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MetalForming
Magazine

From Mine to Mill – Understanding Supply Chain Management and How It Impacts Your Company

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Management, University of Tennessee



What is a Supply Chain?

“ A set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from source to a customer ”

Mentzer et al., 2001

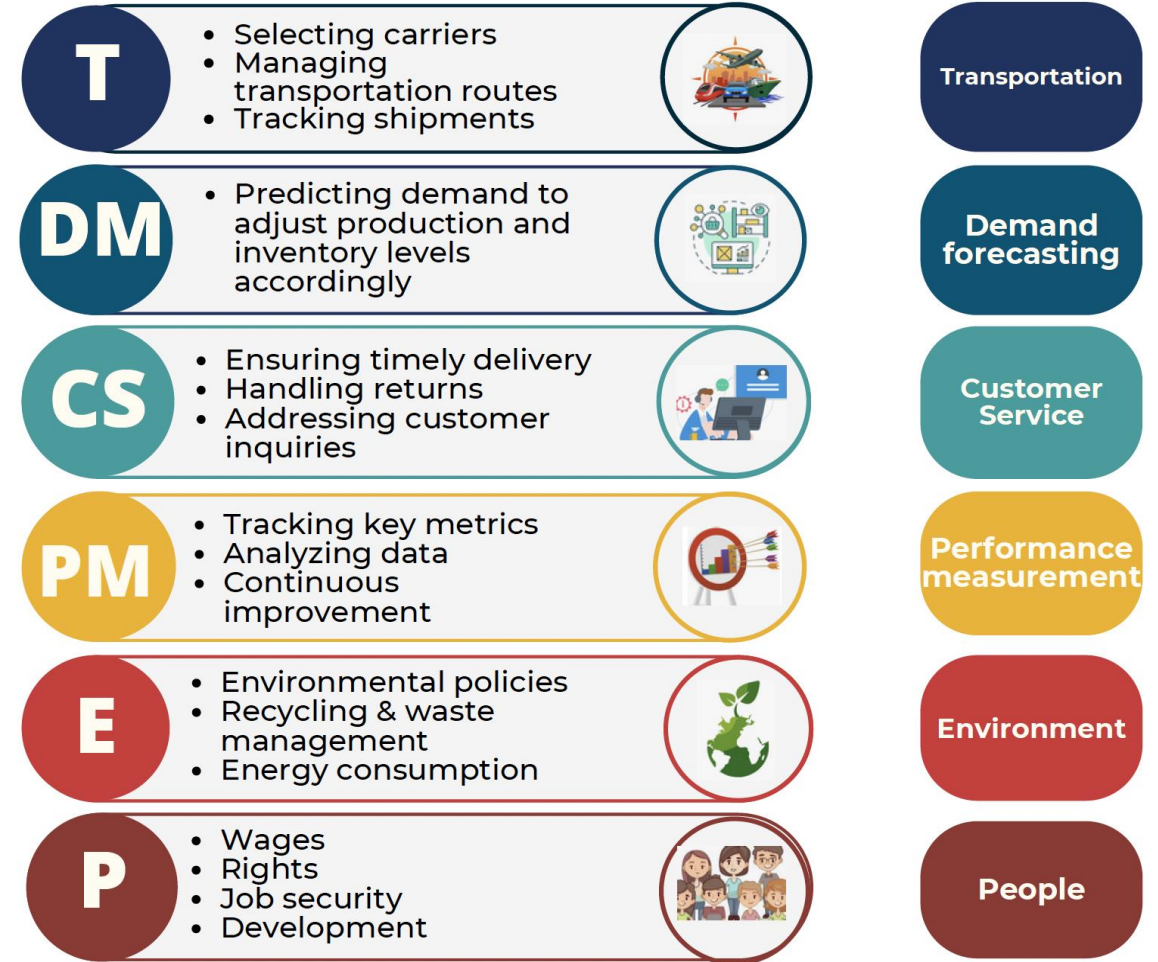


Supply Chain Activities

Upstream



Downstream



Giannakopoulou, 2024



Supply Chain Network Design Objectives

- Efficiency (Cost)
- Effectiveness (Performance)
- Innovation
- Sustainability
- Security
- Resiliency

What are the tradeoffs?

What's the right mix for your firm?





