Evaluating Industrial Policies in Strategic Interactions and Production Networks

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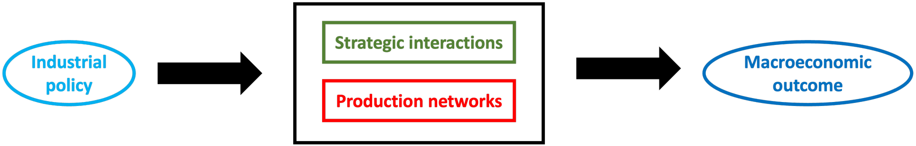
February 6, 2024

Job Market Seminar

Towson, Maryland, USA

Background

- **Industrial policies** have been actively used in many countries/areas for many purposes.
  - e.g., In the U.S., CHIPS and Science Act in 2022; CARES Act during the COVID-19 pandemic.
- It is important to evaluate the **macroeconomic impacts** of these types of policies **before their actual implementation**.
- **Policy effects** are mediated by many features of an economy.
  - Two salient features: **strategic interactions** and **production networks**



Motivation and Goal

- Strategic competition between firms is prevalent in many industries.
  - Changes in costs are not fully translated into changes in output prices.
- Industries are linked through input-output linkages.
  - A shock to one sector propagates through the production network.
- This paper develops a framework for *ex ante* evaluation of the **macroeconomic impacts of subsidies** under **strategic competition** and **production networks**.
  - Model, data, identification and estimation

Literature Contribution

Preview of My Paper

Model implication:

- The production network compounds the firms' markup responses not only with respect to the firms' own choices, but also with respect to competitors' choices.

Identification:

- I assume that firms' equilibrium choices depend on competitors' productivities only through a single aggregate.

Empirical application:

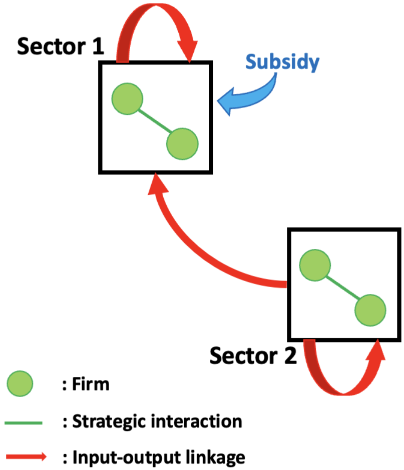
- I consider one part of the CHIPS and Science Act 2022.
- The estimate based on oligopolistic competition is substantially different from the estimate based on monopolistic competition.

Literature

- **Policy effects** in a model of **strategic competition** without production networks:
  - Gaubert, Itskhoki and Vogler (2021); Wang and Werning (2022), etc.
- Optimal policies in a model of perfect competition **with production networks**:
  - Liu (2019), etc.
- Optimal policies in a model of monopolistic competition **with production networks**:
  - Lashkaripour and Lugovskyy (2023), etc.
- **Policy effects** in a model of **strategic competition** **with production networks**:
  - My paper!!

An Illustrative Example

- Two sectors, two firms engaging in a Cournot duopoly.
- Firms' products are combined to a sectoral good.
  - used by firms and a final consumer.
- The value added comes only from markups.
  - No labor input is used.
- There is an input subsidy τ_1^0 to Sector 1.
- Consider changing the subsidy from τ_1^0 to τ_1^1.
- **Policy Question:** How much will GDP change?



Object of Interest

- $GDP(\tau_1) := VA_1(\tau_1) + VA_2(\tau_1)$, where $VA_i(\cdot)$ is value added of Sector i.

- The change in GDP due to the policy reform from τ_1^0 to τ_1^1:

$$\Delta GDP(\tau_1^0, \tau_1^1) := GDP(\tau_1^1) - GDP(\tau_1^0) = \int_{\tau_1^0}^{\tau_1^1} \left(\frac{dVA_1}{d\tau_1} + \frac{dVA_2}{d\tau_1} \right) d\tau_1,$$

with

$$\frac{dVA_1}{d\tau_1} + \frac{dVA_2}{d\tau_1} = A \frac{d\mu_1}{d\tau_1} + B \frac{dy_1}{d\tau_1} + C \frac{dy_2}{d\tau_1},$$

where
  - μ_1: Sector 1's markup;
  - y_i: final consumption of Sector i's good;
  - A, B, C: some coefficients (A and B reflect the **production network**).

