Trade Networks and Economic Power

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BUSINESS

Tesla to Halt Production in Germany as Red Sea Conflict Hits Supply Chains

Disruption related to attacks on ships by Houthi rebels raise risk of supply-chain crisis in Europe

By William Boston Follow , Costas Paris Follow and Benoit Faucon Follow

Updated Jan. 12, 2024 1:45 pm ET

BERLIN—Tesla TSLA -3.67% ▼ plans to halt production at its only large factory in Europe for two weeks because of a lack of parts, a sign of how the fallout from recent attacks on ships in the Red Sea is starting to ripple through the global economy.

Yemen-based, Iran-backed Houthi fighters have launched successive attacks on commercial ships navigating the crucial trade route in recent months,

This Talk

Tractable model of (global, complex) supply chains to:

- characterize and compare impact of shocks over different time horizons
- provide a measure of the "supply chain power" countries have over one another
- investigate role of network structure in conferring power

Some Related Literature

- **Foundational work:** Leontief (1936), Long Jr and Plosser (1983), Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012)
- **Surveys:** Bernard (2018), Carvalho and Tahbaz-Salehi (2019), Baqaee and Rubbo (2022), Antràs and Chor (2022), Elliott and Golub (2022), Baldwin and Freeman (2022).
- **Production networks:** e.g., Dhyne et al. (2015); Magerman et al. (2016); Brummitt et al. (2017); Baqaee (2018); Oberfield (2018); Acemoglu and Tahbaz-Salehi (2020), Acemoglu and Azar (2020), Baqaee and Farhi (2021), Carvalho et al. (2021),Kopytov et al. (2021), Di Giovanni et al. (2022); Bernard et al. (2022), Elliott et al. (2022), Bui et al. (2022), König et al. (2022), Pellet and Tahbaz-Salehi (2023), Grossman et al. (forthcoming, 2023a,b), Bizzarri (2024)
- **Trade networks:** e.g., Furusawa and Konishi (2007); Chaney (2014); Bernard et al. (2019); Grossmand et al. (2021)
- **Micro network structure:** e.g., Bimpikis et al. (2018), Bimpikis et al. (2019), Amelkin and Vohra (2020)

Outline

Model

- $n \in \{1, \ldots, N\}$ countries,
- $m \in \{1, \ldots, M\}$ intermediate goods,
- $f \in \{1, \ldots, F\}$ final goods,
- L_n units of labor, country n,
- T_n set of CRS technologies, country n.

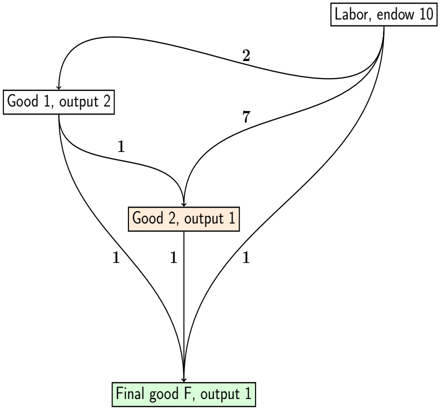
Example: Technologies

Cobb Douglas Example

$$\tau_1 = (\underbrace{-1}_{\text{labor}}, \underbrace{1}_{1}, \underbrace{0}_{2}, \underbrace{0}_{F})$$

$$\tau_2 = (\underbrace{-7}_{\text{labor}}, \underbrace{-1}_{1}, \underbrace{1}_{2}, \underbrace{0}_{F})$$

$$\tau_F = (\underbrace{-1}_{\text{labor}}, \underbrace{-1}_{1}, \underbrace{-1}_{2}, \underbrace{1}_{F})$$



Time Horizons

- Short Run – out of equilibrium
- Medium Run – constrained equilibrium
- Long Run – constrained equilibrium
- Very Long Run – equilibrium

	SR	MR	LR	VLR
Suppliers/Prices	Fixed	Flexible	Flexible	Flexible
Labor	Fixed	Fixed	Flexible	Flexible
Technology	Fixed	Fixed	Fixed	Flexible

Change from VLR to LR makes production Leontief (plants, recipes fixed)

Equilibrium

Unconstrained equilibria (very long run):

- Laborers/Consumers
  - supply labor inelastically, L_n in country n;
  - maximize homothetic preferences for final goods, $U(c_1, \ldots, c_F)$.

- Producers
  - maximize profits $p_\tau y_\tau - \sum_{\tau'} p_{\tau'} x_{\tau'\tau}$,
  - s.t feasible production: $-\tau_k y_\tau = \sum_{\tau':O(\tau')=k} x_{\tau'\tau}$ for all inputs k.

- Markets clear - standard Arrow-Debreu equilibrium.

