Evolution of Global Crude Oil Dependence: A Weighted-Directed Graph Analysis

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Evolution of Global Oil Dependence

Outline

- Introduction
- Framework
- Dataset
- Results
- Conclusions

Introduction and Motivation
What and Why

- Networks increasingly becoming *interdependent*
  - e.g. Internet and power grid
- Interactions are *complex*
  - Internet is complex enough
    - e.g. layers, protocols, domains, planes, *policies*
- Motivation
  - understand and analyze interdependent graphs
  - apply *graph theory in an economic context*
- Highlight of the work
  - graph-theoretic analysis of crude oil exchange over 17 years

Framework
Analysis Method

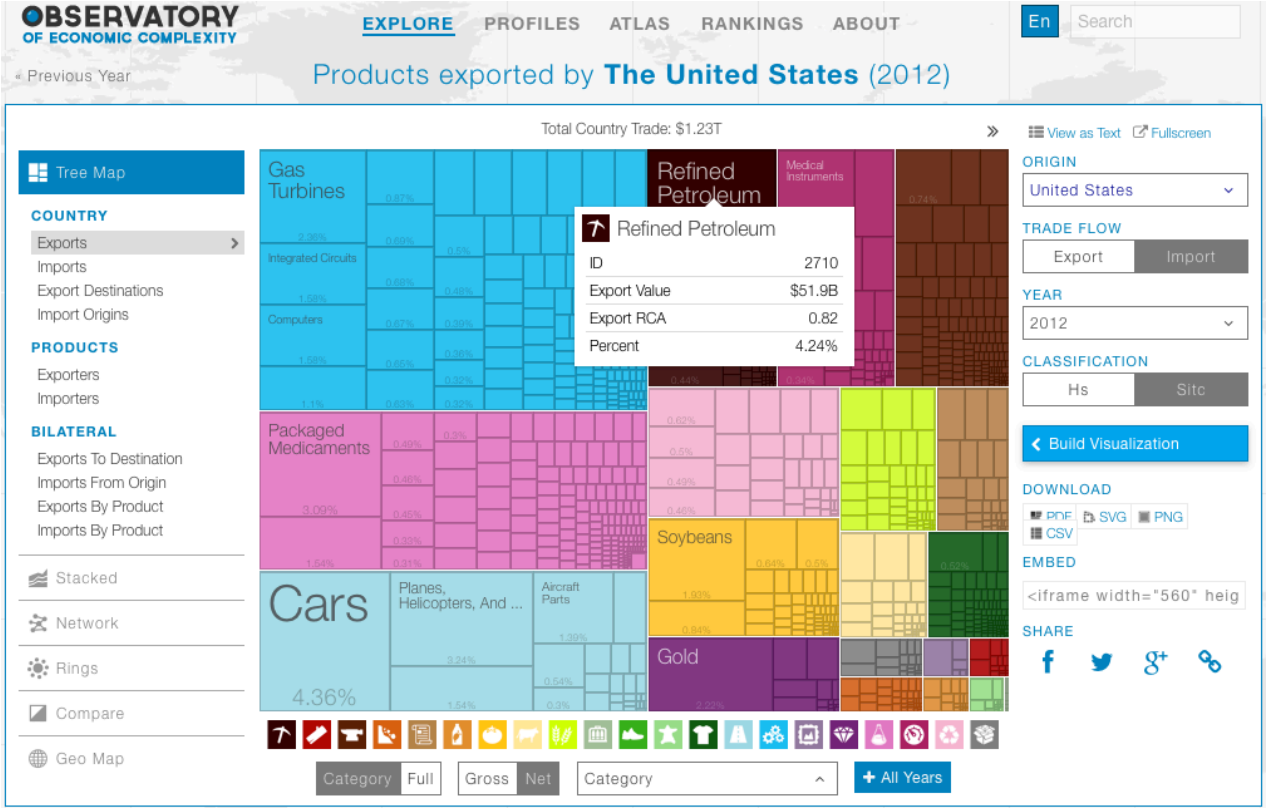
- Graph-theoretic framework
  - to analyze interdependencies among nodes
- Model interdependencies as directed graphs:
  - unidirectional: A → B
  - bidirectional: A ↔ B
- Investigate *connectivity* of *weighted graphs*
  - fraction of nodes remain connected after node/link attacks
- Attacks based on graph *centrality metrics*
  - degree, betweenness, closeness, eigenvector, PageRank
  - adaptive: recalculation after each iteration
- Utilize Python NetworkX library