Global Supply Chain Risk Drivers

- Population growth to 8 Billion people
 - Trending to 9-10 Billion?
- Economic growth of nations
 - Rising middle class incomes and consumption
- Global communications
 - Growing Internet reach and AI capabilities
- Increased buying-up of resources
 - Political response and control of resources
- Increased push for “sustainable” resources
 - Fighting slave labor and environmental damage



Raw Material & Metal Risk Categories

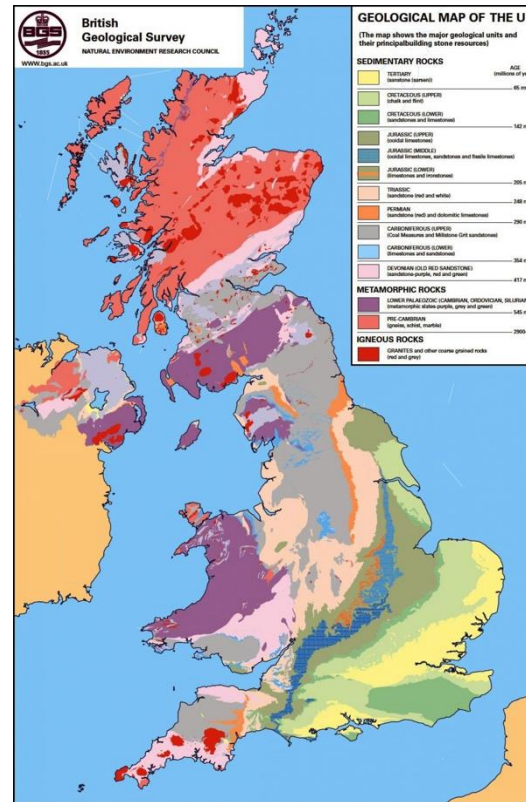
- Scarcity Risk
- Transportation Risk
- Security Risk
- Technological risk
- Sustainability risk
- Geopolitical risk
- Demand Risk
- Disruption risk
- Economic Risk
- Labor risk

Cite: Al-Shwaf & Bell, 2025



Raw Material & Metal Supply Risk Categories

1. Scarcity Risk for Metals
 - Geographic imbalances
2. Transportation Risk
 - Distance and variability
3. Economic Risk
 - Price volatility
 - Supplier insolvency



Raw Material Supply Risk Categories

4. **Security Risk**
 - Illicit & Illegal activity
5. **Demand Risk**
 - Consumer preference
6. **Disruption risk**
 - Natural disaster
7. **Labor risk**
 - Strikes

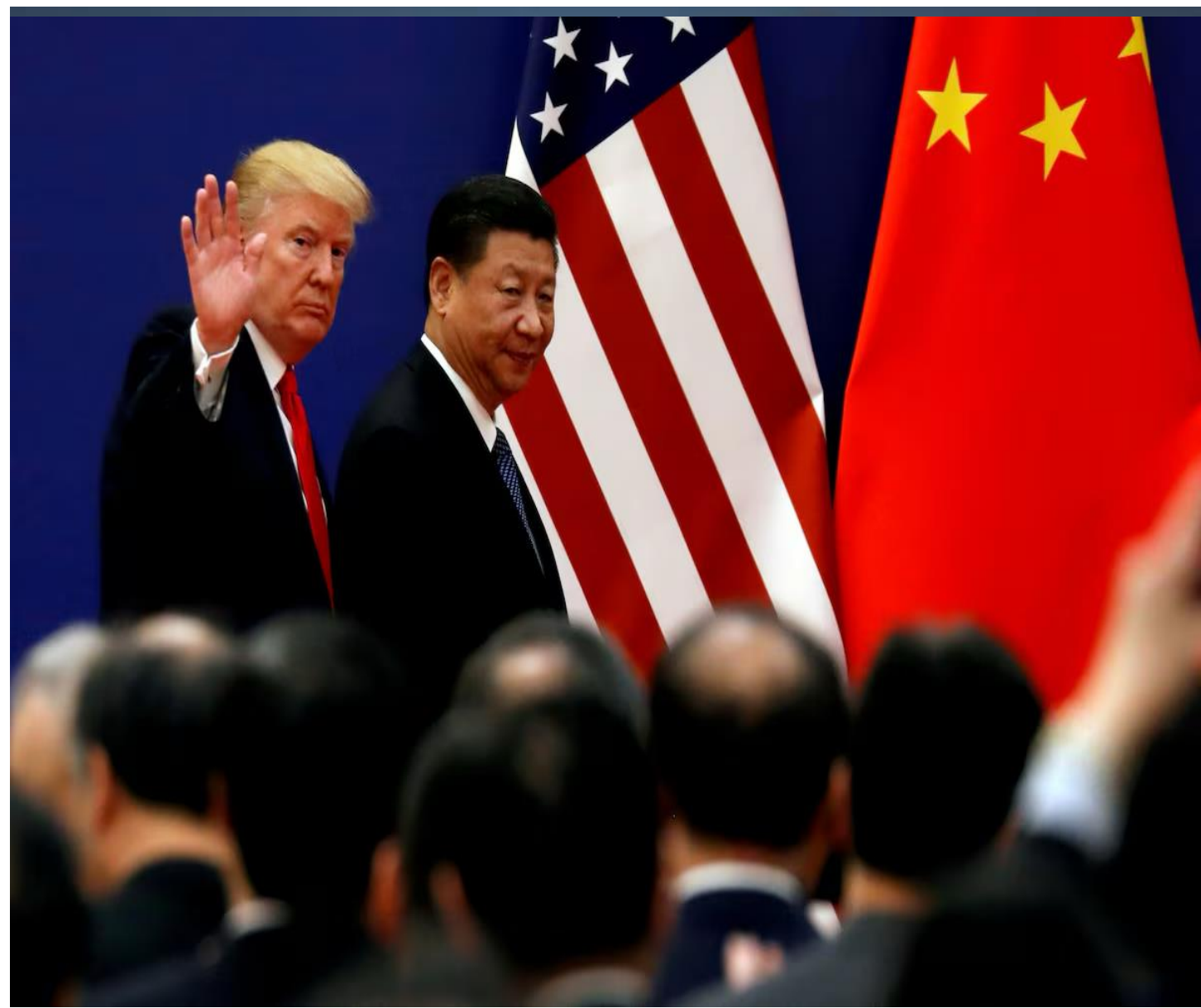
Boeing and Airbus may have used 'counterfeit' titanium in planes, FAA says