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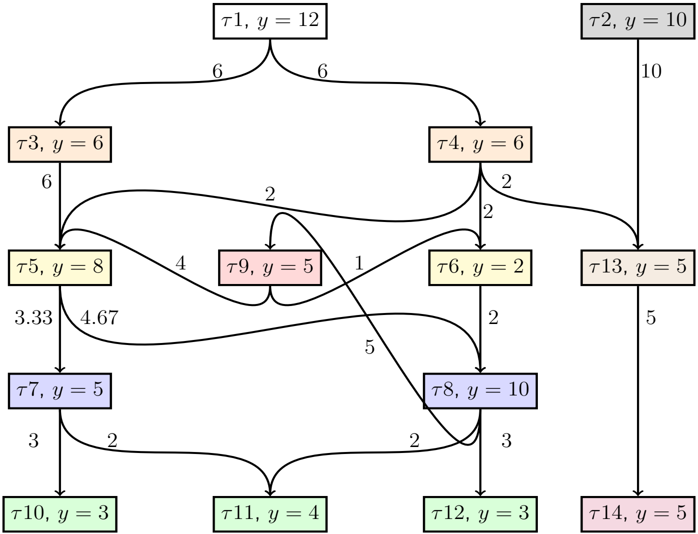
- Markets clear - standard Arrow-Debreu equilibrium.

Constrained equilibria as above except, depending on the time horizon,

- labor is perfectly immobile across technologies and fixed at its pre-shock allocation
- technologies are fixed (and hence Leontief)

Example w Cycles (Labor Omitted)



Outline

Impact of Shock: Long Run - Hulten's Theorem

Shocks/disruptions:

- For technology τ with output k, we normalized $\tau_k = 1$.
- Now vary τ_k to capture shocks/disruptions

Proposition (Hulten's Theorem)

Consider a generic equilibrium and technology τ, with $O(\tau) = k$, used in positive amounts in equilibrium. Then

$$\frac{\partial \log(U)}{\partial \log(\tau_k)} = \frac{\partial \log(GDP)}{\partial \log(\tau_k)} = \frac{p_\tau y_\tau}{GDP}.$$

Long-Run: Hulten's Theorem

$$\frac{\partial \log(U)}{\partial \log(\tau_k)} = \frac{p_\tau y_\tau}{GDP}$$

- Sufficient statistic: *fraction of GDP spent on shocked technology*.
- Intuition—adjust by sourcing more of that input at its cost.
- Network matters in background as it determines equilibrium
  - but don't need to see network to estimate long-run impact.
- Also holds in the VLR if firms' available technologies are "smooth."

Larry Summers 2013

"I always like to think of these crises as analogous to a power failure or analogous to what would happen if all the telephones were shut off for some time. Consider such an event. The network would collapse. The connections would go away. And output would, of course, drop very rapidly. There would be a set of economists who would sit around explaining that electricity was only 4% of the economy, and so if you lost 80% of electricity, you couldn't possibly have lost more than 3% of the economy. Perhaps in Minnesota or Chicago there would be people writing such a paper, but most others would recognize this as a case where the evidence of the eyes trumped the logic of straightforward microeconomic theory. . . . And we would understand that somehow, even if we didn't exactly understand it in the model, that when there wasn't any electricity, there wasn't really going to be much economy.

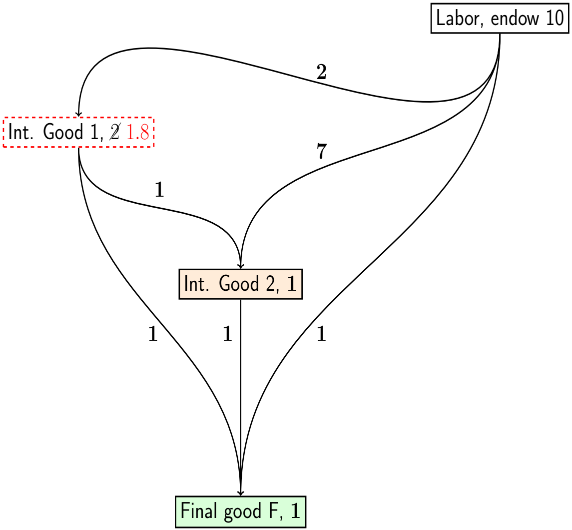
Short-Run Impact of a Shock

Now: Opposite benchmark with no adjustments.
(Our result holds away from the margin.)

- Cannot adjust the technologies being used.
- Cannot source additional units from suppliers.
- Cannot hire additional labor.
- Prices cannot adjust—rationing of disrupted goods is proportional

We define the short run outcome via an algorithm that propagates the shock.

Short Run Disruption 10%



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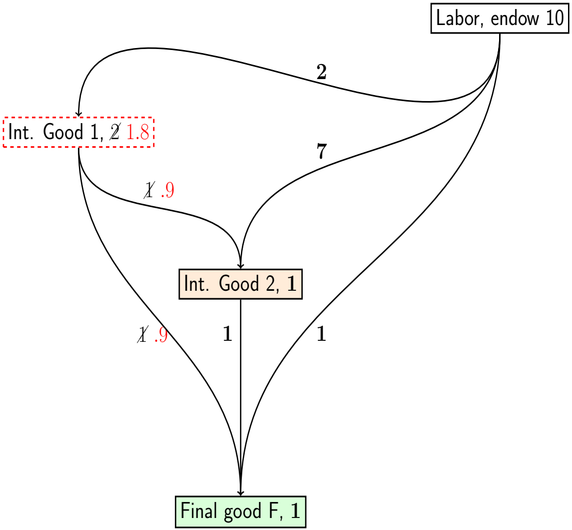

