A Framework for Geoeconomics

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Geoeconomics, Economic Statecraft and Coercion

- Governments use their countries' economic strength from existing financial and trade relationships to achieve geopolitical and economic goals
- Fundamental questions:
  - Is geoeconomic power effective? In which dimensions?
  - Is it a global zero-sum game or positive sum?
  - What goods/industries are strategic?
  - Geoeconomic externalities, increasing returns to scale (emergence of world powers)
  - Government role: national security, official lending (Belt & Road), anticoercion tools

A Theoretical Framework

- Ingredients:
  - A collection of countries
  - Global production network (capital, technology, goods)
  - Incentive problems on enforcing contracts (both private and public)
  - Production and consumer externalities
- Main Mechanism:
  - Geoeconomic power arises from the ability to form joint threats from different economic activities
- How the framework works:
  - **Pressure:** repeated game with punishment among multiple relationships
  - **Extraction:** hegemons extract costly actions, e.g. mark-ups, tariffs, quantity caps
  - Pressure is positive sum, but extraction can be negative sum

Literature

- **International Political Economy:** Baldwin (1985), Frieden (1994), Drezner (2003), Farrell and Newman (2019), Camboni and Porcellacchia (2021), Mangini (2022), Parks et al. (2022)

- **Industrial Policy and Trade Theory:** Hirschman (1945,59), Berger, Easterly, Nunn and Satyanath (2013), Bagwell and Staiger (2017), Liu (2019), Baqaee and Farhi (2022), Bartelme, Costinot, Donaldson and Rodriguez-Clare (2019), Bocola and Bornstein (2023), Juhasz, Lane, Oehlsen and Perez (2022), Kleinman, Liu, Redding (2023)

- **Networks:** Gabaix (2011), Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012), Chaney (2014), Baqaee and Farhi (2019), Liu (2019), Elliott, Golub and Leduc (2022), Antras and Chor (2022)

- **Theory Tools: Trigger Strategies, Multitask Contracting, Externalities.** Abreu, Pierece, and Stacchetti (1986,1990), Holmstrom and Milgrom (1991), Greenwald and Stiglitz (1986), Geanakoplos and Polemarchakis (1985), Bernheim and Whinston (1990), Farhi and Werning (2016)

Model Set-Up

- Infinite horizon: $t = 0, 1, \dots$
- N countries and a set $\mathcal{I}$ of productive sectors
- Each sector is located in one country. $\mathcal{I}_n$ is the set of sectors of country n
- Unit mass of firms in sector i produces a differentiated good y_i using:

$$y_i = f_i(x_i, z) + \ell_i$$

- x_i is a vector of intermediate inputs x_{ij}, ℓ_i local factor of production
- Vector z of aggregate quantities, tracks externalities
- Repeated stage game, discount factor β

Representative Consumer in Country n

- Representative consumer in country n has per-period linear preferences,

$$U_n(C_n) = \sum_{i \in \mathcal{I}} \tilde{p}_i C_{ni} + u_n(z)$$

- Consumer owns firms and factor endowments $\bar{\ell}_i$ in their country
- Budget constraint

$$\sum_{i \in \mathcal{I}} p_i C_{ni} \leq \sum_{i \in \mathcal{I}_n} [\Pi_i + w_i \bar{\ell}_i]$$

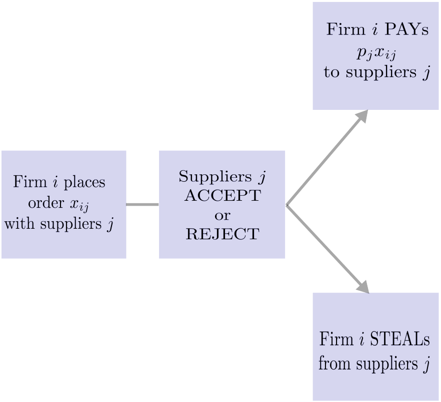
  Firm profits Π_i, good price p_i, factor price w_i

- Assume sufficiently large factor endowments, competitive factor pricing:

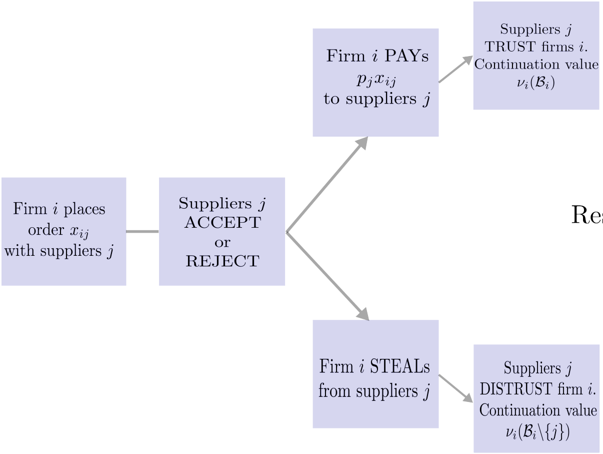
  Consumer optimization + positive consumption of all goods $\Rightarrow p_i = \tilde{p}_i$

- In general, can allow for arbitrary preferences and endogenous prices

Firm-Supplier Stage Game



Firm-Supplier Stage Game: Continuation Values

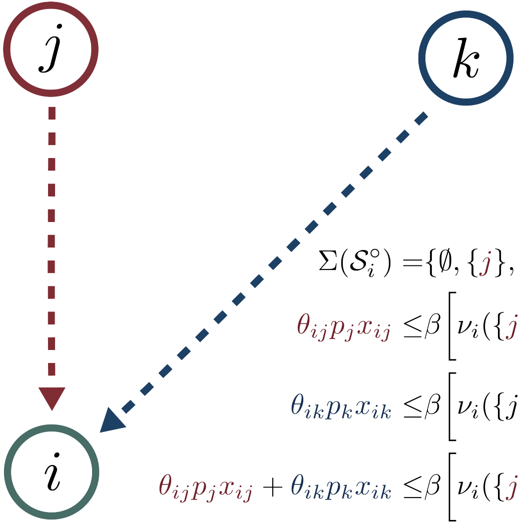


Total Net Payoffs	
Individual Firm i	Suppliers in j
$\Pi_i + \beta\nu_i(\mathcal{B}_i)$	0
$\Pi_i + \theta_{ij} p_j x_{ij} + \beta\nu_i(\mathcal{B}_i\backslash\{j\})$	$-\theta_{ij} p_j x_{ij}$

Resulting Incentive Compatibility Constraint:

$$\theta_{ij} p_j x_{ij} \leq \beta\Big[\nu_i(\mathcal{B}_i) - \nu_i(\mathcal{B}_i\backslash\{j\})\Big]$$

Example: IC Constraints Under Unrestricted Stealing



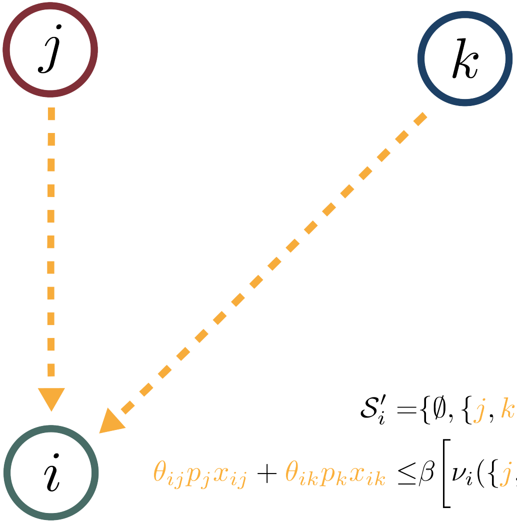
$$\Sigma(\mathcal{S}_i^\circ) = \{\emptyset, \{j\}, \{k\}, \{j, k\}\}$$

$$\theta_{ij} p_j x_{ij} \leq \beta \Big[\nu_i(\{j, k\}) - \nu_i(\{k\})\Big]$$

$$\theta_{ik} p_k x_{ik} \leq \beta \Big[\nu_i(\{j, k\}) - \nu_i(\{j\})\Big]$$

$$\theta_{ij} p_j x_{ij} + \theta_{ik} p_k x_{ik} \leq \beta \Big[\nu_i(\{j, k\}) - \nu_i(\emptyset)\Big]$$