The Federal Aviation Administration said it would investigate allegations that titanium had entered the supply chain via falsified documents.



Raw Material Supply Risk Categories

8. **Technological risk**
 - Innovation
 - Obsolescence
9. **Sustainability risks**
 - Carbon Emissions
 - Slave Labor
10. **Geopolitical risk**
 - Tariffs, Taxes
 - Weaponization of SC



Which supply risks impact your firm's Supply Chain?



Geopolitical Risk – March 7th 2025

- The growing "Trade Wars" impact the mining, refining and flow of critical minerals to US industries

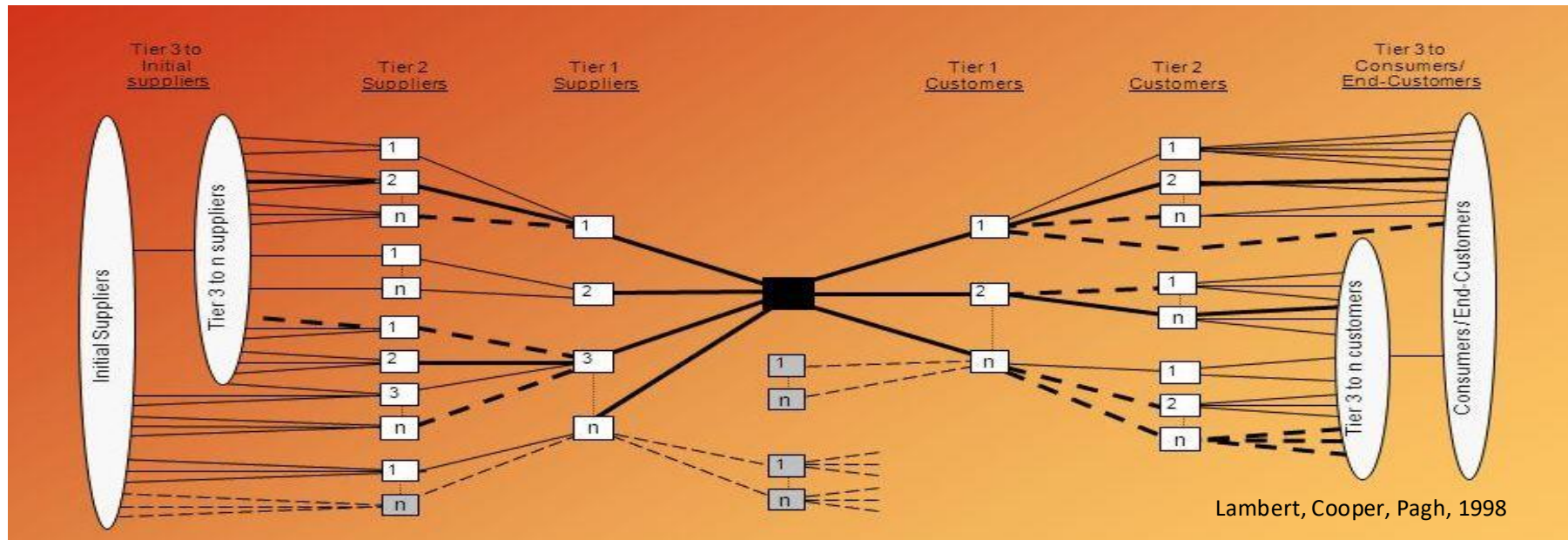
Germanium	Tungsten
Gallium	Indium
Antimony	Tellurium
Bismuth	Molybdenum
Graphite	Aluminum
Copper	