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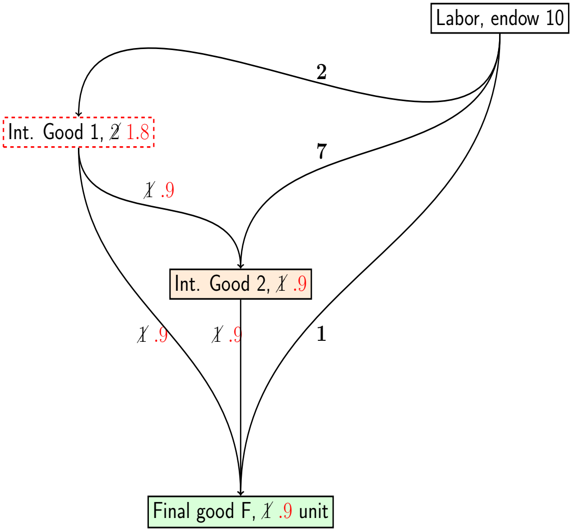
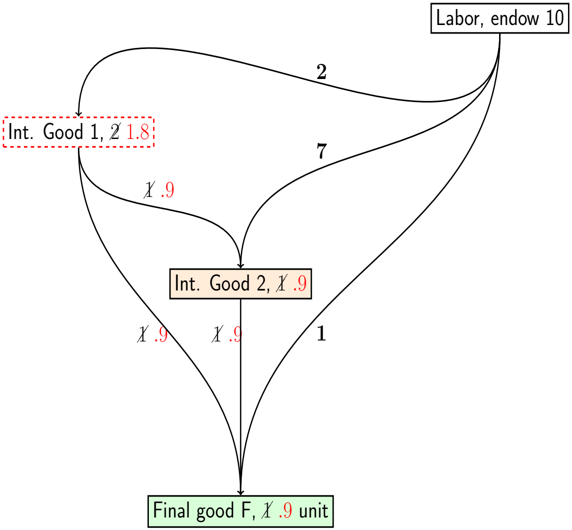


Short Run Disruption 10%



Long Run Disruption 2%

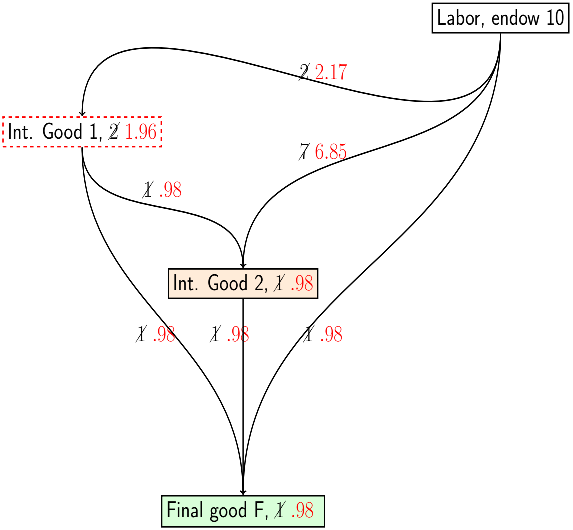
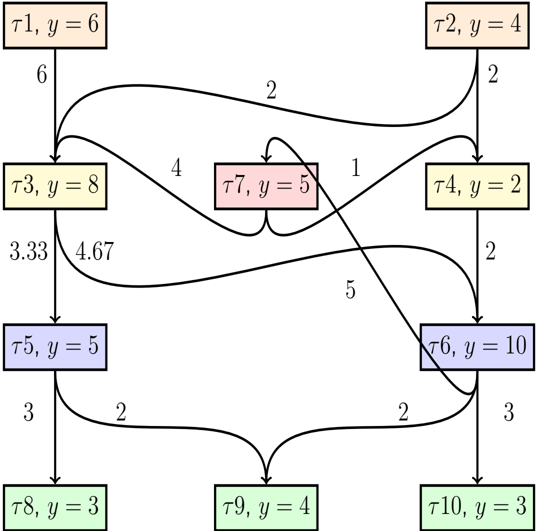


Figure: Shock Propagation Algorithm



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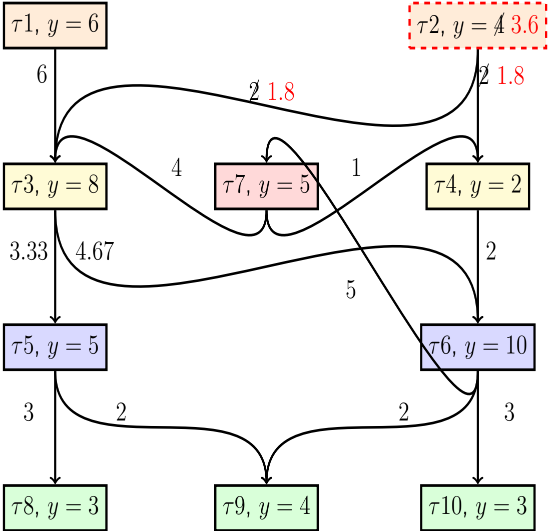

