Measuring Market Power in International Trade

Problems with Centralities in Trade Networks

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1 Market Power and Influence

2 Networks

3 Centralities

4 TradeRank

5 Application

6 Validation

7 Contributions

National Power

National Power refers to the ability of a state to shape outcomes in the international system through economic, military, or diplomatic means.
Albert O. Hirschman's work on power dynamics emphasizes:

- **National Power and the Structure of Foreign Trade** (1945): Trade relationships create power imbalances; *coercive potential* via concentrated trade (later formalized as HHI).
- **Power as Dependence**: Asymmetric dependencies in economic/political relationships, where power stems from another actor's reliance.
- **Economic Dimension**: Foreign trade is a "pivotal, yet integrated" part of national power.

Note: Hirschman's focus is *coercion*; Nye later expands this with *soft power*.

Market Power: Definition and Scope

Market Power is the capacity of an actor to:

- Influence prices above competitive levels.
- Restrict output or limit supply.
- Shape market conditions to their advantage.

Sources of Market Power include:

- Structural barriers (e.g., high capital requirements, legal restrictions).
- Strategic advantages (e.g., patents, proprietary technology, or exclusive access to resources).
- Network effects, where the value of a product or service increases with the number of users.

Market Power in Practice:

- Monopolies and oligopolies exploit market power to set prices, terms or force other actors to change their behaviour.
- Dominant actors may engage in predatory pricing or bundling to exclude competitors.

Joseph Nye: Soft Power and Interdependence

Joseph Nye's work refines Hirschman's framework by introducing **soft power**:

- **Soft Power**: The ability of a state to "get other countries to *want* what it wants"—achieved through attraction, persuasion, and cultural appeal (e.g., diplomacy, branding, or thought leadership).
- **Hard Power vs. Soft Power**: Contrasts with Hirschman's coercive power (hard power), emphasizing *mutual dependence* across spheres like security, trade, and finance.
- **Interdependence**: Power is not zero-sum; it arises from asymmetric but *interdependent* relationships, where influence is shaped by structural changes (e.g., supply chain shifts, policy incentives).

Relevance to Trade Networks:

- Soft power aligns with **market influence**—gradual restructuring of trade flows, standards, or consumer behavior (e.g., US decarbonization efforts reshaping oil markets).
- Complements Hirschman's coercive focus by capturing *indirect* influence (e.g., Singapore's brokerage role in crude oil ITNs).

Market Influence: Mechanisms and Impact

Market Influence shapes behavior beyond direct price control:

- Setting industry standards (e.g., patent) or shaping consumer preferences (e.g., branding).
- Controlling supply chains via terms to suppliers/distributors or through organized dumping prices.

Key Distinction from Power:

- *Influence* = Gradual structural changes (e.g., policy incentives, trade flow redirection).
- *Power* = Immediate coercion (e.g., export bans, price manipulation).

Impact:

- Distorts competition/innovation; may lead to regulatory capture.
- *Aligned with Nye*: Influence thrives in interdependent systems (e.g., global supply chains).

From Market Dynamics to Networks

To analyze power and influence in markets, we model interactions as **networks**:

- Markets are not just collections of buyers and sellers but interconnected systems where relationships and dependencies define power structures.
- Network analysis helps uncover hidden power dynamics, such as central actors, bottlenecks, or vulnerable dependencies.

Defining a Market as a Network

- Networks allow us to model and **understand the flow** of resources, information, and influence in markets.
- **Network Setups** vary by structure:
  - Directed (e.g., supply chains) or undirected (e.g., collaboration networks).
  - Weighted (e.g., trade volumes) or unweighted (e.g., binary trade relationships).
  - Singular or multilayer (e.g., combining trade, ownership, and social networks).
- **Centrality measures** (e.g., degree, betweenness, eigenvector) are key tools for analyzing power and influence in these networks, with results varying significantly by the chosen metric.

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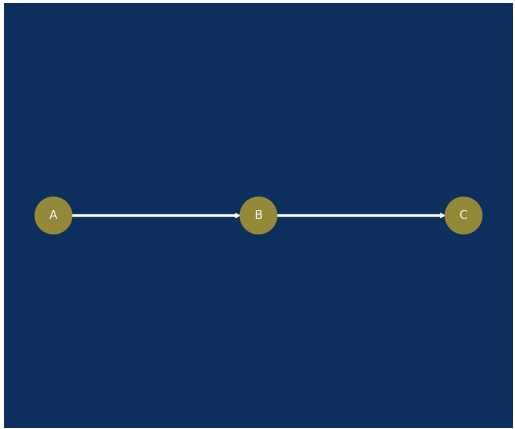
Defining Networks

$$Network = (V, E, \mathbf{W})$$

where

- V represents the set of **nodes**
- $E = \{e_{ij} : i, j \in V\}$ is the set of **directed edges**
- $\mathbf{W} = \{w_{ij} : i, j \in V\}$ is the Adjacency Matrix of **edge weights** [a]

[a] Unless otherwise specified, all edge weights W_{ij} are set to 1 for illustrative simplicity in the examples.



