

Multidimensional Connectivity and Growth

A Network Analysis with applications to Europe and Central Asia (ECA)

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Why this study?

- Connectivity—or “globalization”—and its relationship to economic growth is often viewed in one dimension (i.e., trade, migration, FDI, transport, etc.) through its impact on the transfer of ideas and technological knowledge
 - But these connections can be complements or substitutes
 - Migration and trade; FDI and trade; Migration and FDI
- To whom you are connected to might be just as important as the type of connection
 - Trade with Germany may be more important than trade with Algeria—not only due to the level of technological potential embodied in exports/imports, but also the connections of your partner’s connections
- Growth analysis using a “multidimensional connectivity” in a network framework is a natural way to address these potential complementarities and “partner-of-partner” effects.
- This is the first study to develop a multidimensional network connectivity measure and apply it to analyzing growth

Key findings

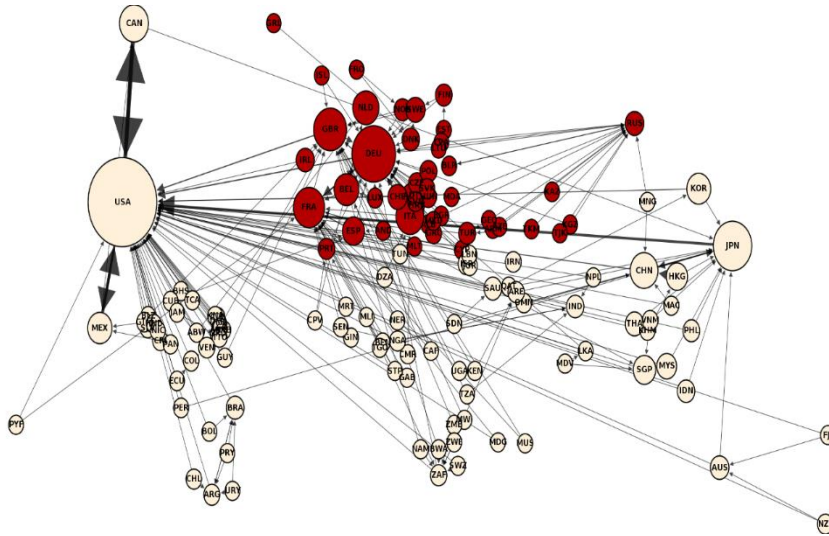
- Being well-connected in the global network of countries of is important for long-run economic growth.
- Nonetheless, because of complementarities in types of connections (trade, FDI, migration, etc.), a balanced connectivity profile maybe more important for growth than being well connected in a single dimension.

Stylized Facts for ECA

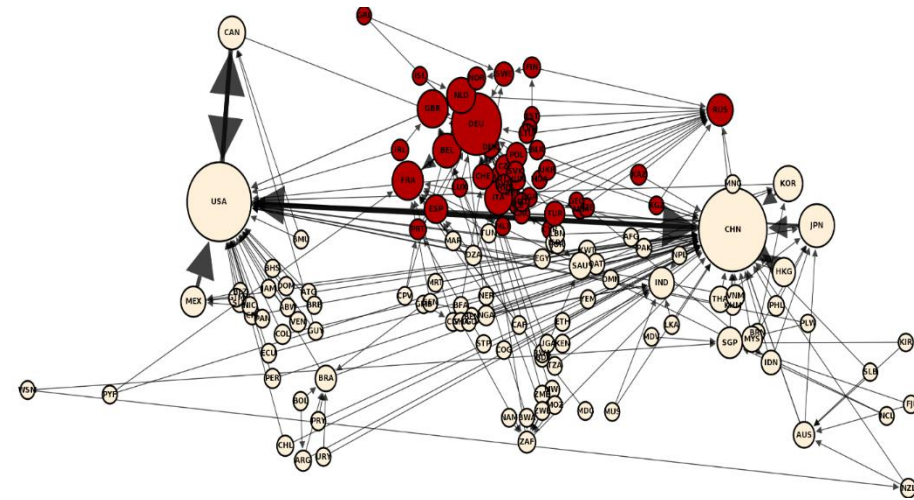
Trade has grown within ECA, although China is taking a larger share of global trade