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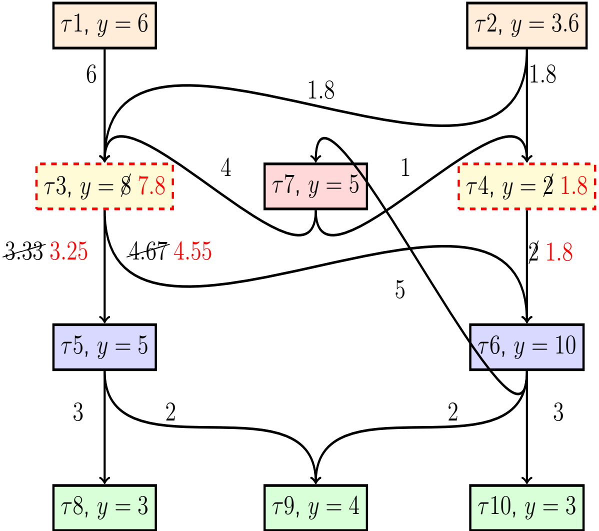

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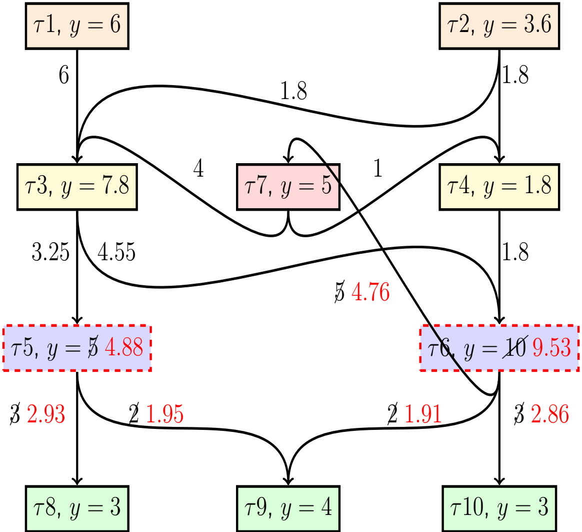

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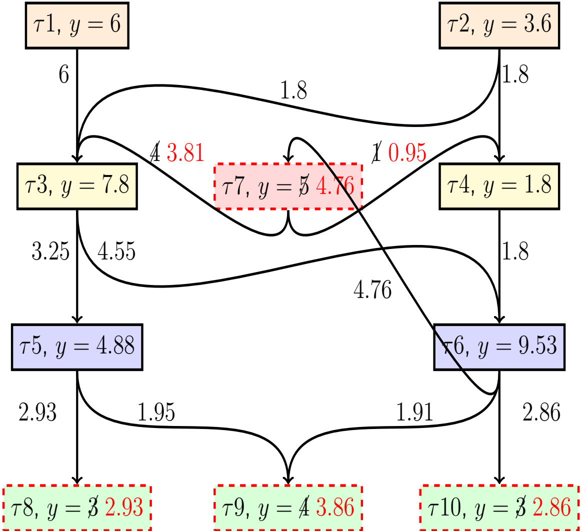

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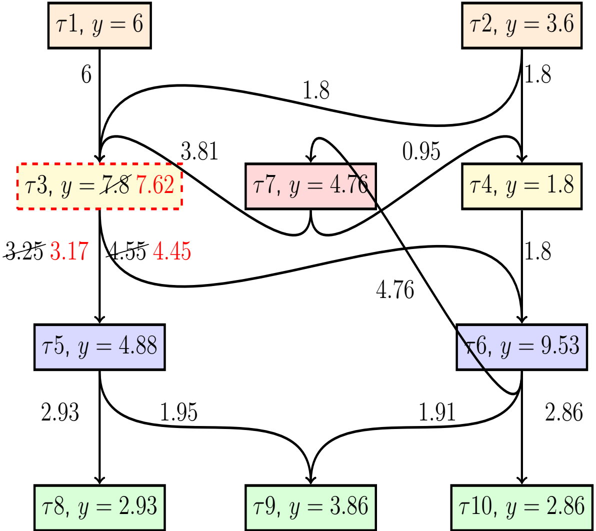

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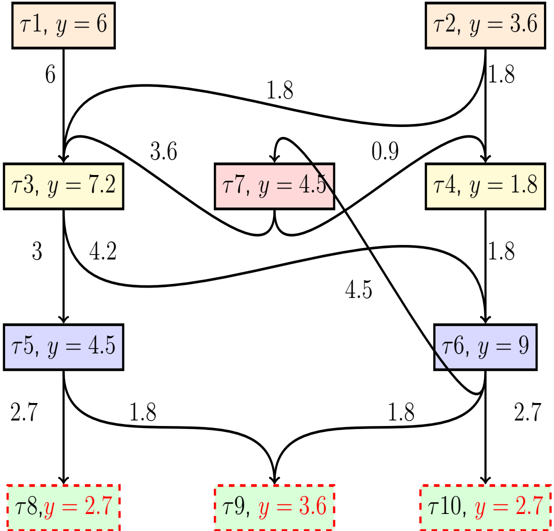

Shock Propagation Algorithm

Let $F(T^{shocked})$ be the final goods on directed paths from shocked technologies.

Proposition (Upper Bound)

Consider a shock that reduces the output of technologies $T^{shocked}$ to $\lambda < 1$ of their original levels. The proportion of lost GDP is bounded above by

$$(1-\lambda)\left(\frac{\sum_{f \in F(T^{shocked})} p_f c_f}{GDP}\right).$$

Sufficient Conditions for Bound to Bite

- All producers of given good and any “substitute” for it in a supply chain are shocked.
- Globalization/Low shipping costs: for low enough transportation costs generically get unique technologies used.
- Other sufficient conditions (graph-cut) in paper.