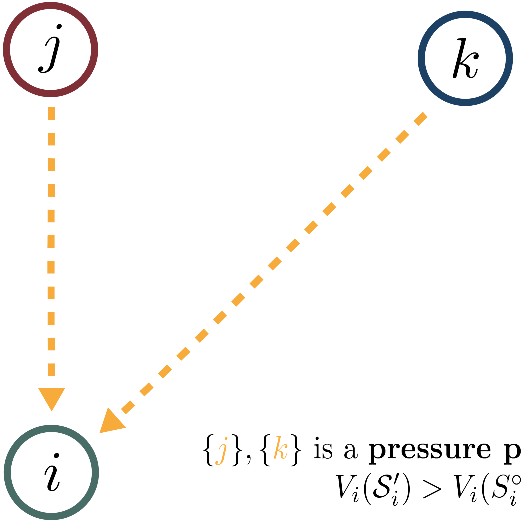
Example: Joint Threat



$$\mathcal{S}_i' = \{\emptyset, \{j, k\}\}$$

$$\theta_{ij} p_j x_{ij} + \theta_{ik} p_k x_{ik} \leq \beta \Big[\nu_i(\{j, k\}) - \nu_i(\emptyset) \Big]$$

Example: Pressure Point

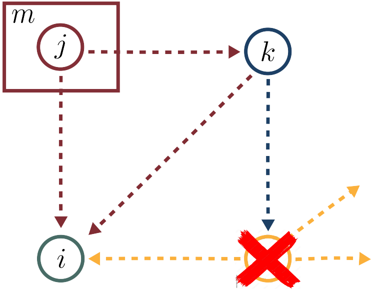


$\{j\}, \{k\}$ is a **pressure point** on i if

$$V_i(\mathcal{S}_i') > V_i(S_i^\circ)$$

Introducing a Hegemon

- Country m can become a hegemon by paying fixed cost F_m
- Hegemon contracts with domestic and downstream (up to one-step) foreign firms:
  - **Joint threats** $\mathcal{S}_i'$ that are *feasible*
  - **Transfers** $T_{ij} \geq 0$ to hegemon's representative consumer for $j \in \mathcal{J}_{im}$
  - Revenue neutral **wedges** on inputs τ_{ij} for $j \in \mathcal{J}_i$
- Local rejection of contract: if firm i rejects contract, reverts to outside option



The Hegemon Maximization Problem

Hegemon chooses feasible contract $\{\mathcal{S}_i', \mathcal{T}_i, \tau_i\}_{i \in \mathcal{C}_m}$ to maximize representative consumer m welfare,

$$\underbrace{\sum_{i \in \mathcal{I}_m} \left[\Pi_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) + w_i \bar{\ell}_i \right]}_{\text{Profits of Domestic Firms and Factor Payments}} + \underbrace{u_m(z)}_{\text{Externalities}} + \underbrace{\sum_{i \in \mathcal{D}_m} \sum_{j \in \mathcal{J}_{im}} T_{ij}}_{\text{Transfers from Foreign Entities}} .$$

subject to firms' participation constraints,

$$V_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) \geq V_i(\mathcal{S}_i, z)$$

and feasibility of joint threats

The Hegemon Maximization Problem

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subject to firms' participation constraints,

$$V_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) \geq V_i(\mathcal{S}_i, z)$$

and feasibility of joint threats

Lemma

It is weakly optimal for the hegemon to offer a contract with maximal joint threats to every firm it contracts with, that is $\mathcal{S}_i' = \overline{\mathcal{S}}_i'$ for all $i \in \mathcal{C}_m$.

Externalities and Input-Output Amplification

- Some sectors have larger impact on the economy
- Production externalities lead to endogenous amplification
- $f_i(x_i, z)$ where z is a vector that includes all x_k
- Derive a Leontief Inverse matrix based on externalities

Proposition

The aggregate response of z^* to a perturbation in exogenous variable a is

$$\frac{dz^*}{da} = \Psi^z \frac{\partial x^*}{\partial a}, \text{ where } \Psi^z = \left(\mathbb{I} - \frac{\partial x^*}{\partial z^*}\right)^{-1}.$$

$\mathcal{E}_{ij} \equiv \frac{\partial \mathcal{L}_m}{\partial z^*_{ij}}$ tracks the effects of externalities and amplification on hegemon problem

