Analysing the Impact of Export Controls on the Semiconductor Supply Chain using Network Science

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1. Background

A. Semiconductor industry

Semiconductor: specialised components that allow electronic devices to process, store & transmit data.

$1T
Projected Sales by 2030

4x
Global Trade Vol vs Sales

Used in AI, defense systems

Crucial to national security interest

B. US Export Controls on China

In Oct 2022, the USA placed export controls targeting China's ability to access & develop advanced chips.

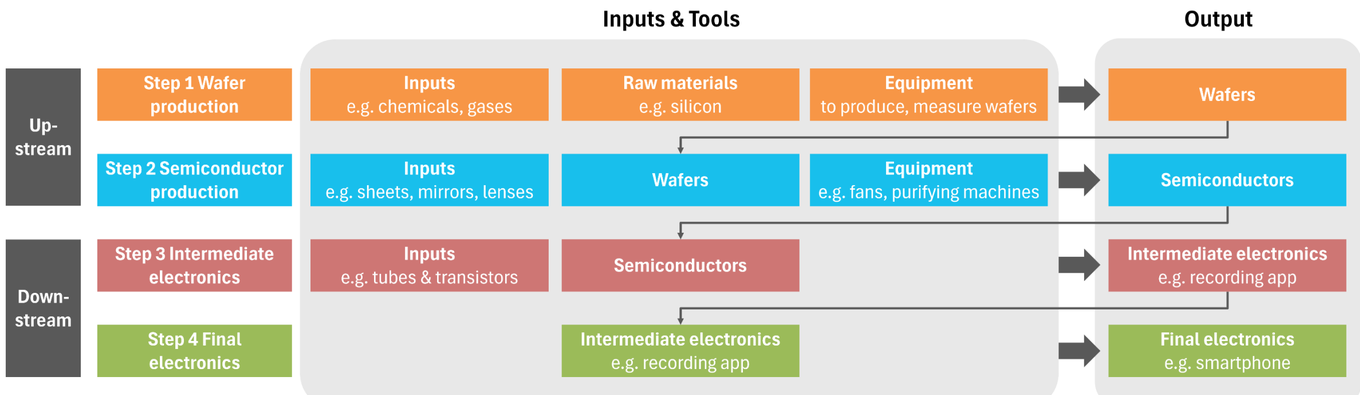
Extensive implications:

Most equipment & software globally contains US tech

The USA's stance shifts: maintaining a slight lead → largest possible lead

2. Objective

Through network analysis, explore the impacts of the 2022 US export controls on the global semiconductor trade network, across the supply chain :

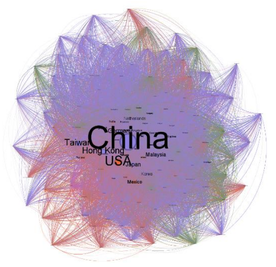


Adapted from RaboResearch (2023)

3. Dataset

UN Comtrade trade data of 244 markets (Jan 2022-Dec 2023)

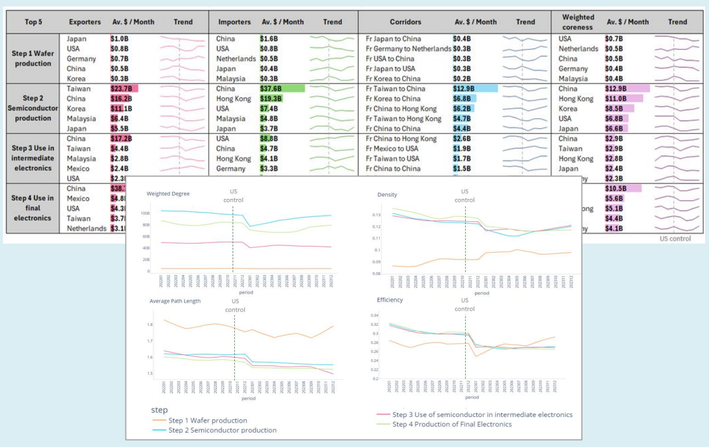
- 86 trade (HS) codes grouped into 4 steps as shown above
- Nodes: markets (entities), edge weights: trade value in USD