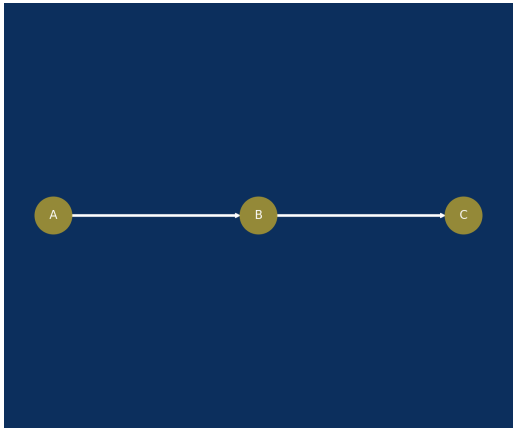
Defining Networks

$$Network = (V, E, \mathbf{W})$$

where

- $V = \{A, B, C\}$
- $E = \{e_{AB}, e_{BC}\}$ is the set of **directed edges**
- $\mathbf{W} =$

	A	B	C
A	0	1	0
B	0	0	1
C	0	0	0



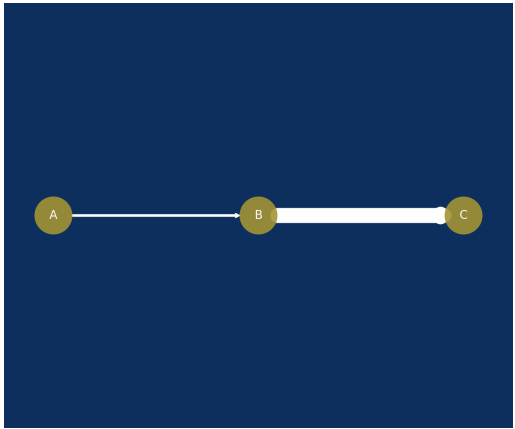
Defining Edges

$$Network = (V, E, \mathbf{W})$$

where

- $V = \{A, B, C\}$
- $E = \{e_{AB}, e_{BC}\}$ is the set of **directed edges**
- $\mathbf{W} =$

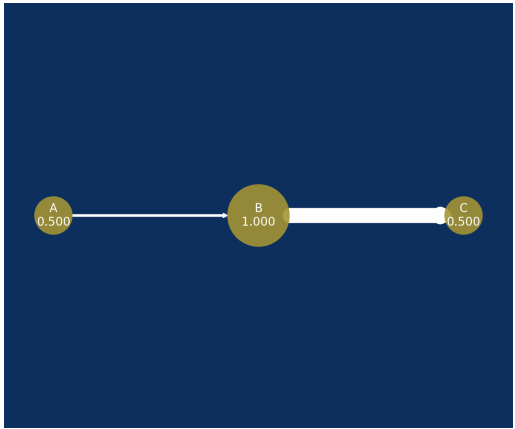
	A	B	C
A	0	1	0
B	0	0	15
C	0	0	0



Defining Degree Centrality

$$dc_i = \frac{\deg(i)}{n-1}$$

- dc_i is the degree centrality of node i.
- $\deg(i)$ is the number of edges connected to node i.
- n is the total number of nodes in the graph.



TLDR Networks

- Networks allow us to better **understand the flow of various things** - information, goods, electricity, ownership, money, viruses and countless more
- Different **network setups** are available and can be setup and visualized in various ways [1]
- **Centralities are our main tool for analyzing** the complex systems being modeled with networks and depending on the chosen centrality our results/visualizations can vary drastically

[1] Directed/Undirected; Weighted/Unweighted; Singular/Multilayer

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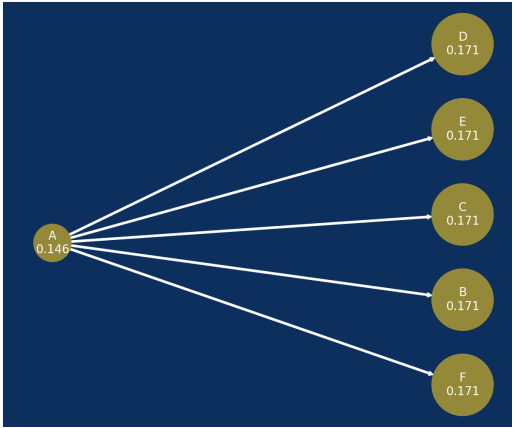
PageRank

$$pr_i = \alpha \sum_{j=1}^{N} \underbrace{\left(\frac{W_{ji}}{\sum_{k=1}^{N} W_{jk}} \right)}_{\text{Transition Prob.}} r_j + \underbrace{(1-\alpha)\frac{1}{N}}_{\text{Teleportation}} \quad (1)$$

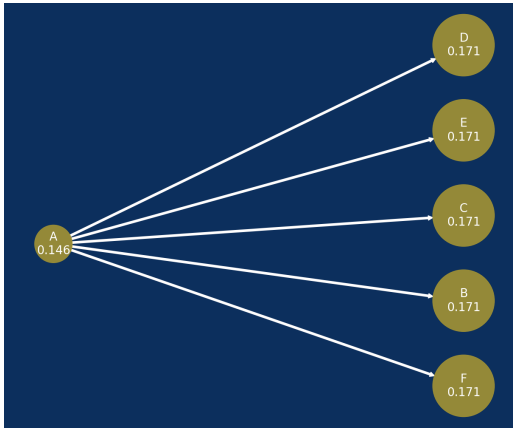
where:

- pr_i is the PageRank score of node i
- α is the damping factor ($\alpha = 0.85$)
- W_{ji} is the weight of the edge from node j to node i
- $\sum_{k=1}^{n} W_{jk}$ is the total outgoing weight from node j
- N is number of nodes in the network