Hegemon Optimal Contract

Proposition

Conditional on entry, an optimal contract is:

1. *For domestic firms $i \in \mathcal{I}_m$ where $\mathcal{S}_i^D$ is a pressure point,*
   (a) *Wedges satisfy:* $(\overline{\Lambda}_{iS}\theta_{ij} + \eta_i + 1)\tau_{ij} = -\mathcal{E}_{ij}$.
   (b) *Transfers are zero:* $\overline{T}_i^* = 0$.
2. *For foreign firms $i \in \mathcal{D}_m$ where $\mathcal{S}_i^D$ is a pressure point,*
   (a) *Wedges satisfy:* $(\overline{\Lambda}_{ij}\theta_{ij} + \eta_i)\tau_{ij}^* = -\mathcal{E}_{ij}$.
   (b) *Transfers satisfy:* $\eta_i \geq 1 - \overline{\Lambda}_{iS_i^D}$, *with equality if* $\overline{T}_i^* > 0$.
3. *If $\mathcal{S}_i^D$ is not a pressure point on i, then wedges and transfers are zero*

Lagrange multipliers: Λ_{iS} on IC for action S, and η_i PC. Define $\overline{\Lambda}_{ij} = \sum_{S \in \Sigma(\overline{\mathcal{S}}_i') | j \in S} \Lambda_{iS}$

Friends and Enemies

- Theory-based definition of friend and enemies
- Under the hegemon's optimal contract, foreign firm i is:
  1. **Unfriendly** if $\mathcal{E}_{ij} \leq 0$ for all $j \in \mathcal{J}_i$, with strict inequality for at least one j.
  2. **Neutral** if $\mathcal{E}_{ij} = 0$ for all $j \in \mathcal{J}_i$.
  3. **Friendly** if $\mathcal{E}_{ij} \geq 0$ for all $j \in \mathcal{J}_i$, with strict inequality for at least one j.
- Hegemon treats these firms differently:
  - Unfriendly: taxed (positive wedges), mitigate externality
  - Neutral: untaxed (zero wedges)
  - Friendly: subsidized (negative wedges), boost externality
- Leading special case: no z externalities, all firms are neutral, participation binds.

Geoeconomics Power: Positive or Negative Sum?

Proposition

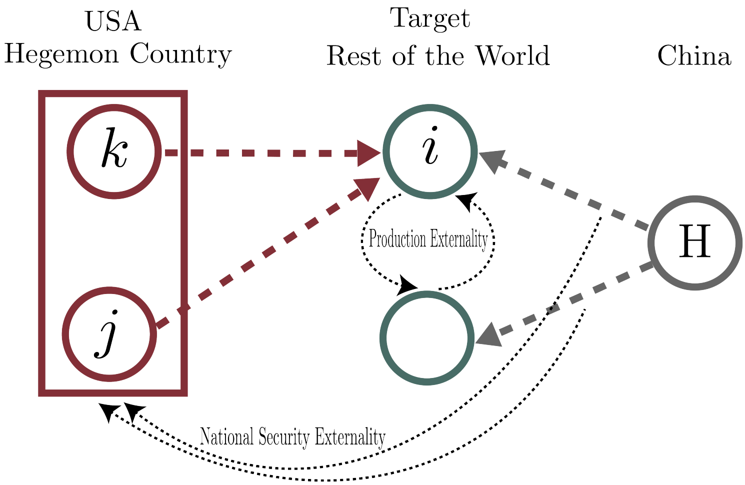
The global planner's efficient contract for all firms $i \in \mathcal{C}_m$ is:

(a) *Wedges satisfy:* $(\overline{\Lambda}_{ij}\theta_{ij} + \eta_i + 1)\tau^*_{ij} = -\mathcal{E}^P_{ij}$.

(b) *Transfers are zero:* $\overline{T}^*_i = 0$.