Detail

Markup Responses

- The markup response of Sector 1:

$$\frac{d\mu_1}{d\tau_1} = \underbrace{D_1\left(\frac{\partial\mu_{11}(\cdot)}{\partial q_{11}}\frac{dq_{11}}{d\tau_1} + \frac{\partial\mu_{11}(\cdot)}{\partial q_{12}}\frac{dq_{12}}{d\tau_1}\right)}_{\text{Firm 1's markup response}} + \underbrace{D_2\left(\frac{\partial\mu_{12}(\cdot)}{\partial q_{11}}\frac{dq_{11}}{d\tau_1} + \frac{\partial\mu_{12}(\cdot)}{\partial q_{12}}\frac{dq_{12}}{d\tau_1}\right)}_{\text{Firm 2's markup response}},$$

  where
  - q_{ik}: the firm k's output quantity.
  - $\mu_{1k}(q_{11}, q_{12})$: the firm k's markup.
  - D_k: a coefficient reflecting the firm k's market share in sector 1.

- **The purple parts** capture the markup responses with respect to **the firms' own choices**.
- **The green parts** capture the markup responses with respect to **the competitors' choices**.

Implications

- The change in GDP due to the policy reform from τ_1^0 to τ_1^1:

$$\begin{aligned}\Delta GDP(\tau_1^0,\tau_1^1) = & \int_{\tau_1^0}^{\tau_1^1}\left(B\frac{dy_1}{d\tau_1}+C\frac{dy_2}{d\tau_1}\right)d\tau_1 \\ & + \int_{\tau_1^0}^{\tau_1^1} A\left(D_1\frac{\partial\mu_{11}(\cdot)}{\partial q_{11}}\frac{dq_{11}}{d\tau_1}+D_2\frac{\partial\mu_{12}(\cdot)}{\partial q_{12}}\frac{dq_{12}}{d\tau_1}\right)d\tau_1 \\ & \underbrace{+ \int_{\tau_1^0}^{\tau_1^1} A\left(D_2\frac{\partial\mu_{12}(\cdot)}{\partial q_{11}}\frac{dq_{11}}{d\tau_1}+D_1\frac{\partial\mu_{11}(\cdot)}{\partial q_{12}}\frac{dq_{12}}{d\tau_1}\right)d\tau_1}_{(\star)}.\end{aligned}$$

- In monopolistic competition, $(\star)$ is absent.
- The policy effects are **theoretically** different due to $(\star)$.
- Using real-world data, I find that $(\star)$ is **empirically** relevant as well.

Setup

- A closed-economy, multi-sector model with N sectors:
  - Sectors are linked via **input-output linkage**.
- In sector i, a finite number N_i of firms engage in **Cournot competition**.
- Firms' products in each sector are aggregated into a sectoral good.
  - consumed by a representative consumer and by a government;
  - used by firms as an input.
- The government provides **input subsidies specific to purchasing sectors**:
  - i.e., when the total value of intermediate goods purchased by firm k in sector i is M_{ik}, the firm's actual expenditure is $(1 - \tau_i)M_{ik}$.

Open Economy Static or dynamic

Firm-Level Production

- Firm k in sector i:

$$q_{ik} = z_{ik} f_i(\ell_{ik}, m_{ik}) \qquad \text{with} \qquad m_{ik} = \prod_{j=1}^{N} m_{ik,j}^{\gamma_{i,j}},$$

with q_{ik}: quantity of output, z_{ik}: productivity, ℓ_{ik}: labor, m_{ik}: material, and $m_{ik,j}$: use of sector j's good by firm k in sector i.