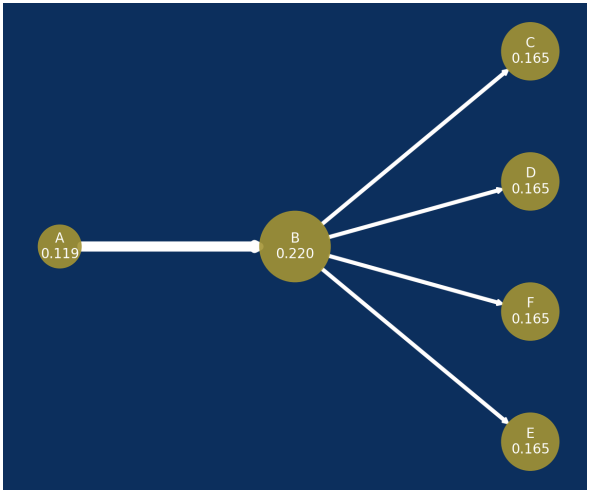


PageRank

- An initial score $\frac{1}{N} = \frac{1}{6} = 0.1666$ is iteratively updated
- Drops a **random** surfer into the network which teleports to a **random node** with $1 - \alpha$ probability
- PageRank measures how often other high scoring nodes link to you
- As a **normalized** Centrality -¿ the sum of assigned scores adds up to 1

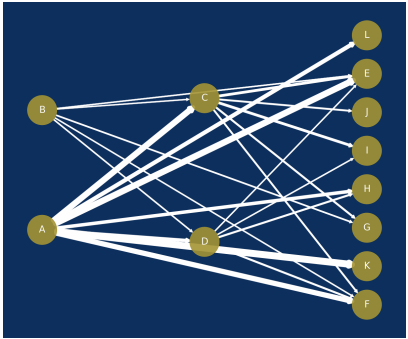


PageRank with Broker



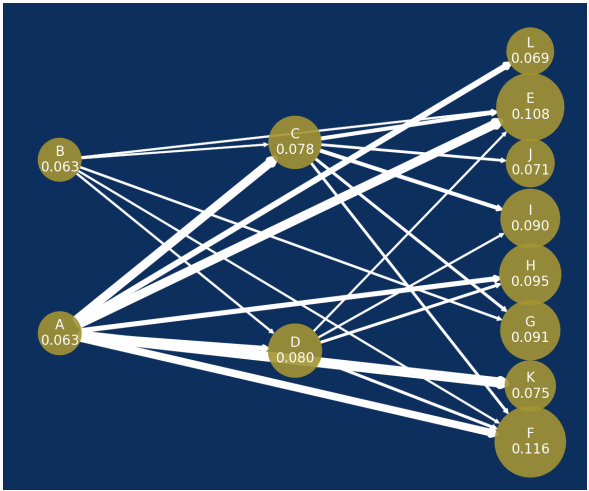
Dominated Market

- The initial score is $\frac{1}{N} = \frac{1}{10} = 0.1$
- A dominates the market with supplying 95%(28.5) of the goods and B supplying the remaining 5%(1.5)
- Brokers C and D receive $\frac{1}{3}$ of each Exporters goods to pass on
- E and F import from a multitude of sources
- G and H import one Broker and one Exporter
- I and J import only from Brokers[a]
- K and L directly import from A



[a] Geographical constraints could play a role f.e.

Dominated Market: PageRank



PageRank Intuition

- Connections from important nodes are more important
- Long-term probability 'How likely am I to visit this node if surf the network randomly and jump nodes?'
- **Underrepresents nodes of origin** -¿ especially relevant if thinking about physical goods

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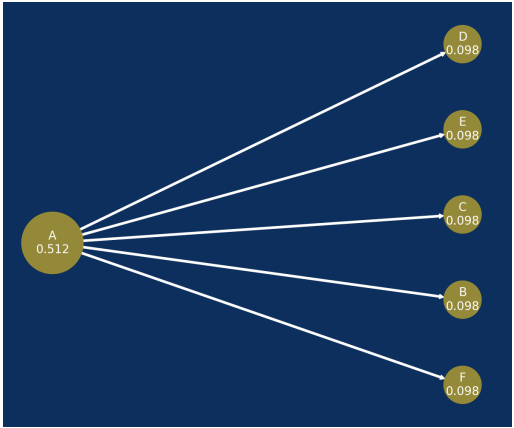
CheiRank

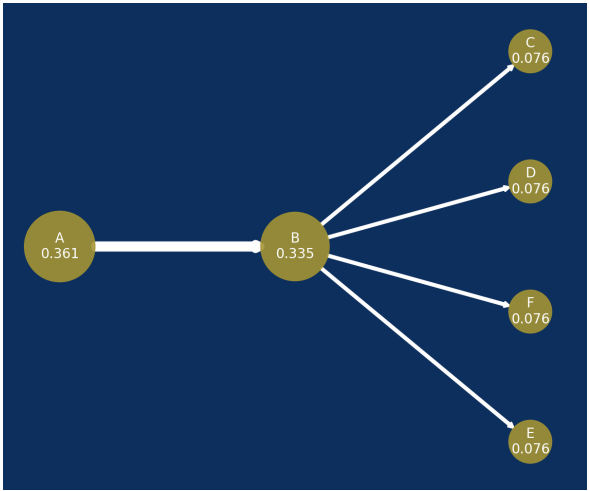
$$cr_i = \alpha \sum_{j=1}^{N} \underbrace{\left(\frac{W_{ij}}{\sum_{k=1}^{N} W_{jk}} \right)}_{\text{Transition Prob.}} r_j + \underbrace{(1-\alpha)\frac{1}{N}}_{\text{Teleportation}} \quad (2)$$

where:

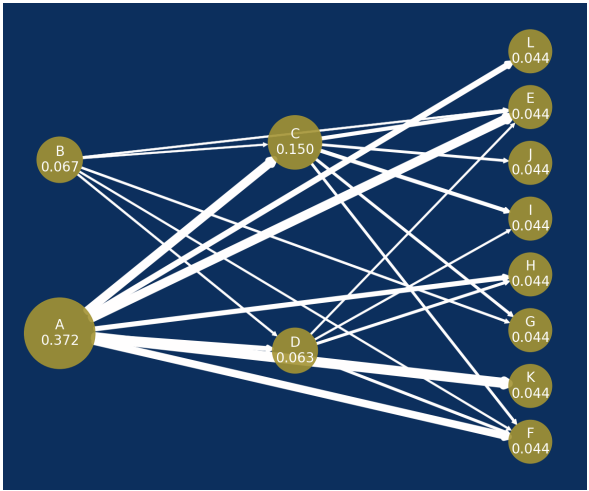
- cr_i is the CheiRank score of node i
- α is the damping factor ($\alpha = 0.85$)
- W_{ij} is the weight of the edge from node i to node j
- $\sum_{k=1}^{n} W_{jk}$ is the total outgoing weight from node j
- N is number of nodes in the network



CheiRank with Broker



Dominated Market: CheiRank



CheiRank Intuition

- Exact Reverse of PageRank
- Long-term probability 'How likely am I to come from this node if surf the network randomly and jump nodes?'
- **Underrepresents nodes of destination** -¿ Market Power of Importers - like the USA - is underappreciated

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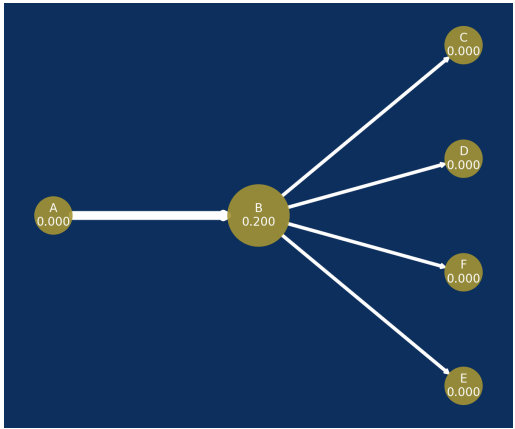
Weighted Betweenness

$$bt(i) = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}} \qquad (3)$$

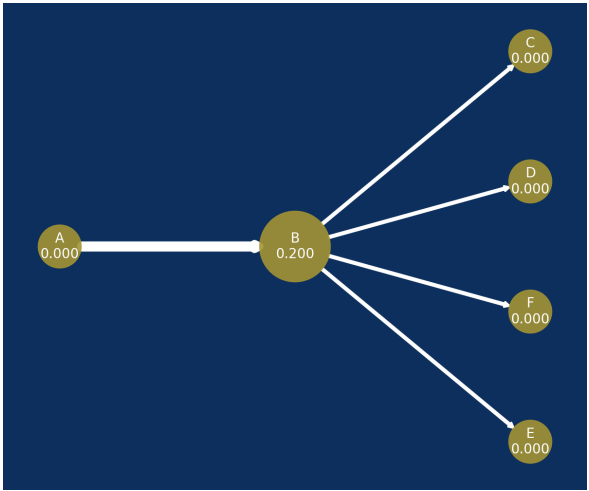
where:

- σ_{st} is the total number of weighted shortest paths from node s to node t.[a]
- $\sigma_{st}(i)$ is the number of those paths passing through i.

[a] Shortness for Trade Networks is defined as $\frac{1}{w_{ij}}$



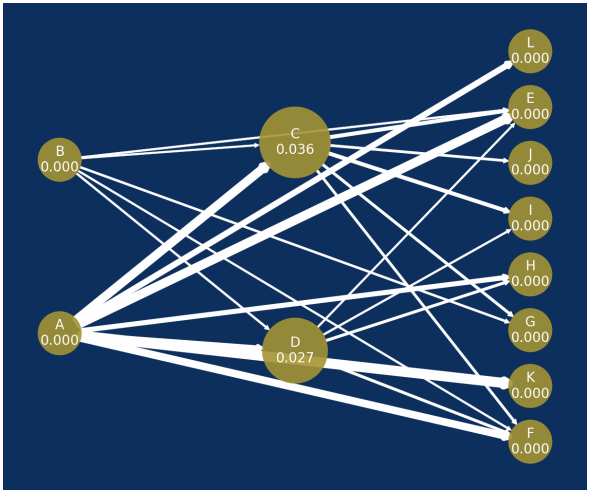
Weighted Betweenness



Weighted Betweenness Intuition

- Finds **brokers** and central hubs in the network
- Highlights nodes that control the flow of information or goods
- Is **not a normalized** centrality across the network, but **measures each individual node** on how central it is. It assigns every node a value between $[0 - 1]$

Dominated Market: Betweenness



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Problem

Inspired by Alfred Hirschmanns work, we want to measure **Foreign Trade** as an important part of the **economic dimension of National Power**. Instead of looking only **at the market concentration**, we want to take a holistic approach and look at global trade networks and the power inside all connections. Previously explored centralitites highlight different aspects of power in international trade.