- Hegemon and global planner agree:
  - maximal joint threats are *positive sum*
  - transfers are *negative sum*
- Hegemon and global planner have different objectives
  - Hegemon values transfers
  - Different values from externalities: $\mathcal{E}^P_{ij} \neq \mathcal{E}_{ij}$
- Role for anti-coercion tools that reduce distortionary surplus extraction

Application 1: National Security Externalities



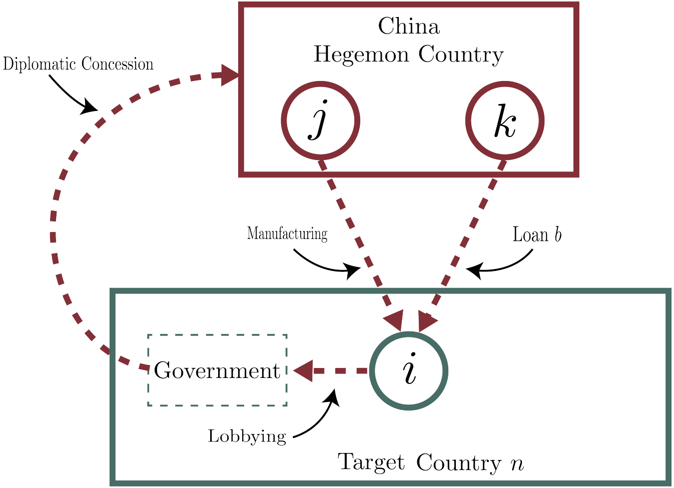
Import Restrictions On National Security Concerns

- Hegemon asks third party countries to curb imports of tech from hostile country on the basis of national-security

$$\tau_{iH} = - \overbrace{\frac{1}{\eta_i}\frac{\partial u_m}{\partial z_{iH}}}^{\text{Direct Externality}} - \overbrace{\frac{1}{\eta_i}\frac{\partial u_m}{\partial z_{jH}}\frac{\xi_{ji}}{\gamma_j - \xi_{jj}}\frac{z_{jH}}{z_{iH}}}^{\text{Network Amplification}}$$
$$+ \underbrace{p_i A_{iH}(z^H)\left[g_{iH}(x^*_{iH}(z^H)) - g_{iH}(x_{iH})\right]\left(\xi_{ii} + \xi_{ij}\frac{\xi_{ji}}{\gamma_j - \xi_{jj}}\right)\frac{1}{z_{iH}}}_{\text{Indirect Effect on Participation Constraint}}$$

- **Strategic sector:** Network amplification increases incentives to impose restriction
- Restrictions are costly for targeted firms, tightens participation constraint
- Network amplification reduces costs to firms if successful

Application 2: China's Belt and Road Initiative



Joint Threats As Endogenous Cost of Default

- Sector i has a separable production function in inputs j and k
- Sector k is lending to i: $x_{ij} = b$, interest rate $p_k = R$
- No enforeceability of loan, $\theta_{ik} = 1$, perfect enforceability of manufacturing $\theta_{ij} = 0$
- Under isolated threats the IC is:

$$Rb \leq \beta \nu_i(\{b\}) = \beta \frac{p_i f_{ik}(b^*) - Rb^*}{1-\beta}$$

- Under joint threats the IC is:

$$Rb \leq \beta \left[\frac{p_i f_{ik}(b^*) - Rb^*}{1-\beta} + \nu_i(\{j\}) \right]$$

- Manufacturing export act as endogenous cost of default, increases debt capacity

Our Ongoing Agenda

- Empirics:
  - Measuring strategic sectors
  - Measuring returns to hegemonic power
- Geopolitical Competition:
  - Escalating rivalry between US and China
  - Ongoing work: equilibrium with multiple hegemons
  - Existance of an alternative as a limit to power
- Countering Economic Coercion:
  - G7 Partnership for Global Infrastructure and Investment as an alternative to BRI
  - EU ongoing pursuit of an "Anti-Coercion Instrument"
  - Ongoing work: Characterizing optimal policy in targeted countries
- Geopolitics of International Currency Competition

Conclusion

- A framework to understand geoeconomic power arising from joint threats across disparate economic activities
- Geoeconomic power can be positive-sum, but scope for government intervention
- Starting point for rich set of future research

Trigger Strategy Details

- Beliefs of suppliers in j in their relationship with individual firm i in the End:

$$B'_{ij}(S) = \begin{cases} B_{ij}, & \exists K_{ij} \cap S = \emptyset \\ 0, & o.w. \end{cases}, \quad K_{ij} = \{j\} \cup \bigcup_{x \in R_{ij}} K_{ix}$$