4. Methodology, Results & Insights

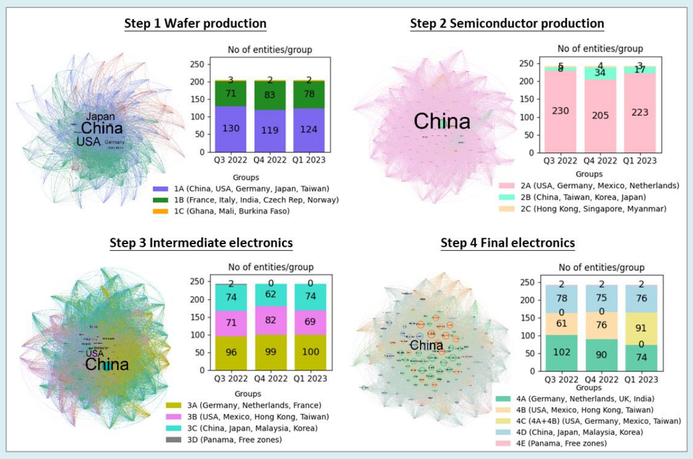
A Descriptive summary of trade network

Why: to understand fundamental network characteristics & trends
How: Node & network level metrics



B Identification of trade communities

Why: to observe changes in communities after the export controls
How: Louvain Method



C Evolution of trade network

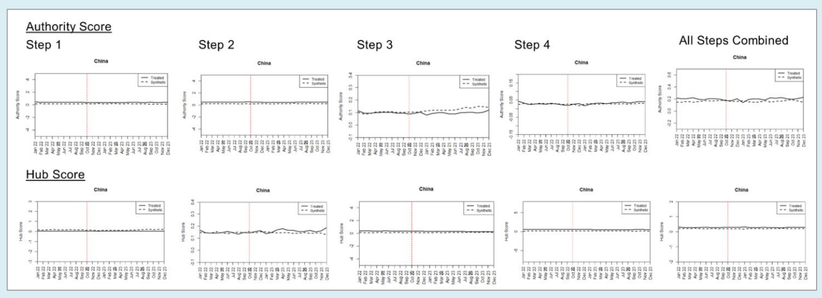
Why: to understand why & how the network changes in response to trade controls & other factors
How: Stochastic Actor-Oriented Models (SAOMs)