Short Run vs Long Run

Long Run, Hulten's Theorem,

$$\frac{\partial \log(U)}{\partial \log(\lambda)} = \frac{\partial \log(GDP)}{\partial \log(\lambda)} = \frac{(1-\lambda) p_\tau y_\tau}{GDP}.$$

Short Run, when bound bites

$$\frac{\Delta \log(U)}{\Delta \log(\lambda)} = \frac{\Delta \log(GDP)}{\Delta \log(\lambda)} = \frac{(1-\lambda) \sum_{f \in F(\tau)} p_f c_f}{GDP}.$$

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$$\frac{\Delta \log(U)}{\Delta \log(\lambda)} = \frac{\Delta \log(GDP)}{\Delta \log(\lambda)} = \frac{(1-\lambda)\sum_{f \in F(\tau)} p_f c_f}{GDP}.$$

- Long Run: shocking more expensive technologies has a larger impact.
- Short Run: shocking technologies that are used in more final goods has a larger impact.

Short Run vs Long Run

Short Run:

- Network position matters,
- Disrupt all final goods downstream

Long Run:

- (Much) cheaper than Short Run,
- Relative cost of input matters,
- Network matters, but only to extent changes costs.

Outline

Economic Power

Economic power of i over j: How much can country i disrupt the output of country j per unit of disruption it suffers itself.

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- Country i can target its disruptions:
  - reducing supply of intermediate goods to target country (directly and/or indirectly),
  - reducing demand for the target country's intermediate outputs (directly and/or indirectly).
- Assume labor is used locally and focus on the SR
- GDP of a country is the sum of its value-added
- The value added by an industry is its labor costs
- So we need to track idle labor by country

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AUTOS

Automakers Race to Find Workaround to China's Stranglehold on Rare-Earth Magnets

Major manufacturers, fearful they will have to shut down assembly lines, consider moving some parts production to China

By Sean McLain Follow *and Ryan Felton* Follow

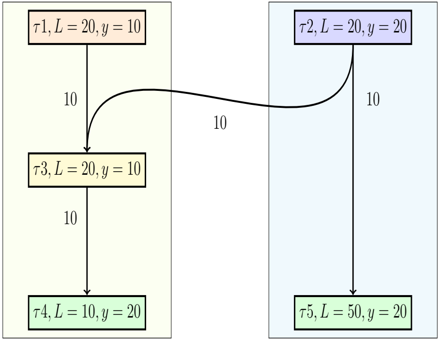
June 3, 2025 at 9:00 pm ET

Power Definition

$$\text{Power}_{ij} = \max_{\text{disruption of flows in/out of } i\text{'s technologies}} \frac{\%\text{ lost GDP in Country } j}{\%\text{ lost GDP in Country } i}$$

- Percentage losses helps to capture the power of larger countries with more diversified economies
- Sometimes the ratio of GDP losses might be a better measure.
- But the same disruption maximizes both measures
- If $\text{Power}_{ij} < 1$ then Country i has to be willing to suffer larger losses than it imposes.

Simple Example

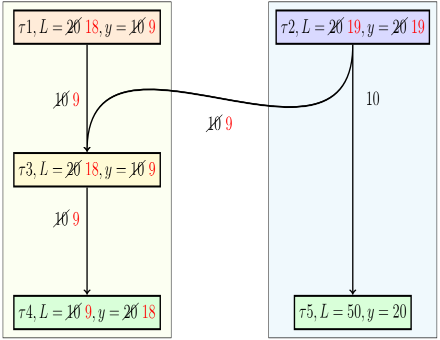


(a) Initial Equilibrium

- Country 1 operates $\{\tau_2, \tau_5\}$
- Country 2 operates $\{\tau_1, \tau_3, \tau_4\}$
- Wage in both is 1
- GDP in Country 1 is 70
- GDP in Country 2 is 50

Simple Example

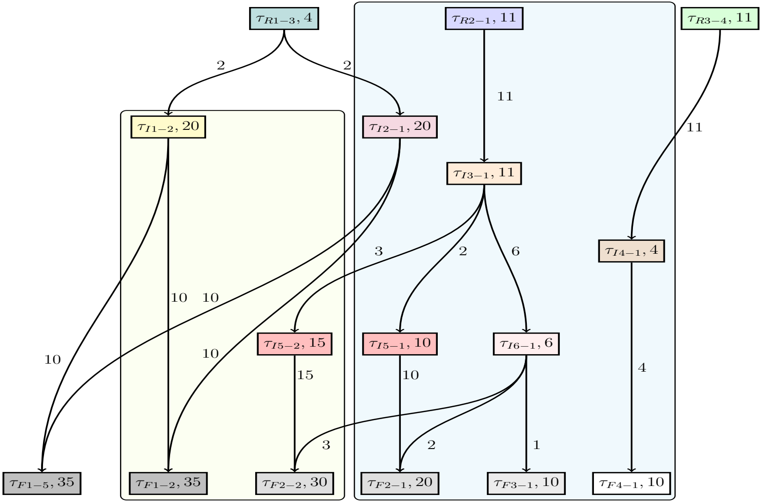
- The power of country 1 is 7.
- Comes from reducing the flow τ_2, τ_3
- GDP in Country 1 falls by $1/70$th
- GDP in Country 2 falls by $1/10$th.
- Observations:
  - Upstream disruptions are important
  - Ability to direct disruptions matters
  - Country 2 has little power over 1
  - If τ_4 and τ_5 are different goods, consumers suffer additional losses