- R_{ij}: joint trigger set. Symmetric: $k \in R_{ij} \iff j \in R_{ik}$
- Basis action set $\mathcal{S}_i = \bigcup_{j \in \mathcal{J}_i} \{K_{ij}\}$

Lemma

The order (x_i, ℓ_i) is incentive compatible with respect to $P(\mathcal{J}_i)$ if and only if it is incentive compatible with respect to $\Sigma_i(\mathcal{S}_i)$

Firm Maximization

$$\max_{\{x_{ij}\}_{j\in\mathcal{J}_i}} p_i f_i(x_i, z) - \sum_{j\in\mathcal{J}_i} p_j x_{ij}$$

subject to incentive constraints,

$$\sum_{j\in S} \theta_{ij} p_j x_{ij} \leq \beta \left[\nu_i(\mathcal{B}_i) - \nu_i(\mathcal{B}_i \backslash S) \right] \qquad \forall S \in \Sigma(\mathcal{S}_i^\circ)$$

$\mathcal{B}_i$: set of suppliers that trust firm i

$\mathcal{B}_i \backslash S$ reduces set following stealing from suppliers in S

$\mathcal{S}_i^\circ = \{\{j\}\}_{j\in\mathcal{J}_i}$ set of individual stealing actions, Σ set of supersets

Market Clearing

- Market clearing for good j:

$$\sum_{n=1}^{N} C_{nj} + \sum_{i \in \mathcal{D}_j} x_{ij} = y_j$$

$\mathcal{D}_j = \{i \in \mathcal{I} | j \in \mathcal{J}_i\}$ the set of firms that source from supplier j

- Market clearing for factor i: $\ell_i = \bar{\ell}_i$

Joint Threats

Definition

A **joint threat** is a transformation of action set $\mathcal{S}_i$ into a new action set $\mathcal{S}_i'$ that combines $n \geq 2$ elements $S_1, \ldots, S_n \in \mathcal{S}_i$ into a single action,

$$\mathcal{S}_i' = \{\bigcup_{x=1}^{n} S_x\} \cup (\mathcal{S}_i \backslash \{S_1, \ldots, S_n\}).$$

- Keep track of joint threats as reductions in the action sets of firms
- A firm that faces a joint threat will face permanent shutoff in all relationships if stealing from just one. Firm never choose to only pay some suppliers within the joint threat

Identifying ex-ante when a Joint Threat Generates Value

Definition

A **pressure point** is a collection of stealing actions $S_1, \dots, S_n \in \mathcal{S}_i$ that, when used to form a joint threat $\mathcal{S}_i'$, strictly increases value of firm i, $V_i(\mathcal{S}_i') > V_i(\mathcal{S}_i)$

$V_i(\mathcal{S}_i)$ is value of firm i under optimal production given action set $\mathcal{S}_i$,

$$V_i(\mathcal{S}_i) = \max_{x_i} \; p_i f_i(x_i, z) - \sum_{j \in \mathcal{J}_i} p_j x_{ij} + \beta \nu_i(\mathcal{J}_i)$$

$$s.t. \quad \sum_{j \in S} \theta_{ij} p_j x_{ij} \leq \beta \Big[\nu_i(\mathcal{J}_i) - \nu_i(\mathcal{J}_i \backslash S) \Big] \quad \forall S \in \Sigma(\mathcal{S}_i),$$

Note: here, $\mathcal{B}_i = \mathcal{J}_i$, i.e. all suppliers trust firm i ex ante

Example: Identifying Pressure Points

Proposition

Suppose production function is separable. Then, for any firm i, a collection of actions $S_1, \ldots, S_n \in \mathcal{S}_i$ is a pressure point if and only if $\lambda_{iS} \neq \lambda_{iS'}$ for some $S, S' \in \{S_1, \ldots, S_n\}$

- Identify all pressure points from Lagrange multipliers on ICs in ex-ante equilibrium
- $\lambda_{iS} \geq 0$ the Lagrange multiplier on IC wrt action S
- Use variational math to identify pressure points in a discrete-choice problem