- f_i : neoclassical
- $\gamma_{i,j}$: the input share of sector j's good, reflecting the **production network**.

- Each output market is **oligopolistic** (complete information).
- Input markets are perfectly competitive.
- Firm k's decision proceeds in three steps: $\underbrace{q_{ik}}_{\text{profit maximization}} \rightarrow \underbrace{(\ell_{ik}, m_{ik}) \rightarrow \{m_{ik,j}\}_j}_{\text{cost minimization}}$

▸ Structural vs. sufficient statistics ▸ Input markets

Sectoral Aggregators / "Demand Functions"

- A sectoral aggregator is the only purchaser of firms' products.
  $\longrightarrow$ "Demand function" from firm's perspective.

- **Assumption** (*a demand system of Homothetic with a Single Aggregator* (HSA)): The inverse demand function can be parametrized as

$$p_{ik} = \frac{\Phi_i}{q_{ik}} \Psi_i\left(\frac{q_{ik}}{A_i(\{q_{ik'}\}_{k'=1}^{N_i})}\right) \quad \text{with} \quad \sum_{k'=1}^{N_i} \Psi_i\left(\frac{q_{ik'}}{A_i(\{q_{ik'}\}_{k'=1}^{N_i})}\right) = 1,$$

  where Φ_i: the sectoral aggregator's expenditure, $\Psi_i(\cdot)$: the share of firm k's good in Φ_i, and $A_i(\cdot)$: a function of all firms' quantities.

- **Key 1**: Cobb-Douglas, CES, translog $\subset$ HSA $\subset$ Homothetic
- **Key 2**: Strategic interactions are encapsulated in $A_i(\{q_{ik'}\}_{k'=1}^{N_i})$.

CES example Counterexample

Object of Interest

- The policymaker is interested in **shifting the subsidy specific to sector n from τ_n^0 to τ_n^1**.
  - e.g., an additional subsidy to the semiconductor industry.
- Subsidies to other sectors are held constant.

- **Object of interest**: the change in GDP due to the policy reform from τ_n^0 to τ_n^1:

$$\Delta Y(\tau_n^0, \tau_n^1) := \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^0),$$

where $Y_i(\boldsymbol{\tau})$: the sector i's GDP under policy regime $\boldsymbol{\tau} := \{\tau_j\}_{j=1}^{N}$.

Details of the Model | Policy invariance | Other policy parameters | Multiple subsidies | Short-run vs. long-run | Welfare gains

Aggregate and Sector-Level Data

- Data source 1: The U.S. Bureau of Labor Statistics (BLS)
  - The dataset provides wage W^*.

- Data source 2: The Bureau of Economic Analysis (BEA)
  - The dataset provides sectoral price indices $\{P_i^*\}_{i=1}^N$ and input-output table.
  - The input share $\{\gamma_{i,j}\}_{i,j=1}^N$ and (net) subsidies $\boldsymbol{\tau}^0$ can be obtained.

Detail

Firm-Level Data

- Data source: Compustat.
  - The coverage is all public firms, i.e., the firms listed on the stock exchange.

- In this dataset, I directly observe firm-level revenue and total cost.
- Using the model and aggregate data, I can recover
  - labor input ℓ_{ik}^*;
  - material input m_{ik}^*;
  - input demand for sectoral goods $\{m_{ik,j}^*\}_{j=1}^N$.

- **Important**: Data on firm-level price p_{ik}^* and quantity q_{ik}^* are not available.

Detail

Identification Strategy and Challenges

- Under differentiability assumption:

$$\Delta Y(\tau_n^0, \tau_n^1) := \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^0) = \sum_{i=1}^{N} \int_{\boldsymbol{\tau}^0}^{\boldsymbol{\tau}^1} \frac{dY_i(s)}{ds} ds.$$

- Goal: to identify $\frac{dY_i(s)}{ds}$ for all $s \in [\boldsymbol{\tau}^0, \boldsymbol{\tau}^1]$.

- Existing literature assumes that firms **are** infinitesimally small.
  $\implies \frac{dY_i(s)}{ds}$ **can** be expressed in terms of sector-level variables only.