Atomic Number	Element	Symbol
21	Scandium**	Sc
39	Yttrium	Y
57	Lanthanum	La
58	Cerium	Ce
59	Praseodymium	Pr
60	Neodymium	Nd
61	Promethium*	Pm
62	Samarium	Sm
63	Europium	Eu
64	Gadolinium	Gd
65	Terbium	Tb
66	Dysprosium	Dy
67	Holmium	Ho
68	Erbium	Er
69	Thulium	Tm
70	Ytterbium	Yb
71	Lutetium	Lu

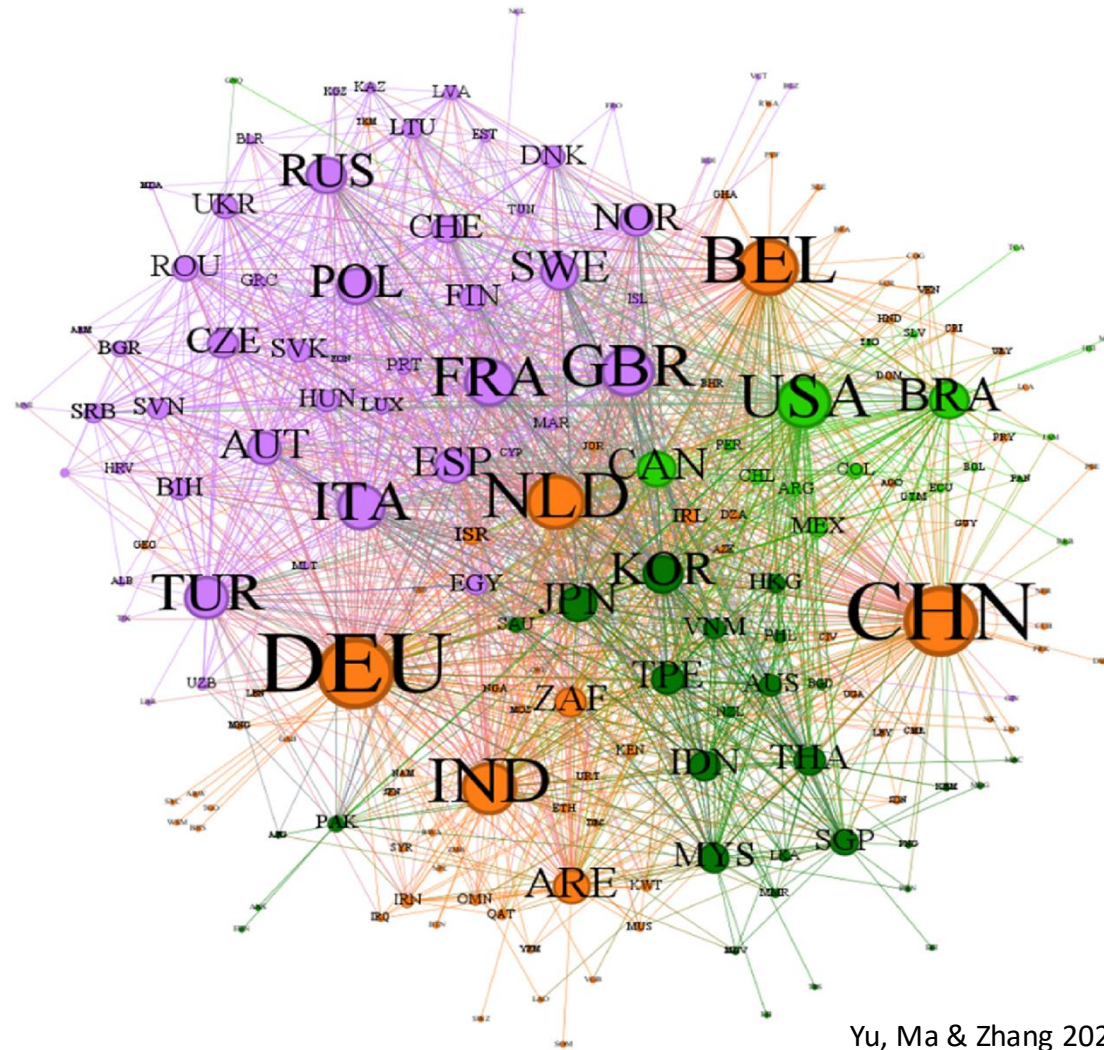


Supply Chain Visibility Defined

Supply Chain Visibility refers to the ability of a firm to “see” what is going on (upstream/down- stream) across the supply chain.