(Exports + Imports, size of node is total value)

2000



2014

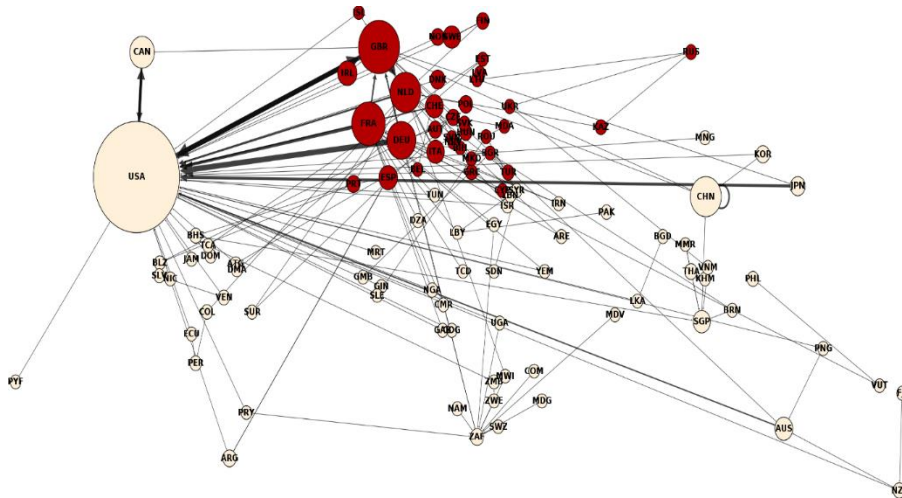


Red nodes are Europe and emerging ECA countries

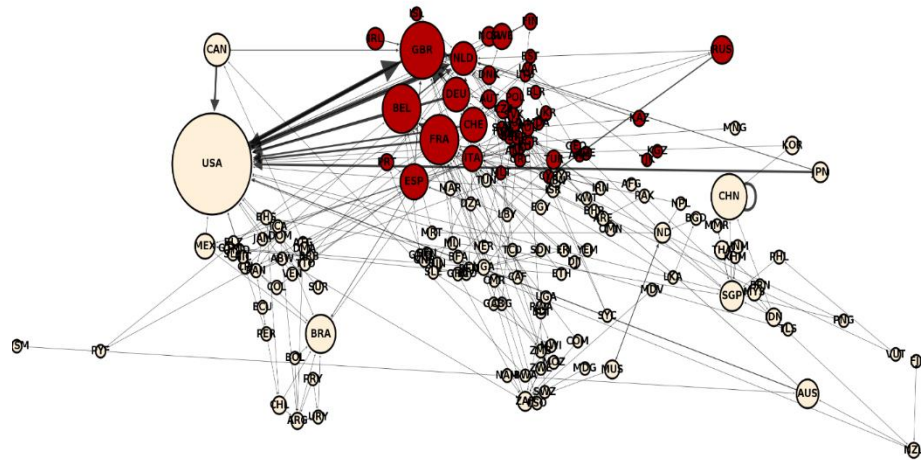
ECA's inward FDI has grown, but inflows have increased from outside the region

(Inward stocks, size of node is total value)