Dataset
Global Crude Oil Exchange

- Utilized Atlas dataset by MIT
  - `https://atlas.media.mit.edu`
- Global petroleum exchange data: from 1995 to 2012
- We utilize data on: 1995, 2000, 2005, 2010, 2012
  - first and last years, as well as increments of 5 years
  - NSRCI abstract shows only for 1995 and 2012
    - due to space constraint
    - more on extended version [YPÇ2015]
- Weight of a link is export or import value in USD $

Dataset

Atlas Data

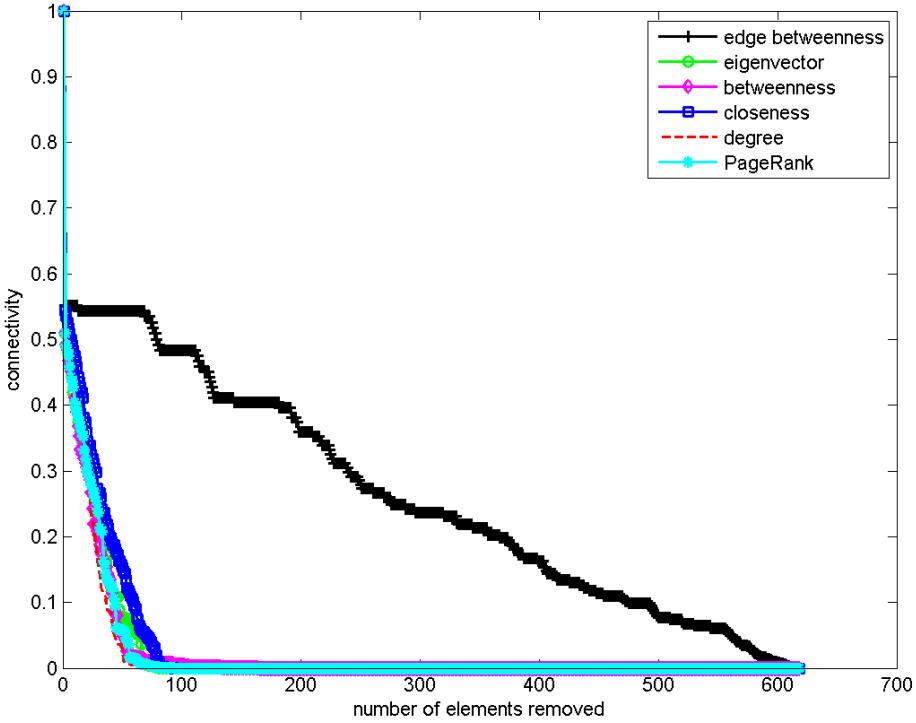


- [Atlas] https://atlas.media.mit.edu

Dataset
Graph Properties per Year

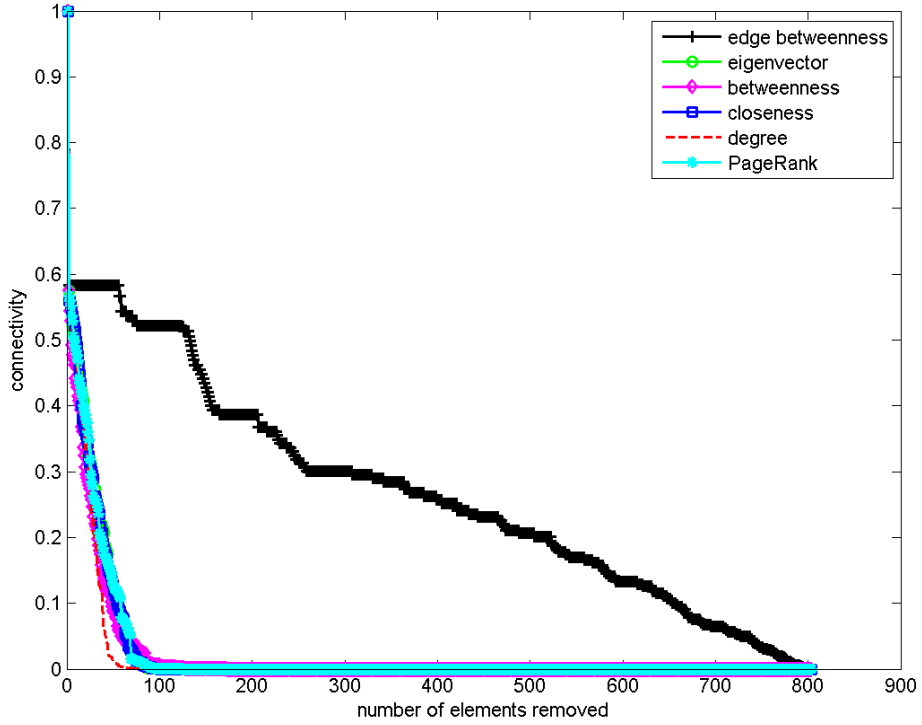
Year	Number Nodes (countries)	Number of Links (exchanges)
1995	190	678
2000	191	867
2005	192	1002
2010	194	1080
2012	199	993