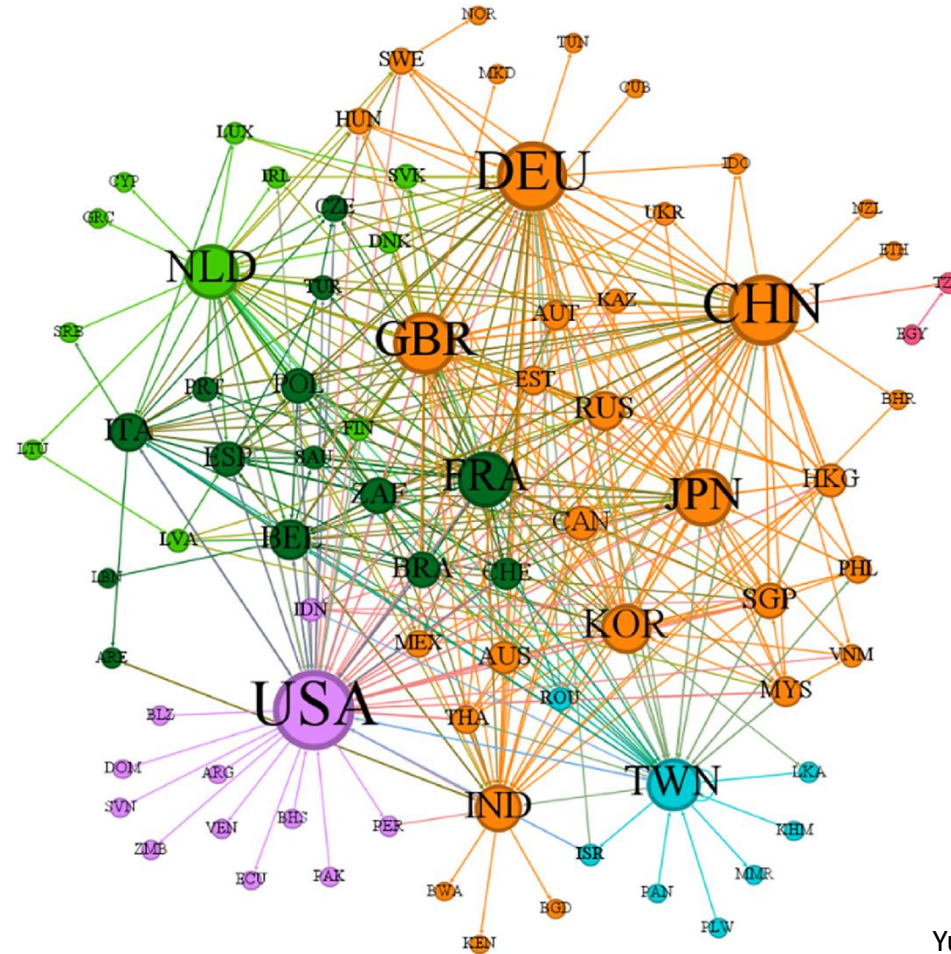
Import/Export Network for Silicon



Yu, Ma & Zhang 2024

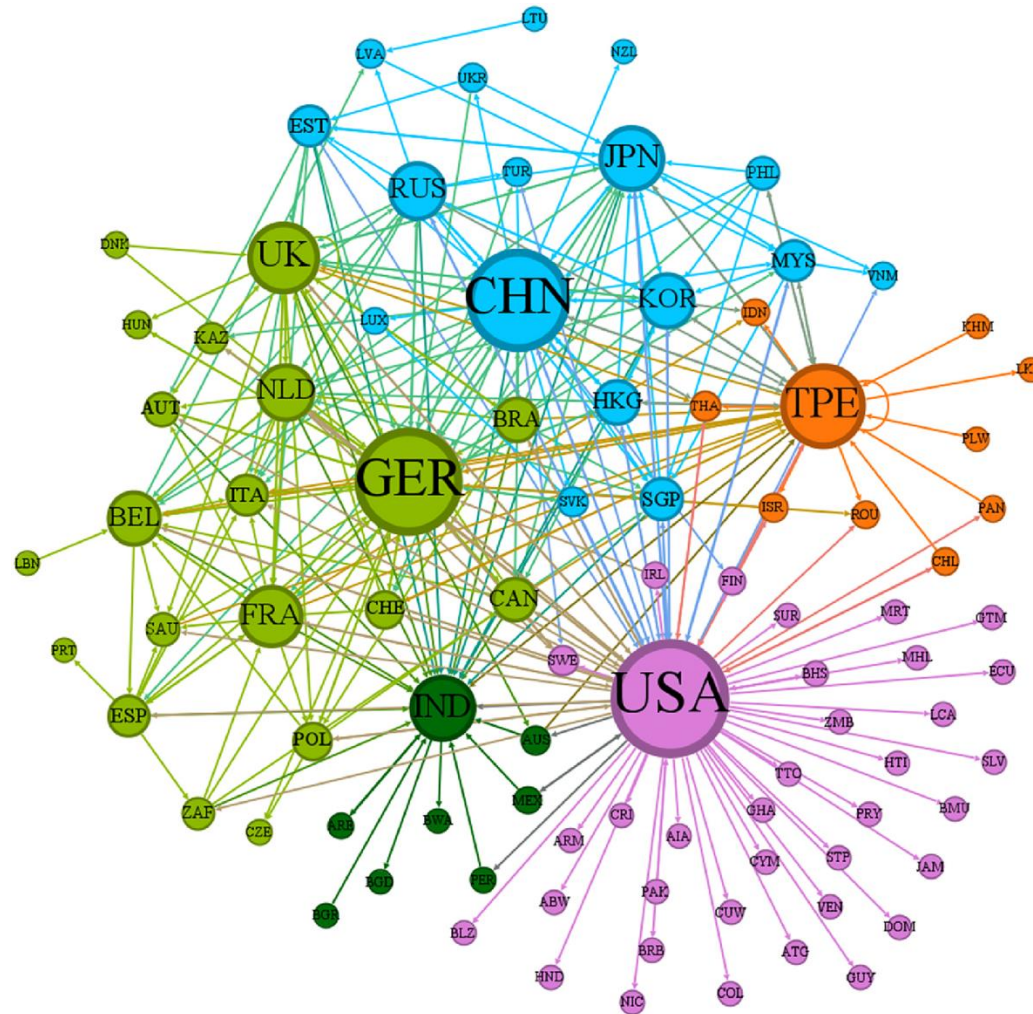


Import/Export Network for Germanium



Yu, Ma & Zhang 2024

Import/Export Network for Gallium



Global network density and connectivity differences in the network for each metal

However, this view doesn't provide firm-to-firm "Supply Chain Visibility"