2003



2012



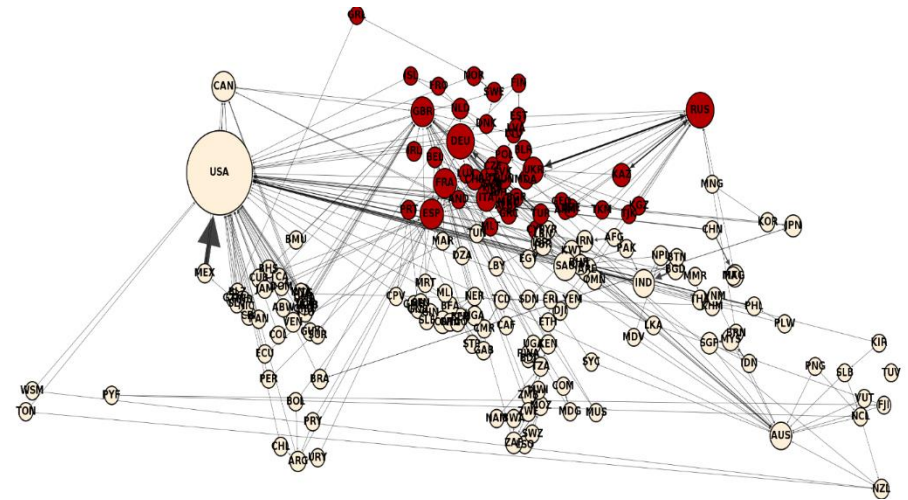
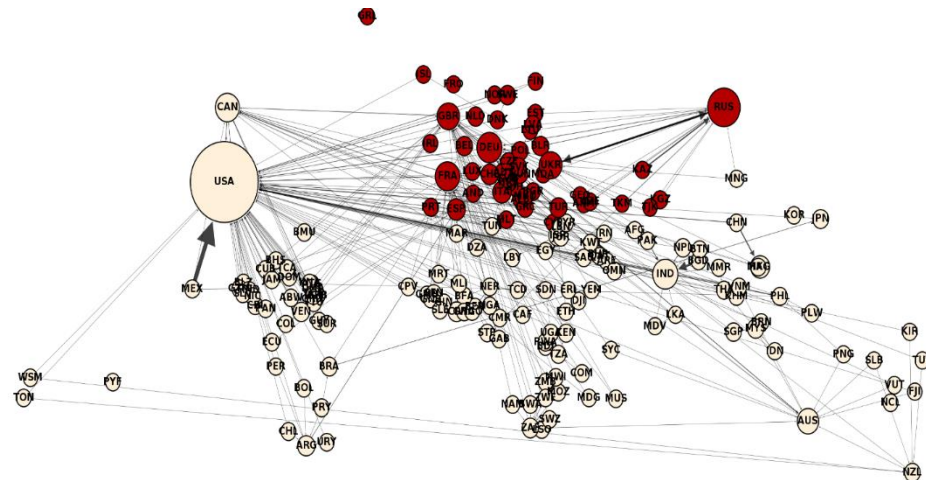
Red nodes are Europe and emerging ECA countries

ECA's intra-regional migration has increased and is a larger share of global migration

(Inward Stocks, size of node is total number)