Results
Connectivity in 1995



- Adaptive attacks based on node and link centralities

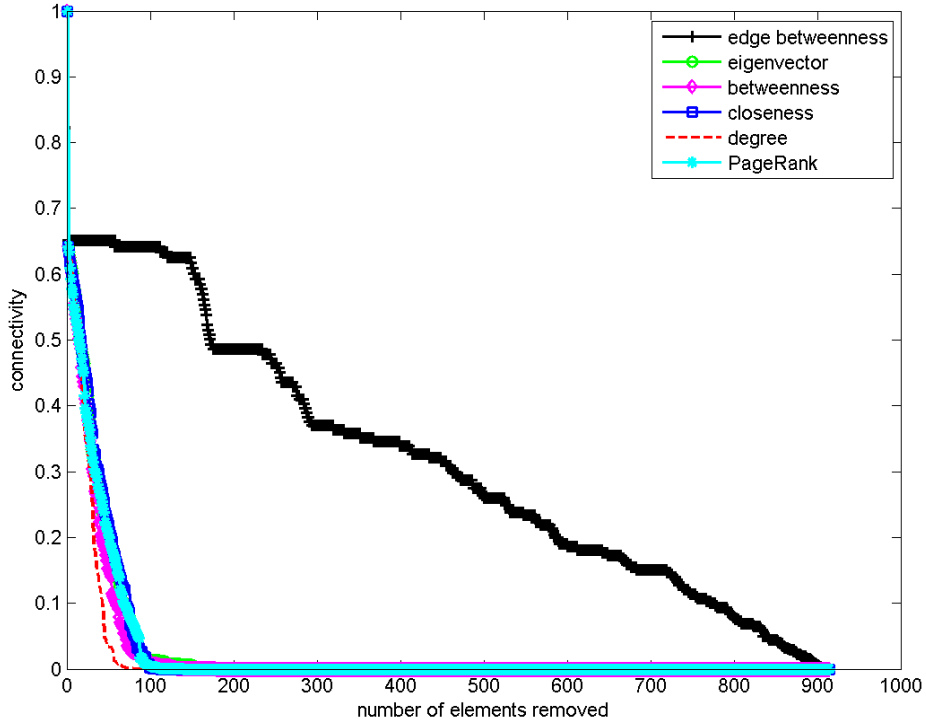
Results
Connectivity in 2000



- Adaptive attacks based on node and link centralities