Building Continuation Value ν

- Fix action sets $\mathcal{S}_i$ and externalities z
- Start from $\nu_i(\emptyset) = 0$
- Construct the value function $\nu_i(\mathcal{B}_i)$ iteratively as a fixed point of

$$\nu_i(\mathcal{B}_i) = \max_{x_i} p_i f_i(x_i, z) - \sum_{j \in \mathcal{J}_i} p_j x_{ij} + \beta \nu_i(\mathcal{B}_i)$$

$$s.t. \quad \sum_{j \in S} \theta_{ij} p_j x_{ij} \leq \beta \Big[\nu_i(\mathcal{B}_i) - \nu_i(\mathcal{B}_i \backslash S) \Big] \quad \forall S \in \Sigma_i(\mathcal{S}_i(\mathcal{B}_i)),$$

where $\mathcal{S}_i(\mathcal{B}_i) = \{S \in \mathcal{S}_i \mid S \subset \mathcal{B}_i\}$

- Constructing $\nu_i(\mathcal{B}_i)$ uses the constructions of $\nu_i(\hat{B}_i)$ for $\hat{B}_i \in \Sigma_i(\mathcal{B}_i) \backslash \mathcal{B}_i$ in the previous steps

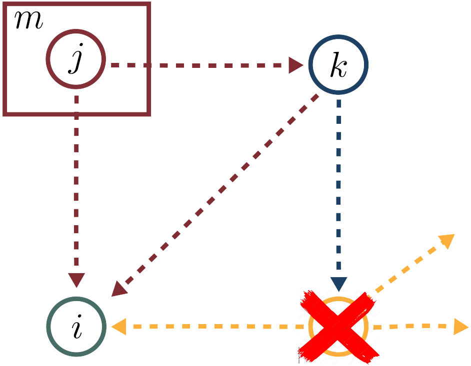
Defining the Hegemon's Contract

- Hegemon has ability to coordinate its firms and propose contracts on their behalf
- Hegemon contracts with domestic firms and their immediately downstream firms
  - Firms hegemon can contract with: $\mathcal{C}_m = \mathcal{I}_m \cup \bigcup_{i \in \mathcal{I}_m} \mathcal{D}_i$
  - Set of inputs that firm i sources directly from country m: $\mathcal{J}_{im} = \mathcal{J}_i \cap \mathcal{I}_m$
- Terms of the contract offered to firm $i \in \mathcal{C}_m$
  - **Joint threats** $\mathcal{S}_i'$ that are *feasible*
  - **Transfers** $T_{ij} \geq 0$ to hegemon's representative consumer for $j \in \mathcal{J}_{im}$
  - Revenue neutral **wedges** on inputs τ_{ij} for $j \in \mathcal{J}_i$
- Local rejection of contract: if firm i rejects contract, reverts to outside option

Feasible Joint Threats

Definition

Hegemon m can consolidate $S \in \mathcal{S}_i$ under **direct transmission** if $\exists j \in S$ with $j \in \mathcal{C}_m$.
Let $\mathcal{S}_i^D \subset \mathcal{S}_i$ denote firm i's actions that can be consolidated under direct transmission.



Timing of Payments, Wedges, and Lump-Sum Rebates

- Individual firm i only makes transfer T_{ij} if chooses Pay
- Firm i faces price for input j of $p_j + \tau_{ij}$
- Rebates $\tau_{ij} x_{ij}^*$ are pro-rated on fraction paid θ_{ij} following Steal
- Revenue-neutral wedges similar to quantity restrictions
- Define $\mathcal{T}_i = \{T_{ij}\}_{j \in \mathcal{J}_{im}}$, and $\overline{T}_i$ is the sum of the transfers
- Define $\tau_i = \{\tau_{ij}\}_{j \in \mathcal{J}_i}$, the set of wedges faced by firm i

Firm Participation Constraint

- Firm i value function is

$$V_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) = \max_{x_i} \; p_i f_i(x_i, z) - \sum_{j \in \mathcal{J}_i} [p_j x_{ij} + \tau_{ij}(x_{ij} - x_{ij}^*) + T_{ij}] + \beta \nu_i(\mathcal{J}_i)$$

$$s.t. \; \sum_{j \in S} \left[\theta_{ij}[p_j x_{ij} + \tau_{ij}(x_{ij} - x_{ij}^*)] + T_{ij} \right] \leq \beta \left[\nu_i(\mathcal{J}_i) - \nu_i(\mathcal{J}_i \backslash S) \right] \quad \forall S \in \Sigma(\mathcal{S}_i)$$

- If firm rejects contract, gets outside option $V_i(\mathcal{S}_i, z)$
- **Participation constraint:** $V_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) \geq V_i(\mathcal{S}_i, z)$

Geoeconomics Power: Positive or Negative Sum?