2000

2010

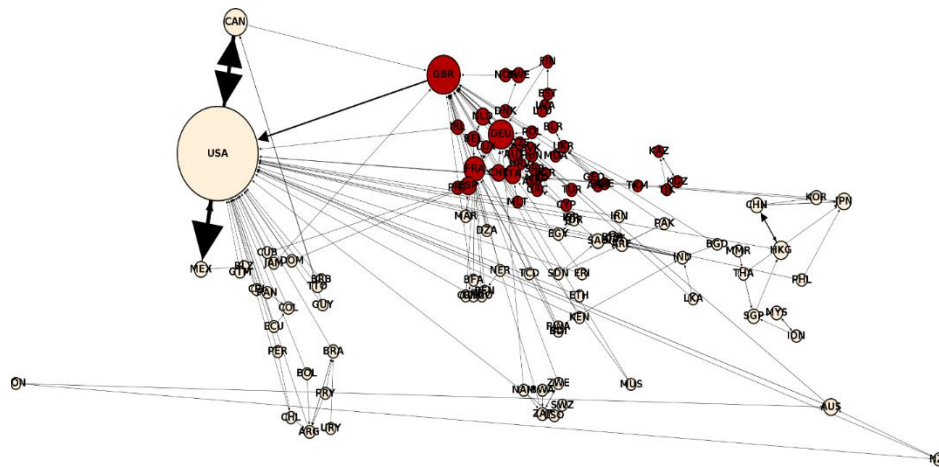


Red nodes are Europe and emerging ECA countries

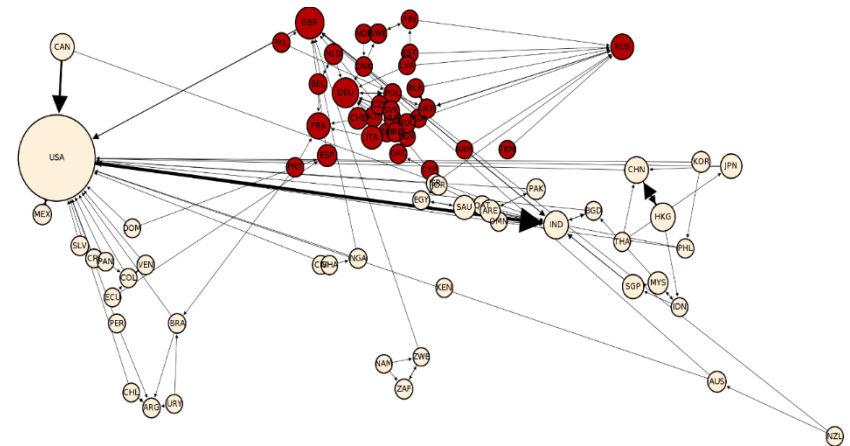
ECA's intra-regional ICT has not increased relative to the rest of the world

(Index of internet and phone flows, size of node is outgoing communication)