Evolution of Trade Networks	Model A		Model B		Model C		Model D		Model E	
	Overall Network		Step 1 Wafer production only		Step 2 Semiconductor production only		Step 3 Intermediate electronics only		Step 4 Final electronics only	
Trade rate (period 1)	15.8669***	(0.3467)	10.8311***	(0.5341)	13.5883***	(0.3705)	14.4538***	(0.3612)	15.4423***	(0.3787)
Trade rate (period 2)	25.4390***	(0.4956)	15.7581***	(0.6639)	21.0375***	(0.5103)	22.8135***	(0.5241)	23.8360***	(0.5361)
Outdegree (density)	-1.4625***	(0.0142)	-3.1764***	(0.0486)	-1.7906***	(0.0167)	-1.7645***	(0.0163)	-1.6921***	(0.0153)
Reciprocity	0.3366***	(0.0318)	0.2279***	(0.0666)	0.1204**	(0.0380)	0.3507***	(0.0357)	0.5068***	(0.0349)
GDP alter	0.1276***	(0.0073)	0.1020***	(0.0132)	0.1381***	(0.0083)	0.1085***	(0.0082)	0.0636***	(0.0083)
GDP ego	0.1003***	(0.0086)	0.1122***	(0.0143)	0.1029***	(0.0090)	0.1026***	(0.0092)	0.1186***	(0.0098)
GDP similarity	0.2846***	(0.0632)	0.0390	(0.1061)	0.1676*	(0.0713)	0.2065**	(0.0690)	0.2486***	(0.0699)
Initiator of trade control alter	0.0757	(0.1591)	0.4784**	(0.1837)	0.2643	(0.1488)	0.0149	(0.1457)	-0.0479	(0.1436)
Initiator of trade control ego	-0.8291**	(0.2961)	-2.0187	(2.5277)	-0.8636**	(0.3340)	-0.8245*	(0.3468)	-0.7939*	(0.3259)
Target of trade control alter	-0.7079***	(0.1577)	-0.0478	(0.2319)	-0.1974	(0.1534)	-0.6384***	(0.1621)	-0.9940***	(0.1688)
Target of trade control ego	-0.8258**	(0.3040)	-1.2139*	(0.5067)	-1.0226**	(0.3266)	-0.8374*	(0.3473)	-0.7280*	(0.3287)
Semiconductor trade value alter	0.3161***	(0.0102)	0.2781***	(0.0171)	0.2907***	(0.0110)	0.2985***	(0.0107)	0.2975***	(0.0105)
Semiconductor trade value ego	0.2018***	(0.0122)	0.4359***	(0.0182)	0.2775***	(0.0117)	0.2244***	(0.0127)	0.1527***	(0.0131)
Semiconductor trade value similarity	1.3215***	(0.0885)	1.6256***	(0.1284)	1.5126***	(0.0925)	1.2475***	(0.0884)	0.8619***	(0.0863)

Note: *, ** and *** represents p-value of < 5%, < 1% and < 0.1% respectively

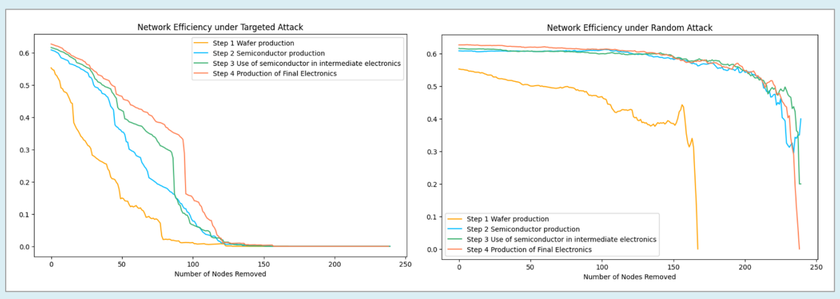
D Causal effect of export controls

Why: to establish causal inference of export controls on China & the USA
How: Synthetic Control Methods (SCM)



E Potential future impact of larger scale trade controls

Why: to assess the network's resilience in case of larger scale controls
How: Targeted & random robustness attack



After trade controls

1) Trade declines across steps, top importers, exporters & corridors (A)

2) Localisation of semiconductor network (A)

- Network becomes less globally efficient & connected.
- Clustering coefficient rises → intra-Asian trade more intensive. (B)

3) Trade controls negatively impact tie formation

- Target entity less attractive as a trading partner, but the initiator does not become less attractive. (C)
- Both the initiator & target tend to form fewer outgoing ties. (C)

4) Nevertheless, overall network is resilient

- Stable modularity → communities are mostly stable. (B)
- Despite fluctuations, overall impact on China & the USA's importance is low & short-lived. (D)

5) However, larger scale controls pose risk to network

- The network, especially the upstream steps, is vulnerable to decline in efficiency. (E)

5. Recommendations

Maintain trade relationships to enhance the semiconductor network's efficiency & resilience, especially for upstream steps

Diversify the global supply chain to safeguard network robustness in case of geopolitical risk
e.g. SEA for assembly, testing & packaging

Form government & private sector partnership to establish R&D leadership, focusing on technological "chokepoints"
e.g. advanced chip equipment

Sustain investment in local companies, infrastructure & workforce to maintain competitiveness