Thinking about a Solution

Metric	Values	Value Range
PageRank	Importers, Brokers	$[0, 1]$
CheiRank	Exporters, Brokers	$[0, 1]$
Betweenness	Brokers	$[0, N]^2$

It seems to be possible to have a metric which detects Importers, Exporters and Brokers. **Double-counting** of Brokers could be an issue in adding all three metrics up. Therefore **Betweenness Centrality** needs to be used in a way such that it reduces the double counting.

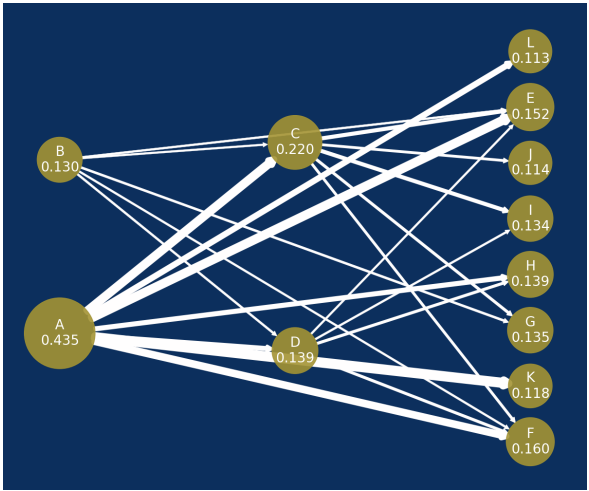
[2] For each individual node the value range is $[0, 1]$

TradeRank I

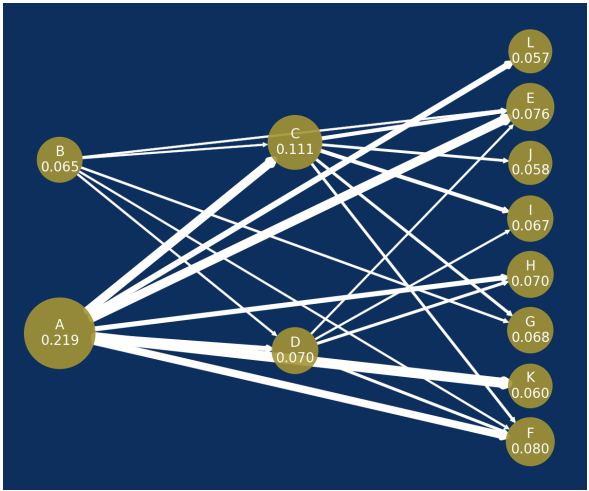
$$tr_i = \frac{pr_i + cr_i}{1 + bt_i} \tag{4}$$

- Nodes with low brokerage add up PageRank (Import Power) and CheiRank (Export Power) and divide by $1 + bt_i \approx 1$
- Brokers with high betweenness get their Power reduced by $1 + bt_i \approx 2$, which **solves the double-counting** issue and even accounts for possible direct trades being an alternative.
- We lose the natural value range of PageRank and CheiRank though.

TradeRank I


A
0.435
B
0.130
C
0.220
D
0.139
L
0.113
E
0.152
J
0.114
I
0.134
H
0.139
G
0.135
K
0.118
F
0.160

TradeRank I Normalized

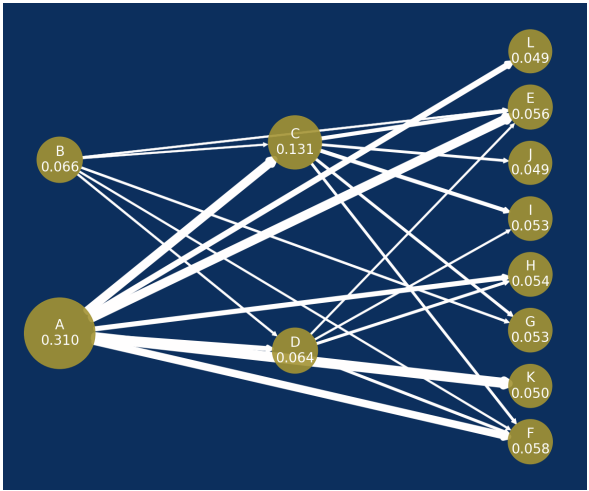


TradeRank II

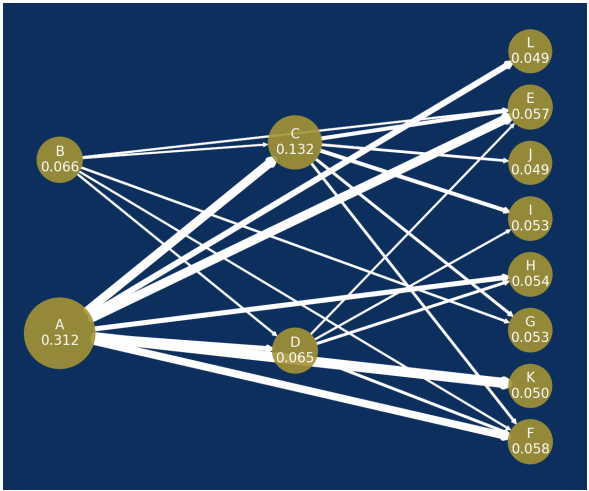
$$tr_i = \frac{(1-\alpha)pr_i + \alpha cr_i}{1 + bt_i} \tag{5}$$

- We want to be able to emphasize the possible superior position of Exporters over Importers
- Introducing α allows us to emphasize the importance of CheiRank
- For now I set the value to be $\alpha = 0.85$

TradeRank II



TradeRank II Normalized



Applications

- Herfindahl-Hirschman Index can measure **concentration** in a single market, but TradeRank allows for potentially going trough different layers of a network in a supply chain.
- Being aware of the different forms of power being highlighted dependend on the centrality allows researcher to better evaluate trade networks
- No matter which centrality we use, it can **only capture network inherent dynamics** - the economic power of Iran being able to shutdown the strait of Hormuz is not captured in trade networks.