2000



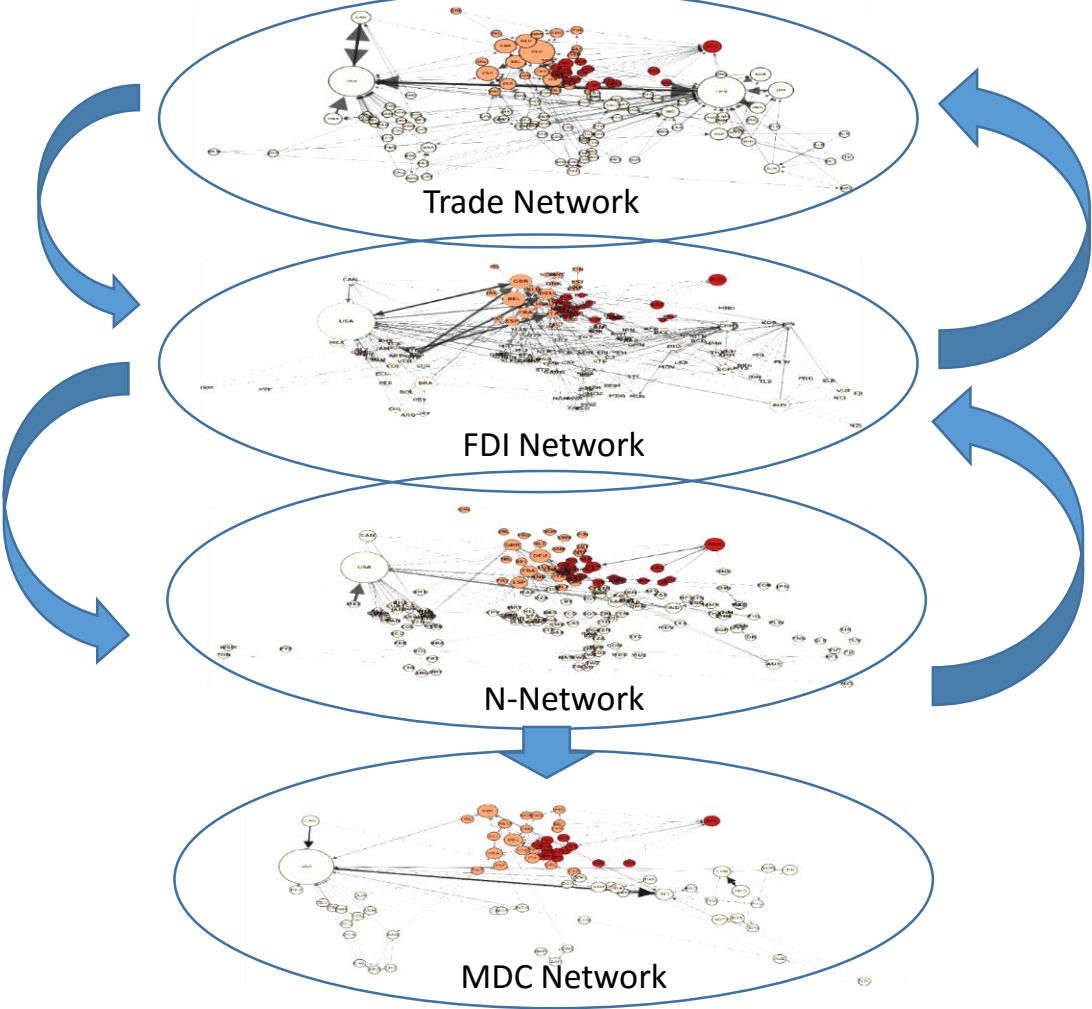
2012



Russia data not available in 2000.

Red nodes are Europe and emerging ECA countries

Multidimensional Connectivity



Trade Network

FDI Network

N-Network

MDC Network

Growth Model with Network Effects

$$g_{it} = a + BX_{it} + \phi\Theta'_{it} + e_{it}$$

- X_i is a matrix of covariates which determine growth (initial GDP per capita, education, government size and inflation)
- Θ'_i is a network centrality measure which proxies the amount of “knowledge” in country i due to its overall connectivity (position in the network)
- We assume that knowledge travels through the various channels: international trade, FDI and migration

Classic PageRank Algorithm

$$PR_i = \lambda \sum_k L_{ki} PR_k + \rho_i$$

where:

L_{ki} indicates if web page k links to web page i

ρ_i indicates the “relevance” of the web page content for a given search query

λ is weight parameter

PageRank Centrality and Economic Growth

$$\Theta_{it} = \lambda \sum_k \left(x_{ik t_0}^\alpha f_{ik t_0}^\beta m_{ik t_0}^\gamma c_{ik t_0}^\eta \right) \Theta_{kt} + y_{it}$$

where y_i is GDP per capita (or another proxy for the intrinsic knowledge in country i)

$$x_{ik} = \frac{TRADE\ FLOW_{ik}}{\sqrt{GDP_i GDP_k}},$$

$$f_{ik} = \frac{FDI\ STOCK_{ik}}{\sqrt{GDP_i GDP_k}},$$

$$m_{ik} = \frac{MIGRATION\ STOCK_{ik}}{\sqrt{POP_i POP_k}},$$

$$c_{ik} = \frac{ICT\ FLOW_{ik}}{\sqrt{POP_i POP_k}},$$

Finally, in order to adjust for the fact that initial GDP per capita appears in the centrality measure as well as the list of independent variables in the growth equation we modify the PageRank centrality in the following way:

$$\Theta'_{it} = \Theta_{it} - y_{it}$$

Econometric model

MAIN EQUATIONS

$$g_i = a + BX_i + \phi\theta'_i + e_i$$

$$\theta_i = \lambda \sum_k x_{ik}^\alpha f_{ik}^\beta m_{ik}^\gamma c_{ikt}^\eta \theta_k + y_i$$