Yu, Ma & Zhang 2024

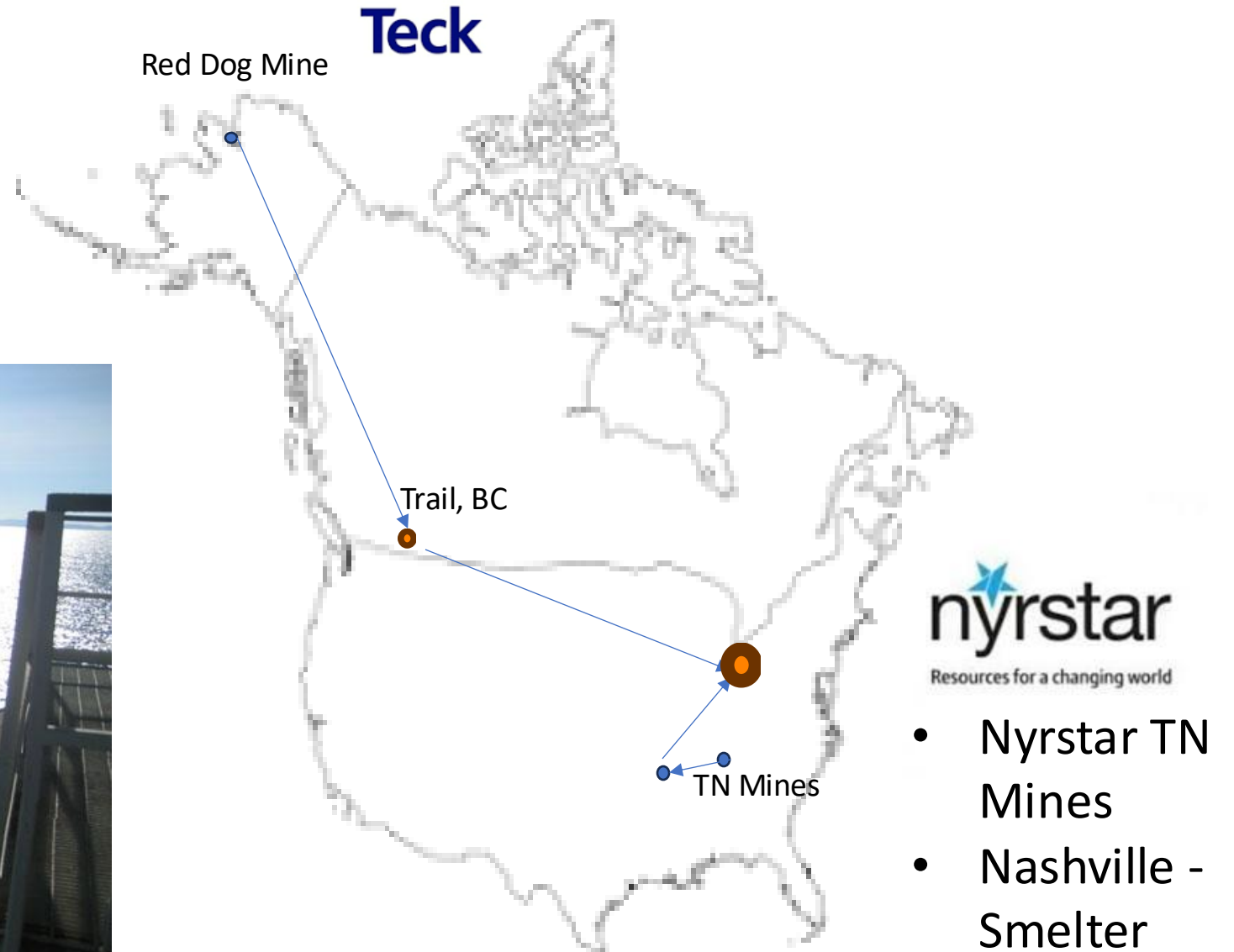


Metal Risk – The case of Zinc

- Price volatility over the last four years
 - Zinc Mining boom in 2021
 - Price hits low of \$2215/MT in May '23
 - Recovered to \$3200/MT recently
 - Small Supply Deficit in 2024
 - Reduced smelting
- Supply Chain Structure for US firms
 - US is a Top 5 exporter of ore
 - Imports refined Zinc from Canada/Peru
 - Domestic mining in Tennessee and Alaska
 - Only one operational US smelter in Nashville



- Mill locations in Michigan/Ohio –
 - Hot Dip Galvanized Operation
- Teck - Red Dog Mine AK
- Trail BC – Smelter



Metal Risk? – The case of Zinc

Relevant Risk....Alaska vs. Tennessee

- Economic Risk
 - Labor agreements
 - Financial instability/stability at firms
- Technology & Operational Risk
 - Adjacent operations for Gallium in TN vs. Germanium in AK
- Sustainability Risk
 - Length of supply chains
 - Different mining strategies
- Transportation Risk
 - Distances and extra handling



Political Risk;

A US mine can still have an international supply chain and higher levels of political and transport risk!

Risk – The Case of Nickel