- In my framework, firms **are not** infinitesimally small.
  $\implies \frac{dY_i(s)}{ds}$ **cannot** be expressed in terms of sector-level variables alone.

A Way-out

- $\frac{dY_i(s)}{ds}$ involves two types of unknown variables.

  (i) Firm-level price p^*_{ik} and quantity q^*_{ik}:
  $\longrightarrow$ unknown due to the data limitation.

  (ii) Firm-level production elasticity and price elasticity of demand:
  $\longrightarrow$ unknown because the model is not fully specified.

- To recover (i) and (ii), I draw from the industrial organization literature.

Control Function Approach

- **Idea:** "control" for the unobservable productivity z_{ik} with a function of observable input variables ℓ_{ik} and m_{ik}.
- Consider case of a Cobb-Douglas production function (in logarithm).

- In perfect or monopolistic competition,

$$q_{ik} = \beta_0 + \beta_1 \ell_{ik} + \beta_2 m_{ik} + \underbrace{z_{ik}}_{\mathcal{M}(\ell_{ik}, m_{ik})} + \varepsilon_{ik} = \underbrace{\phi(\ell_{ik}, m_{ik})}_{\text{a nonparametric function}} + \varepsilon_{ik},$$

where $\beta.$'s: regression coefficients, ε_{ik}: measurement error.

- In oligopolistic competition,

$$q_{ik} = \beta_0 + \beta_1 \ell_{ik} + \beta_2 m_{ik} + \underbrace{z_{ik}}_{\mathcal{M}(\ell_{ik}, m_{ik}, \{z_{ik'}\}_{k' \neq k})} + \varepsilon_{ik} \neq \underbrace{\phi(\ell_{ik}, m_{ik})}_{\text{a nonparametric function}} + \varepsilon_{ik}$$

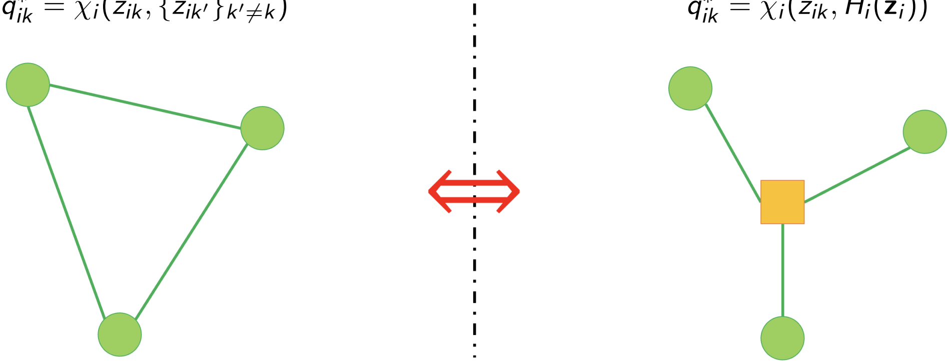
- Unobservable productivities persist!

Construction Sketch of Identification

Solution

- **Assumption**: For each sector i, there exist some functions χ_i and H_i such that (a) $q^*_{ik} = \chi_i(z_{ik}, H_i(\mathbf{z}_i))$ and (b) $\frac{\partial \chi_i(\cdot)}{\partial z_{ik}} \neq 1$ hold for all firm k, where $\mathbf{z}_i := \{z_{ik'}\}_{k'}$.

$$q^*_{ik} = \tilde{\chi}_i(z_{ik}, \{z_{ik'}\}_{k' \neq k}) \qquad \Leftrightarrow \qquad q^*_{ik} = \chi_i(z_{ik}, H_i(\mathbf{z}_i))$$



▸ Intuition

Implication

- Under this assumption, there exist some functions $\mathcal{M}_i$ and $\mathcal{H}_i$ such that

$$z_{ik} = \mathcal{M}_i(\ell^*_{ik}, m^*_{ik}, \bar{\mathcal{H}}_i) \qquad \text{with} \qquad \bar{\mathcal{H}}_i = \mathcal{H}_i(\mathbf{z}_i).$$

- I can identify

  (i) firm-level price p^*_{ik} and quantity q^*_{ik}; and

  (ii) firm-level production elasticity and price elasticity of demand.

