E-02	7.742E-02*	8.783E-02**	8.625E-02**	1.141E-01**
	(1.587E-02)	(4.002E-02)	(3.688E-02)	(3.831E-02)	(4.520E-02)
FCI^2	-2.302E-02	-3.174E-01**	-3.575E-01**	-3.475E-01**	-5.236E-01**
	(8.460E-02)	(1.558E-01)	(1.445E-01)	(1.559E-01)	(2.052E-01)
GDPPC	-2.839E-08***		-5.744E-08	-5.901E-08	-5.316E-08
	(6.778E-09)		(4.708E-08)	(4.925E-08)	(4.804E-08)
EMP	1.040E-06			-3.982E-06	-3.480E-05*
	(1.073E-06)			(1.372E-05)	(1.978E-05)
CAPITAL	-1.047E-05				7.816E-05*
	(1.224E-05)				(4.671E-05)
Country FE	No	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Adj. R^2	0.0522	-0.0643	-0.0499	-0.0513	-0.0289
F-stat	8.0891	9.5564	9.4705	7.1393	8.5810

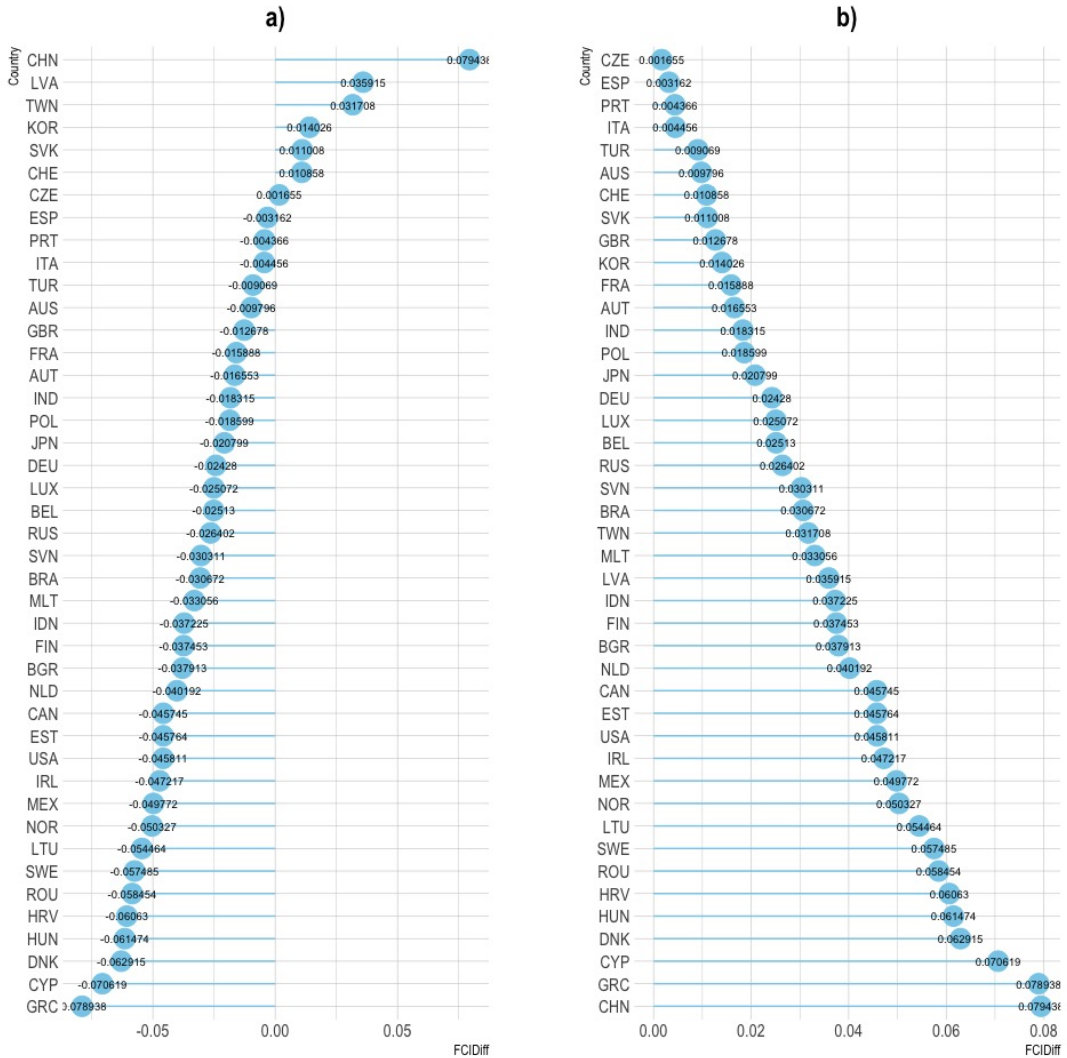
Resilience and self-organization (2)

Figure 7: The optimal level of self-organization



Optimal self-organization

Figure 8: The level of countries' self-organization (2014)



Discussion

- Optimum: ecological vs. experiential
  - Fath (2015) discussed in detail
  - Higher redundancy: sectoral IO data are very aggregated data - denser network
  - Experiential optimum: not stable - weaken the barriers
- Self-organization
  - Openness influnces negatively the cycling index (Braun et al., 2021)
  - Countries with effective (redundant) structure and low (higher) cycling - reduce (increase) the level of international trade
  - Countries with redundant structure and low cycling - deeper structural changes are needed
- Policy implications
  - The results shed light on which country has to reduce the exposure of international trade and which country has to increase the specialization
  - Where is it necessary to strengthen/weaken the level of self-organization?

Thank you for your attention!

All coments and questions are welcome!

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Check our latest papers

- Braun, E. - Sebestyén, T. - Kiss, T. (2021): The strength of domestic production networks: an economic application of the Finn cycling index. *Applied Network Science* 6(1) 1-26.

- Iloskics, Z. - Sebesytén, T. - Braun, E. (2021): Shock propagation channels behind the global economic contagion network. The role of economic sectors and the direction of trade. *PLoS one* 16(10) e0258309.

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