(b) Disruption Consequences

A more involved example

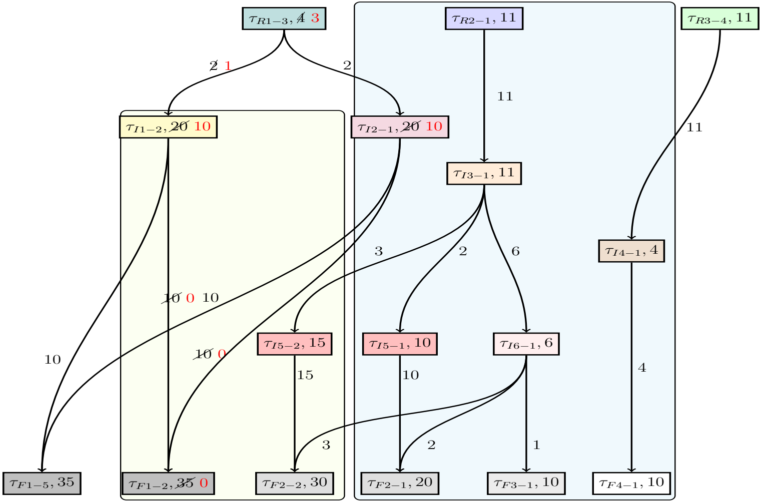
- Countries labeled $1 - 5$,
- Technologies labeled: Good-country
- Immobile Labor
- One unit of labor produces one unit of output
- Country 1 GDP: $100w_1$
- Country 2 GDP: $100w_2$.



(c) Initial Equilibrium

Possible disruption by 1

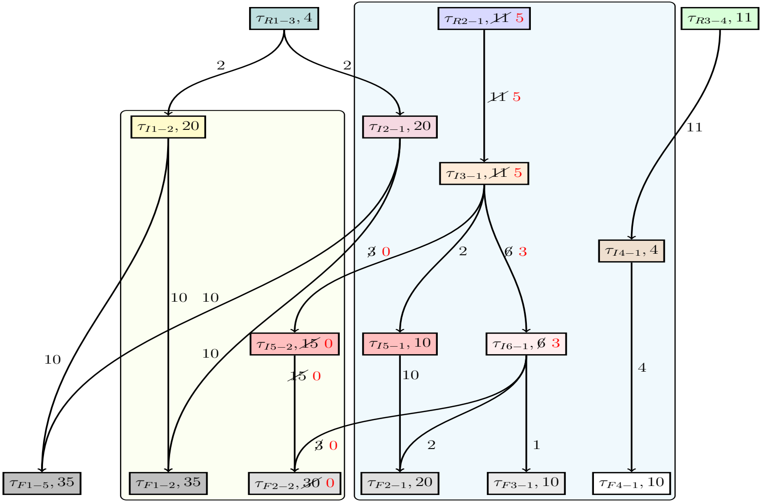
- Disrupt $\tau_{I2-1}\tau_{F1-2}$,
- Reduces 2's GDP by 45%.
- 1's GDP falls by 10%.
- Gives $Power_{12} = 4.5$



(d) Initial Equilibrium

Alternative disruption by 1

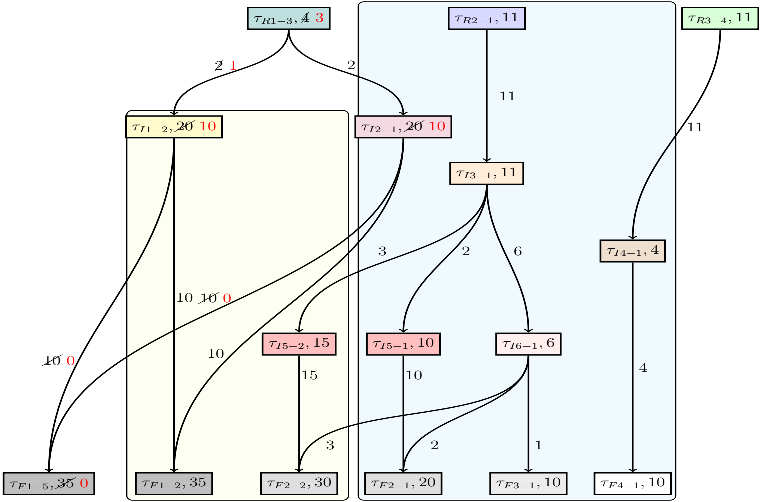
- Disrupt $\tau_{I3-1}\tau_{I5-2}$,
- Reduces 2's GDP by 45%.
- 1's GDP falls by 15%.
- Gives $Power_{12} = 3$



(e) Initial Equilibrium

Third disruption by 1 to hurt 2

- Disrupt $\tau_{I2-1}\tau_{F1-5}$,
- Reduces 2's GDP by 10%.
- 1's GDP falls by 10%.
- Gives $Power_{12} = 1$



(f) Initial Equilibrium

Remarks

- Country 1 has power 4.5 over Country 2.

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- A country i will have (substantial) power over j, when i's output is concentrated in industries j can disrupt at little cost to itself.
- In the example 2 has no real power over 1: $Power_{21} = 1$.
- In general power can be asymmetric or symmetric.
- China withholding the supply of rare earth metals to the US disrupted US manufacturing significantly at limited cost to China.