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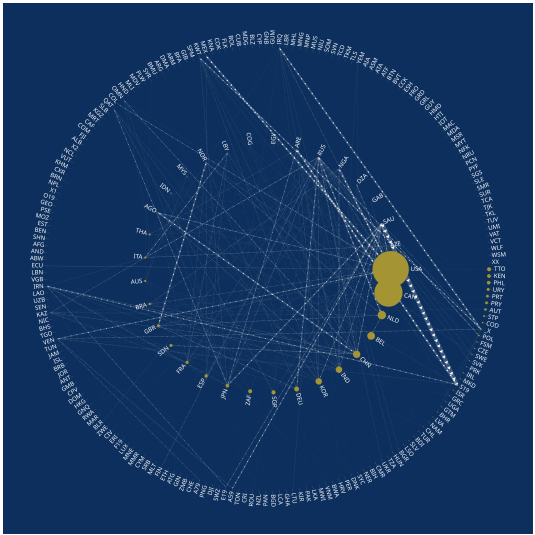
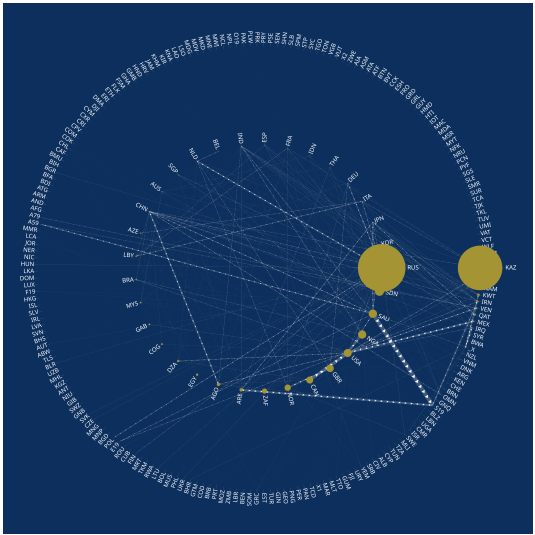
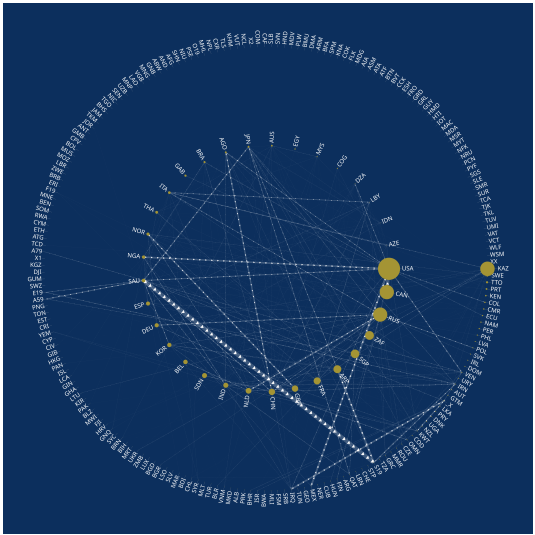
Crude Oil (HS2709) ITN 2010 with PageRank-Centrality



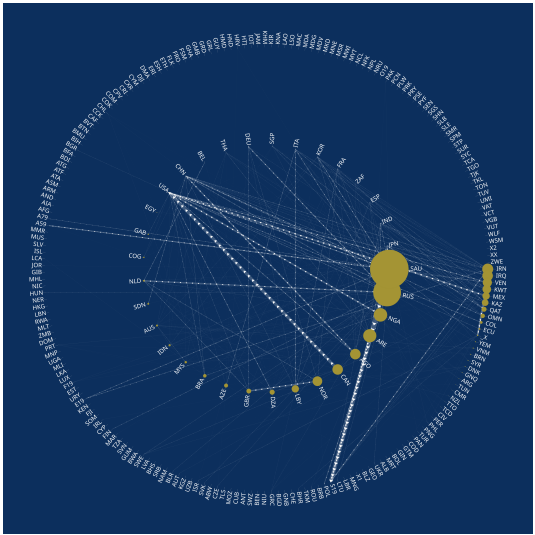
Crude Oil (HS2709) ITN 2010 with CheiRank-Centrality



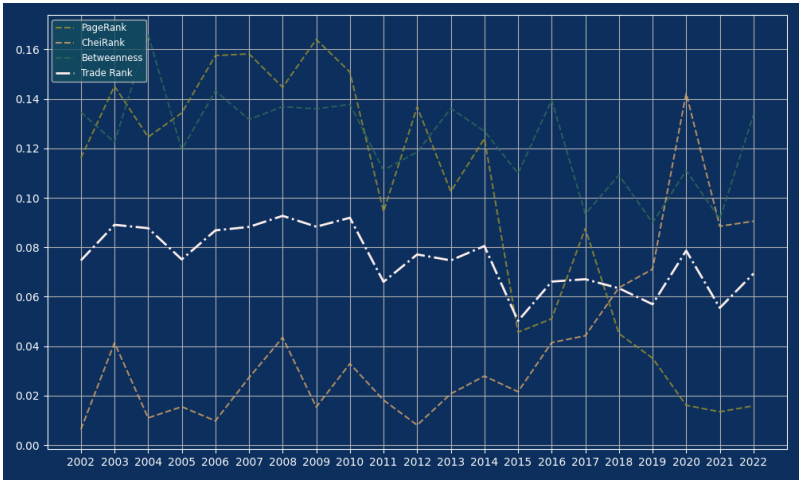
Crude Oil (HS2709) ITN 2010 with TradeRank-Centrality