- Global planner: same power and instruments of Hegemon, different objective:

$$\overbrace{\sum_{i\in\mathcal{I}_m}\left[\Pi_i + w_i\bar{\ell}_i\right] + \sum_{i\in\mathcal{D}_m}\overline{T}_i + u_m(z)}^{\text{Hegemon Objective}} \qquad \overbrace{\sum_{i\in\mathcal{I}}\left[\Pi_i + w_i\bar{\ell}_i\right] + \sum_{n\in N}u_n(z)}^{\text{Global Planner Objective}}$$

$$\underbrace{\sum_{j\in S}\left[\theta_{ij}p_jx_{ij} + T_{ij}\right] \leq \beta\left[\nu_i(\mathcal{J}_i) - \nu_i(\mathcal{J}_i\backslash S)\right]}_{\text{Incentive Constraint}}$$

$$\underbrace{V_i(\mathcal{S}_i', \mathcal{T}_i, \tau_i, z) \geq V_i(\mathcal{S}_i, z)}_{\text{Participation Constraint}}$$

An Example: Lithuania

In the lead-up to the Lithuanian government's decision to open a TRO in Vilnius, China had been slowly applying economic pressure, first by cutting off credit insurance for Lithuanian counterparts of Chinese firms and then by blocking timber and grain exports. After the offending office finally opened, China intensified the pressure by effectively cutting off all trade with Lithuania. However, China's initial punitive measures exerted little economic pain owing to the minimal amount of direct trade between the two countries: Lithuania's exports to China account for just 1 percent of its total exports, and its imports from China make up just 3 percent of total imports. **Beijing adapted by threatening informal secondary sanctions-a novel tactic-on European, primarily German, firms that sourced products from Lithuanian suppliers. This tactic led some European voices to call for Lithuania to back down and prompted the Lithuanian president to express regret over the name choice.** [Emphasis added]

Source: Reynolds and Goodman (2023)

BRI Example

- AidData's dataset of individual project finance by China's lenders
- Loan from the China Export-Import Bank to Ethiopia providing $171 million in preferential buyer's credit to the Government of Ethiopia to complete a section of the Modjo-Hawassa Expressway
- For this project, the China Railway Group Co. Ltd (CRSG) is the contractor
  - Parent firm of this contractor is the China Railway Group Limited, who in turn is owned by the China Railway Engineering Corporation, a state-owned enterprise.

Defining $\mathcal{E}_{ij}$

$$\mathcal{E}_{ij} \equiv \frac{\partial \mathcal{L}_m}{\partial z_{ij}} = e_{ij} + e_{NC} \Psi^z_{NC} \frac{\partial z^*_{NC}}{\partial z_{ij}}$$

- e_{ij}: the direct spillover from z_{ij}

$$e_{ij} = \sum_{i \in \mathcal{I}_m} p_i \frac{\partial f_i(x_i, z)}{\partial z_{ij}} + \frac{\partial u_m(z)}{\partial z_{ij}} + \sum_{i \in \mathcal{C}_m} \eta_i \left[p_i \frac{\partial f_i(x_i, z)}{\partial z_{ij}} - \frac{\partial V_i(\mathcal{S}_i, 0, 0, z, \mathcal{J}_i)}{\partial z_{ij}} \right]$$

- $\mathcal{NC} = \mathcal{I} \backslash \mathcal{C}_m$: agents hegemon does not contract with
- Ψ^z_{NC}: the inverse matrix for firms in $\mathcal{NC}$
- $z_{NC} = \{z_i\}_{i \in \mathcal{NC}}$ and $e_{NC} = \{e_i\}_{i \in \mathcal{NC}}$