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- In general power can be asymmetric or symmetric.
- China withholding the supply of rare earth metals to the US disrupted US manufacturing significantly at limited cost to China.
- Space of possible disruptions even the example is large, but we only needed to consider three of them.
- Can consider disruptions of a specific flow only and only international flows out of the aggressor.
- Identify conditions in the paper under which this holds generally

Power away from the margin

Sometimes the power measure may only apply for very small disruptions.

More general question—how much can Country i disrupt j's GDP for an $x\%$ own disruption.

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More general question—how much can Country i disrupt j's GDP for an $x\%$ own disruption.

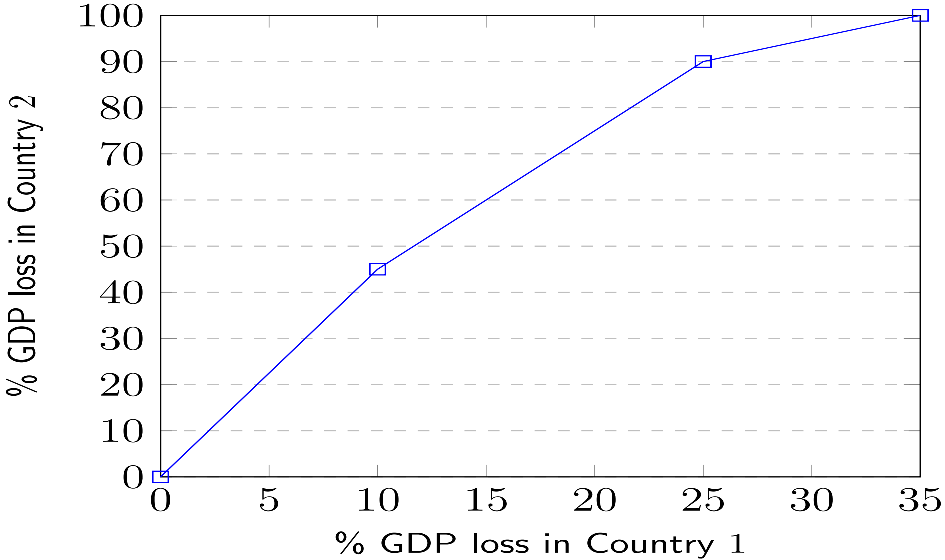
Disruption possibility frontier: Solve, for all $\lambda \in [0,1]$,

$$\min_{\text{Disruptions induced by } i} \frac{GDP_j\big((x_{\tau\tau'}, y_\tau, L_\tau)_{\tau,\tau'}\big)}{GDP_j^*}$$

subject to $GDP_i\big((x_{\tau\tau'}, y_\tau, L_\tau)_{\tau,\tau'}\big) \geq (1-\lambda)GDP_i^*$.

Slope of the disruption possibility frontier for i over j at the origin is $Power_{ij}$

In our example



Limitations

- Our analysis assumes that the aggressor can target specific flows, but elsewhere there is proportional rationing.
  - The aggressor has time to plan the disruption.
  - The disruption is unexpected by the target
- Interesting to think about what will also happen in the medium run
  - How does the ability to control rationing mitigate shocks?
  - How quickly will alternative suppliers be found?
  - Over what time horizon will the global supply network rewire more generally?

Outline

Final Remarks

Main takeaways from today:

- Impact of shocks can differ dramatically over different time horizons
- Propose a measure of the economic power countries have over one another

Other things in the paper:

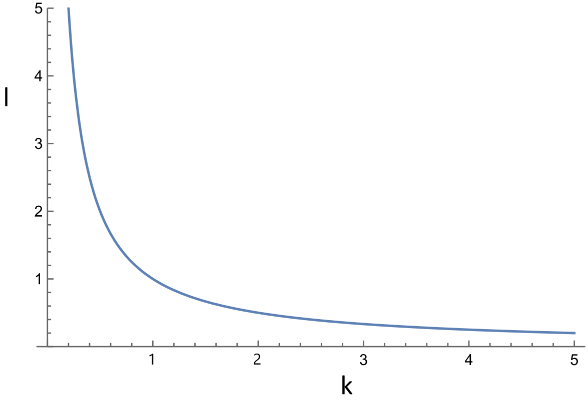
- Analysis of the medium run–flexible prices.
- How network position matters for SR shock amplification (centrality)
- What broad network features matter for SR Vs LR amplication
  - e.g., complexity matters in the short run but not long run
- Policy implications

Thank you!

Arrow-Debreu (1954) Technologies

Suppose country n can produce according to $y = L^{\alpha} K^{1-\alpha}$

Then $T_n = \{(-l, -k, 1) : l^{\alpha} k^{1-\alpha} = 1\}$



Return to Technologies

Acemoglu, D. and P. D. Azar (2020): "Endogenous Production Networks," *Econometrica*, 88, 33–82.

Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi (2012): "The Network Origins of Aggregate Fluctuations," *Econometrica*, 80, 1977–2016.

Acemoglu, D. and A. Tahbaz-Salehi (2020): "Firms, Failures, and Fluctuations: The Macroeconomics of Supply Chain Disruptions," Tech. rep., National Bureau of Economic Research.