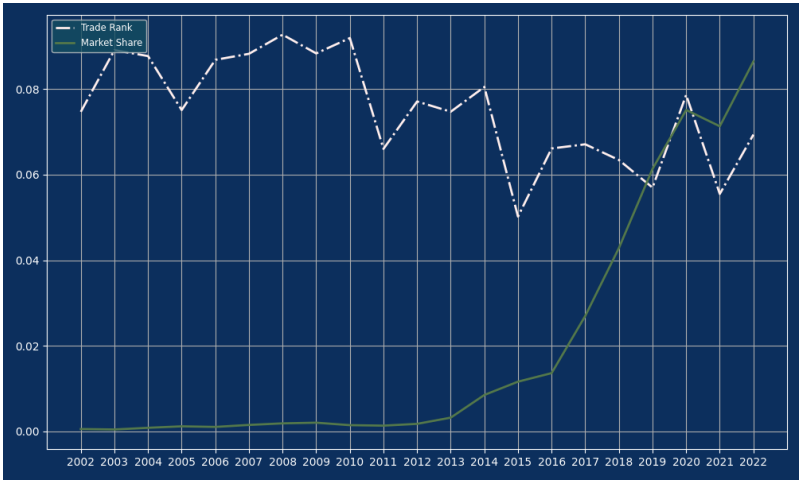
Crude Oil (HS2709) ITN 2010 with ExportShare-Centrality



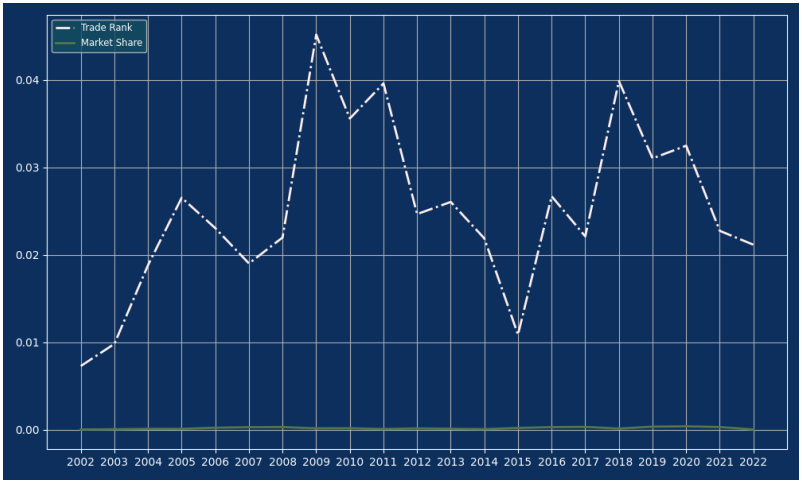
Crude Oil (HS2709) ITN USA TR with Components



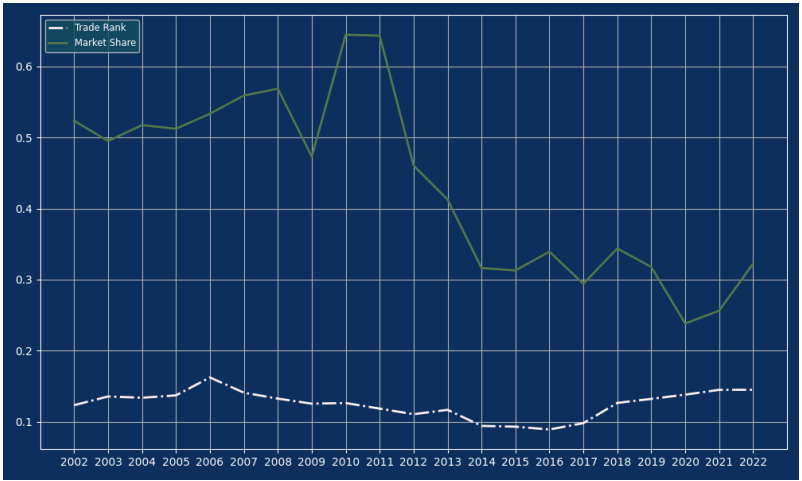
Crude Oil (HS2709) ITN USA TR and ES



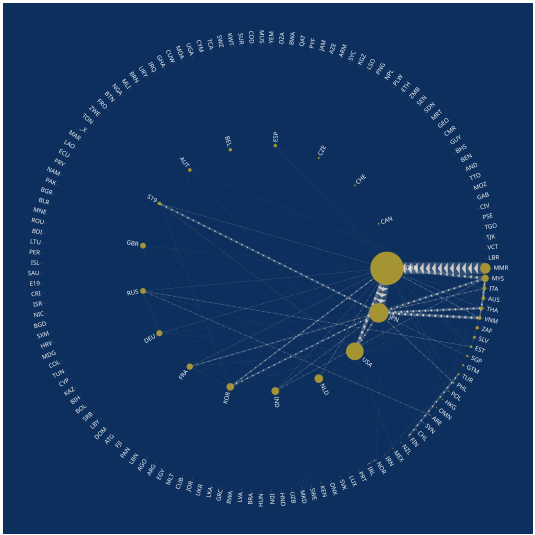
Crude Oil (HS2709) ITN SGP TR and ES



Rare Earth ITN CHN TR and ES



Rare Earth ITN CHN 2020 TR



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Empirical Framework for Commodity Price Determinants

Gleich et al. (2013) develop an empirical regression-based approach to quantify the influence of 11 key factors on the prices of 42 industrially relevant chemical elements over 26 years.