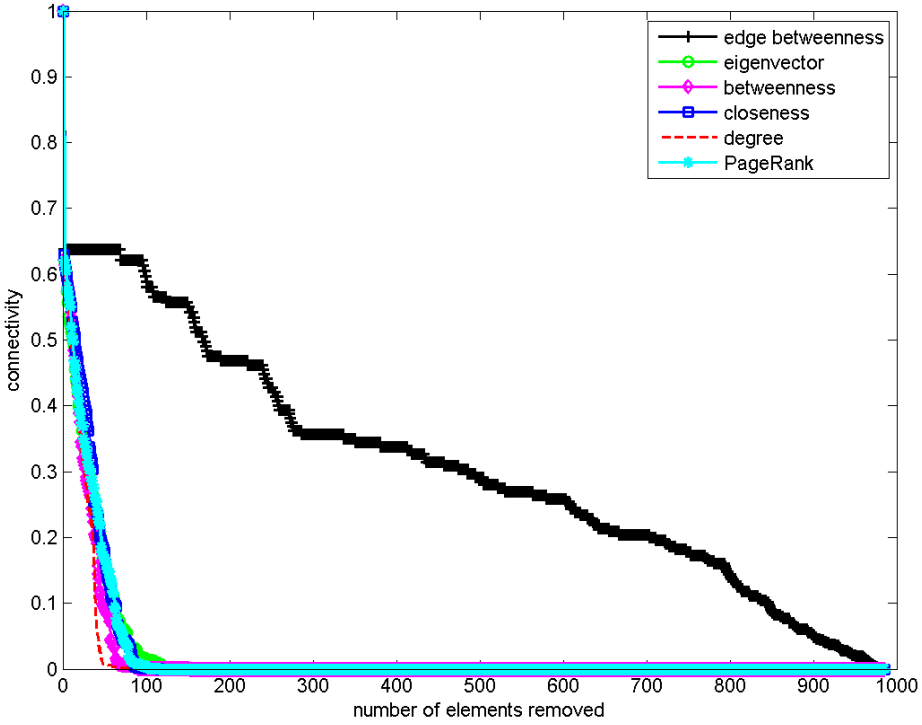
Results

Connectivity in 2005



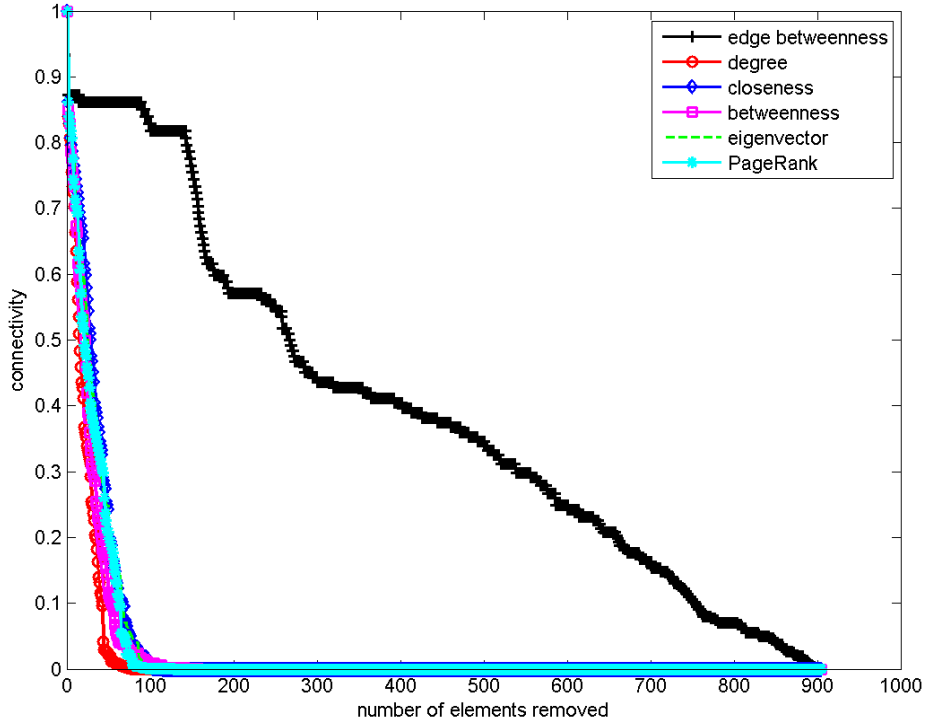
- Adaptive attacks based on node and link centralities