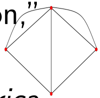
Amelkin, V. and R. Vohra (2020): "Strategic Formation and Reliability of Supply Chain Networks," in *Proceedings of the 21st ACM Conference on Economics and Computation*, 77–78.

Antràs, P. and D. Chor (2022): "Global value chains," *Handbook of international economics*, 5, 297–376.

Baldwin, R. and R. Freeman (2022): "Risks and global supply chains: What we know and what we need to know," *Annual Review of Economics*, 14, 153–180.

Baqaee, D. and E. Farhi (2021): "Entry vs. rents: Aggregation with economies of scale," Tech. rep., National Bureau of Economic Research, working Paper No. 27140.

Baqaee, D. and E. Rubbo (2022): "Micro propagation and macro aggregation," Tech. rep., National Bureau of Economic Research, working Paper No. 30538.



Baqaee, D. R. (2018): "Cascading failures in production networks," *Econometrica*, 86, 1819–1838.

Bernard, Andrew B.and Moxnes, A. (2018): "Networks and trade," *Annual Review of Economics*, 10, 65–85.

Bernard, A. B., E. Dhyne, G. Magerman, K. Manova, and A. Moxnes (2022): "The origins of firm heterogeneity: A production network approach," *Journal of Political Economy*, 130, 1765–1804.

Bernard, A. B., A. Moxnes, and Y. U. Saito (2019): "Production networks, geography, and firm performance," *Journal of Political Economy*, 127, 639–688.

Bimpikis, K., O. Candogan, and S. Ehsani (2019): "Supply Disruptions and Optimal Network Structures," *Management Science*, 65, 5504–5517.

Bimpikis, K., D. Fearing, and A. Tahbaz-Salehi (2018): "Multisourcing and miscoordination in supply chain networks," *Operations Research*, 66, 1023–1039.

Bizzarri, M. (2024): "Multilateral market power in input-output networks," .

Brummitt, C. D., K. Huremović, P. Pin, M. H. Bonds, and F. Vega-Redondo (2017): "Contagious Disruptions and Complexity Traps in Economic Development," *Nature Human Behaviour*, 1, 665.

Bui, H., Z. Huo, A. A. Levchenko, and N. Pandalai-Nayar (2022): "Information frictions and news media in global value chains," Tech. rep., National Bureau of Economic Research, working Paper No. 30033.

Carvalho, V. M., M. Nirei, Y. U. Saito, and A. Tahbaz-Salehi (2021): "Supply chain disruptions: Evidence from the great east japan earthquake," *The Quarterly Journal of Economics*, 136, 1255–1321.

Carvalho, V. M. and A. Tahbaz-Salehi (2019): "Production networks: A primer," *Annual Review of Economics*, 11, 635–663.

Chaney, T. (2014): "The network structure of international trade," *American Economic Review*, 104, 3600–3634.

Dhyne, E., G. Magerman, and S. Rubínová (2015): "The Belgian production network 2002-2012," Tech. rep., NBB Working Paper.

Di Giovanni, J., e. Kalemli-Özcan, A. Silva, and M. A. Yildirim (2022):

"Global supply chain pressures, international trade, and inflation," Tech. rep., National Bureau of Economic Research.

Elliott, M. and B. Golub (2022): "Networks and economic fragility," *Annual Review of Economics*, 14, 665–696.

Elliott, M., B. Golub, and M. V. Leduc (2022): "Supply network formation and fragility," *American Economic Review*, 112, 2701–47.

Furusawa and H. Konishi (2007): "Free trade networks," *Journal of International Economics*, 7, 310–335.

Grossman, G., E. Helpman, and S. Redding (2023a): "When tariffs disrupt global supply chains," Tech. rep.

Grossman, G. M., E. Helpman, and H. Lhuillier (forthcoming): "Supply Chain Resilience: Should Policy Promote International Diversification or Reshoring?" *Journal of Political Economy*.

Grossman, G. M., E. Helpman, and A. Sabal (2023b): "Resilience in Vertical Supply Chains," Tech. rep., National Bureau of Economic Research.

Grossmand, G., E. Helpman, and S. Redding (2021): "When tariffs disrupt global supply chains," *American Economic Review*.

König, M. D., A. Levchenko, T. Rogers, and F. Zilibotti (2022): "Aggregate fluctuations in adaptive production networks," *Proceedings of the National Academy of Sciences*, 119, e2203730119.

Kopytov, A., B. Mishra, K. Nimark, and M. Taschereau-Dumouchel (2021): "Endogenous production networks under supply chain uncertainty," *Available at SSRN 3936969*.

Leontief, W. W. (1936): "Quantitative Input and Output Relations in the Economic Systems of the United States," *The Review of Economic Statistics*, 105–125.

Long Jr, J. B. and C. I. Plosser (1983): "Real business cycles," *Journal of political Economy*, 91, 39–69.

Magerman, G., K. De Bruyne, E. Dhyne, and J. Van Hove (2016): "Heterogeneous firms and the micro origins of aggregate fluctuations," Tech. rep., NBB Working Paper.

Oberfield, E. (2018): "A Theory of Input-Output Architecture," *Econometrica*, 86.

Pellet, T. and A. Tahbaz-Salehi (2023): "Rigid production networks," *Journal of Monetary Economics*.