1. Factor Identification Analyzes 11 quantitative drivers: Mine production, country concentration (HHI), GDP, interest rates, stocks, secondary production, apparent consumption, and time trends.

2. Methodology Uses standardized regression coefficients to calculate the relative weight of each factor on commodity prices: $weight_{\rho_i^{norm}} = \frac{|\beta_i^{norm}|}{\sum_j |\beta_j^{norm}|} \cdot R^2$.

3. Key Findings Challenges generic weighting in criticality studies: Each commodity requires tailored models—e.g., GDP explains 0.4%–50.2% of price variation across materials.

4. Implications Provides empirically derived weights for economic scarcity assessments, improving criticality indices by replacing arbitrary weights with data-driven weights.

Herfindahl-Hirschman Index (HHI): Measuring Market Concentration

The HHI quantifies market concentration as the sum of squared market shares:

$$\text{HHI} = \sum_{i=1}^{N} s_i^2,$$

where:

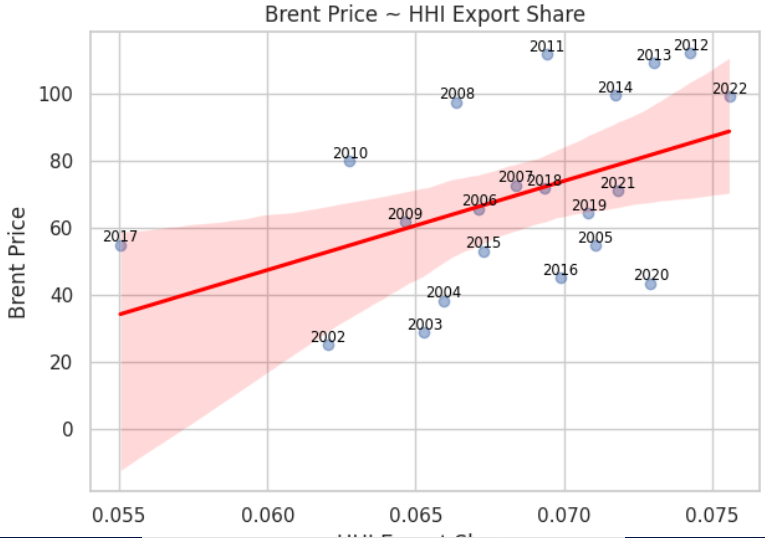
- s_i = market share of actor i,
- N = total number of actors.

US DOJ Interpretation:

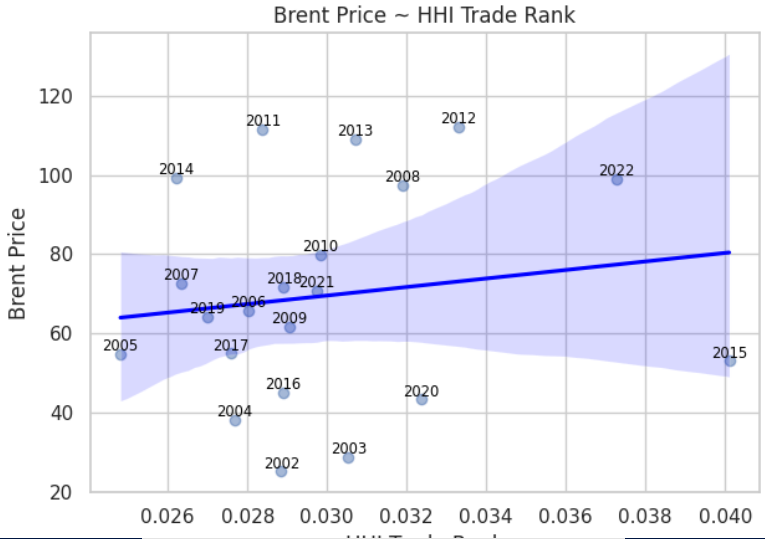
- HHI < 1000: **Unconcentrated** (competitive).
- $1000 \leq$ HHI < 1800: **Moderately concentrated**.
- HHI ≥ 1800: **Highly concentrated**.

A higher HHI signals greater market power for dominant actors, reducing competition and increasing potential for price manipulation.

OLS of Brent Price on Crude Oil (HS2709) ITN Export Share **



OLS of Brent Price on Crude Oil (HS2709) ITN TradeRank



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Contributions

1. Market Power vs. Market Influence
Distinguishes Market Power (immediate coercion, e.g., price manipulation) from Market Influence (gradual structural changes, e.g., standards, supply chains). Extends Nye's framework by linking soft/hard power to economic dependencies in trade networks.

2. Framework for ITN Analysis and Visual Storytelling
Provides a methodological pipeline to model, analyze, and visualize ITNs, enabling intuitive interpretation of power dynamics.

3. TradeRank: A Novel Centrality Index
Proposes TradeRank as a centrality measure tailored for ITNs, capturing some asymmetric dependencies and most flow-based influence (Hirschman/Nye). It offers a starting point for deeper visual and quantitative analysis as shown.

4. Validation of Export Share
Validates export share as a predictor of pricing power.Currently testing whether TradeRank can similarly predict pricing power for specific commodities.