- This assumption is flexible enough to include the specifications widely used in the literature.

▸ Derivation

Example: Duopoly

- Consider a CES sectoral aggregator and Cobb-Douglas firm-level production function.
  - e.g., Atkeson and Burstein (2008); Nakamura and Steinsson (2010); Grassi (2017)
- The Cournot-Nash equilibrium quantities are given by

$$q_{ik}^* = \frac{\sigma - 1}{\sigma} mc_i(z_{ik})^{-\sigma} \mathcal{H}_i(\mathbf{z}_i) \quad \text{with} \quad \mathcal{H}_i(\mathbf{z}_i) := \frac{mc_i(z_{i1})^{\frac{1-\sigma}{\sigma}} mc_i(z_{i2})^{\frac{1-\sigma}{\sigma}}}{\left(mc_i(z_{i1})^{\frac{1-\sigma}{\sigma}} + mc_i(z_{i2})^{\frac{1-\sigma}{\sigma}}\right)^{\frac{\sigma^2-\sigma+2}{\sigma}}}.$$

where σ: elasticity of substitution, $mc_i(z_{ik})$: firm k's marginal cost.

- The input decision is constrained by the production possibility frontier at output level q_{ik}^*:

$$z_{ik}(\ell_{ik}^*)^{\alpha}(m_{ik}^*)^{1-\alpha} = q_{ik}^* = \frac{\sigma - 1}{\sigma} mc_i(z_{ik})^{-\sigma} \bar{\mathcal{H}}_i \qquad \text{with} \qquad \bar{\mathcal{H}}_i = \mathcal{H}_i(\mathbf{z}_i).$$

- Upon solving this for z_{ik}, I obtain the expression $z_{ik} = \mathcal{M}_i(\ell_{ik}^*, m_{ik}^*, \bar{\mathcal{H}}_i)$.

Summary of Approach

Top Layer Decompose the object of interest:

$$\Delta Y(\tau_n^0, \tau_n^1) = \sum_{i=1}^{N} \int_{\boldsymbol{\tau}^0}^{\boldsymbol{\tau}^1} \frac{dY_i(s)}{ds} ds.$$

Middle Layer Further decompose $\frac{dY_i(s)}{ds}$ into firm-level variables using the firm's optimization problem.

Bottom Layer Recover (i) firm-level output price and quantity, and (ii) firm-level production elasticity and price elasticity of demand.

Identification Reconstruct $\Delta Y(\tau_n^0, \tau_n^1)$ by tracing this procedure backward.

Estimation The bottom layer can be nonparametrically estimated.
A nonparametric estimator for $\Delta Y(\tau_n^0, \tau_n^1)$ can be constructed.

Estimation

Policy Scenario

- The CHIPS and Science Act (CHIPS) was enacted in 2022.
- **Investment:** nearly $53 billion in the U.S. semiconductor manufacturing, research and development, and workforce.
- **Subsidy:** a 25% tax credit for manufacturing investment.
  - up to $24.25 billion for the next 10 years.
  - $2.43 billion of subsidy per year.

- In this paper, I consider increasing the semiconductor subsidy by $0.56 billion.
- This corresponds to shifting τ_n from 14.94% (the 2021 level) to 16.00%.

Extrapolation

Main Result

- The estimator for the policy effect:

$$\widehat{\Delta Y}(\tau_n^0, \tau_n^1) = \sum_{i=1}^{N} \int_{\boldsymbol{\tau}^0}^{\boldsymbol{\tau}^1} \widehat{\frac{dY_i(s)}{ds}} ds.$$

- The estimates are compared between monopolistic and oligopolistic competition:

(billion U.S. dollars)	Monopolistic	Oligopolistic
$\widehat{\Delta Y}(\tau_n^0, \tau_n^1)$	-0.71	-1.34

- The contribution of strategic interaction is empirically relevant.