$$x_{ik} = \frac{\text{TRADE FLOW}_{ik}}{\sqrt{\text{GDP}_i \text{GDP}_k}},$$

$$f_{ik} = \frac{\text{FDI STOCK}_{ik}}{\sqrt{\text{GDP}_i \text{GDP}_k}},$$

$$m_{ik} = \frac{\text{MIGRATION STOCK}_{ik}}{\sqrt{\text{POP}_i \text{POP}_k}},$$

$$c_{ik} = \frac{\text{ICT FLOW}_{ik}}{\sqrt{\text{POP}_i \text{POP}_k}},$$

MAIN FEATURES

- More connected countries have greater stocks of knowledge (θ)
 - Each economy has a “base” level of knowledge which is proportional to its income per capita (technology)
- Deeper connections to high income countries are preferable
 - The information channels (trade, FDI, migration, ICT) are not perfect substitutes - the more diversified the links the better
- θ'_i represents the stock of knowledge due only to the network connections

Empirical results

Growth Regressions (2000-2016)

	Model 1	Model 2	Model 3	Model 5	Model 6	Model 7
Initial GDP per capita	-1.00***	-1.017***	-.996***	-1.018***	-1.028***	-1.032***
Years of schooling	.380***	.398***	.369***	.399***	.406***	.411***
Government size	-.059*	-.066*	-.060*	-0.058	-.059*	-.060
Inflation	-.010	-.015	-0.011	-0.015	-.017	-.019
Trade Openness	.004	0.002	.004*	0.004	0.004	0.0038

Network Effects (PageRank)

Multidimensional Connectivity	28.86*					
Trade (t ₀)		72.66**	33.959*			
Migration (t ₀)		25.91		10.848		
Fdi (t ₀)		-19.83			-0.103	
ICT (t ₀)		-58.71				-4.764
Adj-R2	0.436	0.418	0.409	0.393	0.389	0.39

Efficiency of Transmission Channels

MODEL OUTPUT

Parameter	Value
Trade (α)	0.530
Migration (β)	0.416
FDI (γ)	0.053
ICT (η)	0.001

MAIN TAKEAWAYS

- The main transmission channels for growth-relevant technological information are international trade and migration
- FDI links appear to have a weaker effects in transferring information
- We don't find any significant effect of our proxy for ICT

Policy Tool (example)

What is the optimal investment location from a multidimensional connectivity perspective

A Simple Policy Problem

- Kazakhstan wants to invest \$100M in Central Europe
- We assume that the risk-adjusted return on the investment has been equalized across the countries by the market
- What is the optimal location for this investment from the growth/connectivity perspective?

Policy Simulation: Kazakhstan Example

SIMULATION RESULTS

Country	Knowledge in Target Country (θ_r)	Knowledge in Kazakhstan (θ_i)
Bulgaria	0.0067	0.0053
Poland	0.0118	0.0051
Czech Rep.	0.0117	0.0052
Hungary	0.0111	0.0052
Slovenia	0.0068	0.0051
Romania	0.0098	0.0051

- We simulate an FDI investment of \$100M from Kazakhstan to each Central European country and its effect on connectivity and access to knowledge in Kazakhstan
- Although countries like Poland are more integrated in the global network, their weak links with Kazakhstan in terms of migration and trade reduce the informational effectiveness of the investment
- Despite having lower overall knowledge, Bulgaria offers the greatest marginal informational benefits to Kazakhstan due to the deeper bilateral links (there are complementarities between trade, FDI and migration)

Kazakhstan Example (cont'd)

- The optimal investment Central European location for Kazakhstan is Bulgaria
- The difference between the first (Bulgaria) and second place (Poland) is approximately 0.002% of economic growth
- This translates to approximately \$1.85M of additional annual growth grains over the long-run

Areas for Further Research

- Impact of connectivity on the income growth of the poorer members of society
- Effect of the educational level of migrants on the sending and receiving countries
- Growth impact of FDI in different sectors (e.g. excluding FDI in raw materials)