Price over the last four years

- The “Devil’s Metal” has volatility
- Stainless steel still drives the global market
- Prices down again in 2024

Supply Chain Situation for US firms

- **Indonesia**, Philippines, Australia and New Caledonia dominate globally
- US has only one major mining operation
 - Eagle Mine in Michigan provides 15% of US demand





GLENCORE



Other countries in the Top 5 for
Global Nickel Mining:

Australia has 36 Nickel Mines

New Caledonia has 30 Nickel Mines

Philippines has 32 Nickel Mines

Rio Tuba Mine and
Processing Plant on
Palawan island

Indonesia – controls over 65% of
Nickel mining and nearly half of
refining in world

Banned ore export in 2020
Built 44 smelters!

Minister Roselani controls
domestic investment and
export of 28 raw materials



alamy - 2C582M2

Metal Risk? – The case of Nickel

Relevant Supply Risks:

Resource Scarcity

Technology

Economic

Sustainability

Geopolitical – two dominant supply chains emerging?



- US firms rely on Canada;
- Chinese firms rely on Pacific region



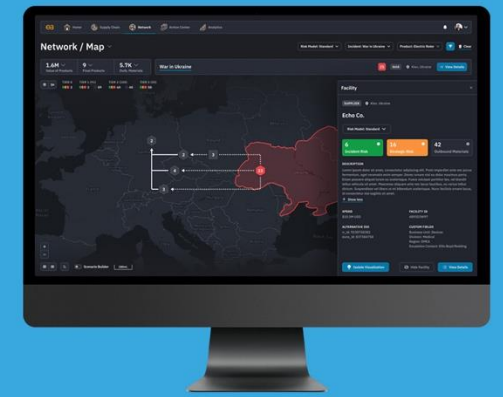
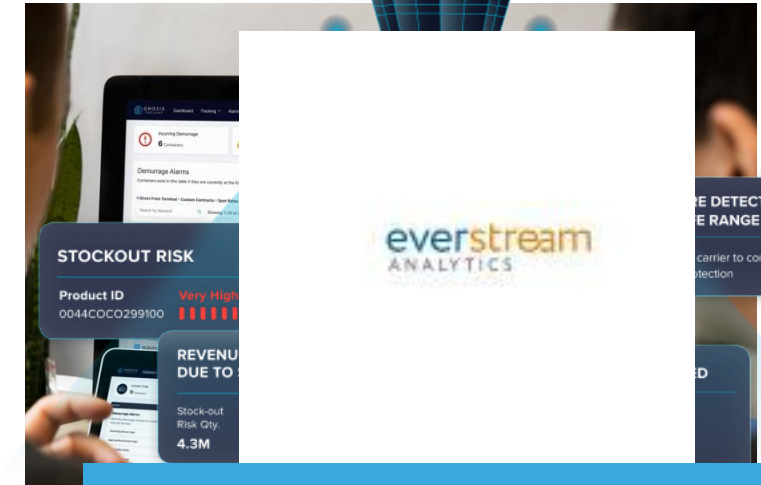
Mitigation Strategies – Metal Risks