Details

Breakdown

- The marginal change in sectoral GDP can be broken down to two parts:

$$\underbrace{\widehat{\frac{dY_i(s)}{ds}}}_{\text{marginal change}} = \textit{effects on firms' revenues} - \textit{effects of firms' material input costs.}$$

- The breakdown at $\tau_n^0 (= 14.94\%)$ for the **semiconductor industry**:

(billions U.S. dollars)	Marginal Change	=	Revenue Effect	−	Cost Effect
Oligopolistic	-94.70		1.29		95.99
Monopolistic	196.76		560.33		363.57

- If oligopolistic, the semiconductor industry "loses" due to the policy change.
- If monopolistic, the semiconductor industry "benefits" from the policy change.

More results
Structural vs. sufficient statistics

Comovements/Pass-Through (Simplified Description)

(Sector-level cost-price pass-through) $$\frac{dP_i^*}{d\tau_n} = \lambda_i \frac{dP_i^{M*}}{d\tau_n}$$

(Sector-level policy-cost pass-through) $$\frac{dP_i^{M*}}{d\tau_n} = -h_{i,n} \frac{P_n^{M*}}{1-\tau_n}$$

where P_i^*: the output price index, and P_i^{M*}: the cost index for material input.

- λ_i: an (weighted) average of the firms' markup responses:
  - with respect to the firms' own choices;
  - with respect to the competitors' choices.
- $h_{i,n}$: the (i,n) entry of $(I-\Gamma)^{-1}$, with $\Gamma := \left[\gamma_{i,j} \frac{P_i^{M*}}{P_j^*} \lambda_j\right]_{i,j=1}^N$.
  - This adds up all the possible direct and indirect channels from sector n to sector i.

Example Full description

Estimates of Pass-Through Coefficients

- $i = n =$ the semiconductor industry:

Competition	λ_i	$h_{i,n}$
Oligopolistic	0.11	1.67
Monopolistic	0.24	4.12

- λ_i is different across two types of competition.
- This is because of the **firms' strategic interactions**.

- $h_{i,n}$ is different across two types of competition.
- This is because $\{\lambda_i\}_{i=1}^N$ are compounded along the **production network**.

- The comovement patterns are completely different.

More results

Summary and Takeaway

- Industrial policies have been (and will continue to be) an active policy tool.
- I establish a framework for *ex ante* evaluations of industrial policies in strategic interactions and a production network.

- I assume that firms' equilibrium choices depend on competitors' productivities only through a single aggregate.
- This is already satisfied by many specifications in the literature.

- I consider a part of the CHIPS and Science Act in 2022.
- The production network compounds the markup responses not only with respect to the firms' own choices, but also with respect to competitors' choices.
- In find that the latter is not negligible.
- **A key takeaway:** To specifying the market competition correctly is very important !!

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Literature: Oligopolistic Competition

- Incomplete pass-through of cost shocks:
  - Atkeson and Burstein (2008)
- Comparative advantage:
  - Gaubert and Itskhoki (2020)
- Endogenous markups (pro-competitive effect of international trade):
  - Edmond, Midrigan and Xu (2015)
- Market power (market concentration):
  - De Loecker, Eeckhout and Mongey (2021); Wang and Werning (2022)

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Literature: Production Networks

- Business cycle:
  - Long and Plosser (1983), Horvath (1998, 2000), Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012)
- Misallocations (market distortions):
  - Jones (2011, 2013), Baqaee and Farhi (2020), Bigio and La'O (2020)
- Inflation:
  - di Giovanni, Kalemli-Özcan, Silva and Yildirim (2022)

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Contribution of This Paper

- Welfare gains from shocks in a model of continuum of firms without production networks:
  - Arkolakis, Costinot and Rodríguez-Clare (2012); Arkolakis, Costinot, Donaldson and Rodríguez-Clare (2019); Adão, Arkolakis and Ganapati (2020), etc.
- Policy effects in a model of oligopolistic competition without production networks:
  - Gaubert et al. (2021); Wang and Werning (2022), etc.