Results
Connectivity in 2010



- Adaptive attacks based on node and link centralities

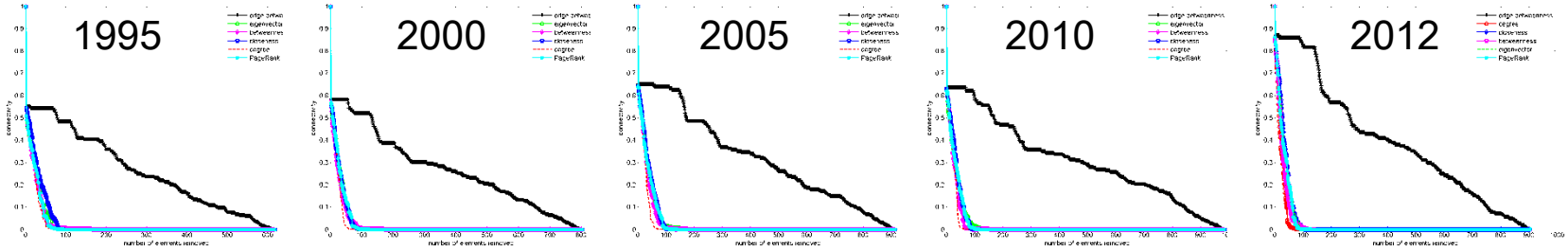
Results
Connectivity in 2012



- Adaptive attacks based on node and link centralities

Results

Connectivity Comparison: 1995-2012



- *Improved connectivity* over years
  - it takes more number of nodes/links to partition the network
  - graph size also increased
    - new countries are born
    - new connections are established between countries
- Rankings of countries vary based on graph metrics
  - degree centrality captures better

Conclusions and Future Work

Interesting Results and What is Next?

- Evaluated evolution of global petroleum exchange
  - 1995 through 2012 over 17 years, using graph theory
- Graph size slightly changed over 17 years
  - number of nodes increased ~ 190 ➔ 200, 5%
  - number of links increased ~ 680 ➔ 1000, 45%
- Connectivity of global network improved
- Future work
  - can we predict energy dependence of a nation?
  - apply framework on other networks
  - improve the resilience of interdependent networks

References and Further Reading

- [PYÇ2015i] Srinath Pinnaka, Rajgopal Yarlagadda, and Egemen K. Çetinkaya, "Evolution of Global Crude Oil Dependence: A Weighted-Directed Graph Analysis", *2nd National Symposium on Resilient Critical Infrastructure*, Philadelphia, PA, August 2015.
- [YPÇ2015] Rajgopal Yarlagadda, Srinath Pinnaka, and Egemen K. Çetinkaya, "A Time-Evolving Weighted-Graph Analysis of Global Petroleum Exchange", *IEEE/IFIP USRR*, Munich, October 2015.
- [PYÇ2015ii] Srinath Pinnaka, Rajgopal Yarlagadda, and Egemen K. Çetinkaya, "Modelling Robustness of Critical Infrastructure Networks", *IEEE/IFIP DRCN*, Kansas City, MO, March 2015, pp. 95 – 98.
- [SHÇ+2010] James P.G. Sterbenz, David Hutchison, Egemen K. Çetinkaya, Abdul Jabbar, Justin P. Rohrer, Marcus Schöller, and Paul Smith, "Resilience and Survivability in Communication Networks: Strategies, Principles, and Survey of Disciplines," *Computer Networks*, Vol. 54, No. 8, pp. 1245 – 1265, June 2010.
- [NetworkX] `https://networkx.github.io`
- [Atlas] `https://atlas.media.mit.edu`