- Hedging and investment strategies
 - Near-shore sourcing alternatives...up to 20% of your raw materials spend
 - Focusing on long term performance and having a risk averse relationship
 - Investments in mining and refining industries by major manufacturers



Mitigation Strategies – Metal Risks

- Visibility and mapping software industry growing
 - But what kind of visibility software do you need?
 - Transportation/Logistics Visibility. Gnosis,
 - Shipment/Transport transactions
 - SC and Supplier Visibility Systems. Project 44, 4Kites
 - Transport/Purchase Datasets
 - SC Risk Systems. Sayari, Supply Trace, Everstream
 - Purchase/Transport data,
 - Manufacturing data, government data



Mitigation Strategies – Metal Risks

• Buffering and Bridging Strategies

- Metal Service Centers offer inventory buffering and value-added services
- They can also be a strategic relationship and create bridging capabilities
 - ThyssenKrupp and Boeing supply chain partnership
 - ThyssenKrupp buys metals; handles logistics to thousands of Boeing suppliers
 - Boeing gets economies of scale and negotiates only on machining prices
 - ThyssenKrupp operates the control tower for metals risk inbound to Boeing
 - **Such a relationship is important for small companies and Boeing**

Top Ten MSCs in FY24

Reliance
Ryerson
ThyssenKrupp
Kloeckner Metals
O'Neal Industries
Worthington Steel
Russel Metals
Steel Technologies
Alro Steel
Tyota Tsuho America



Mitigation Strategies – Metal Risks

- Closed-loop supply chain strategies
 - The Berkley Pit: Rare metals extractable from wastewater in Montana
 - One of the deepest open pit mines by 1970s
 - Then the pumps got turned off...1980s
 - Now a possible source of Rare Earth Metals...
 - Can we mine the wastewater and clean it up at same time?

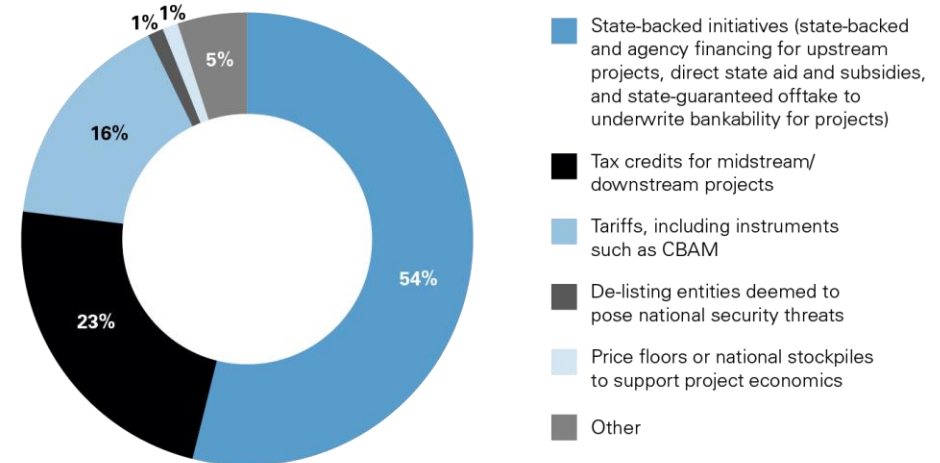


Mitigation Strategies – Metal Risks

- Public-private partnerships
 - Geopolitical risk often includes competing against government subsidized and controlled industries ...state backed capitalism
 - US government involvement and enforcement needed to level the playing field



The Strategic and Critical Minerals Stock Piling Act



White & Case LLP, 2025

“Mine to Mill” Take-aways

- Firms compete within global metal supply chain “networks”
- Geopolitical influence and disruption in those networks are growing
- Sustainability and illicit sourcing create risk in metal supply chains
- Visibility is a requirement for managing supply chain risk
- Need evaluation of your “firm-to-firm” supply chain structure
- Building and investing in mitigations strategies will prepare you for volatility and disruption



Questions?

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