- Welfare loss in a model of continuum of firms with a production network:
  - Baqaee and Farhi (2020, 2022); Bigio and La'O (2020), etc.
- Optimal policies in a model of continuum of firms with a production network:
  - Liu (2019); Lashkaripour and Lugovskyy (2023), etc.

- Policy evaluations in a model of oligopolistic competition with a production network:
  - My paper!!

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Welfare Gains from Trade Cost Shocks

- The existing welfare gain literature proceeds in three steps.

  Step 1. Characterize the welfare gain $\%\Delta\mathcal{W}$ in terms of the "trade elasticity" ε and the domestic absorption share λ: e.g., $\%\Delta\mathcal{W} = 1 - \lambda^{1/\varepsilon}$.

  Step 2. Estimate the trade elasticity $\hat{\varepsilon}$, while λ is typically observed in data.

  Step 3. Plug in the estimate $\hat{\varepsilon}$ into the characterization: e.g., $\widehat{\%\Delta\mathcal{W}} = 1 - \lambda^{1/\hat{\varepsilon}}$.

- In Step 2, the literature assumes that the trade policy is a "random realization."
  - e.g., Arkolakis et al. (2012), Adão et al. (2020), Boehm, Levchenko and Pandalai-Nayar (2023).
- This is compatible to the analysis of "shocks to trade costs."
- But this is not compatible to the analysis of policy making.

- My paper proposes a conceptually consistent framework for the policymaker's problem.

back

More on Arkolakis et al. (2012)

- *Ex ante*, the policy shock is known only up to its probability distribution.
- The appropriate evaluation criteria should take the form of an expectation of the welfare gain: e.g.,

$$E[\%\Delta\mathcal{W}] \qquad \text{or} \qquad E[\Delta\mathcal{W}]$$

- The famous expression for the "*ex ante*" welfare gain from going to autarky $\%\Delta\mathcal{W} = 1 - \lambda^{1/\varepsilon}$ (Arkolakis et al. 2012) only corresponds to one possible realization of the shock (i.e., autarky).
- Any inference based solely on this expression is merely as useful as an *ex post* assessment.

back

Policy Evaluation and Policy Design

- My framework can naturally fit into an optimal policy design problem.
- One criterion for the optimal industrial policy ${\tau_n^1}^*$ is defined by

$$ {\tau_n^1}^* \in \max_{\tau_n^1} \Delta Y(\tau_n^0, \tau_n^1) $$

- The expression for $\%\Delta\mathcal{W}$ cannot be used in this way for the reason explained above.

- The welfare gain literature and the optimal trade policy literature are conceptually distinct.
- My framework bridges these two different strands of the literature.

back

Empirical vs. Structural Approach

Empirical Approach

Advantages:

- less assumptions

Limitations:

- no general equilibrium effects
- no strategic interactions
- no peer effects
- *ex post* assessment
- policy parameters are locally defined

Structural Approach

Limitations:

- more assumptions

Advantages:

- general equilibrium effects
- strategic interactions
- peer effects
- *ex ante* assessment
- policy parameters are locally or globally defined

back

Two-Sector Economy

Seller \ Purchaser	Sector 1	Sector 2	Final Consumption	Total Sales
Sector 1	$\omega_{1,1}\tilde{x}_1$	0	y_1	x_1
Sector 2	$\omega_{1,2}\tilde{x}_1$	1	y_2	x_2
Total Cost	$\tilde{x}_1$	$\tilde{x}_2$		
Value Added (VA)	$(1-\mu_1^{-1})x_1$	$(1-\mu_2^{-1})x_2$		

- $x_i = \mu_i \tilde{x}_i$

- $\omega_{1,1}\tilde{x}_1 + y_1 = x_1 \implies x_1 = (1-\omega_{1,1}\mu_1^{-1})^{-1}y_1$
- $\omega_{1,2}\tilde{x}_1 + \tilde{x}_2 + y_2 = x_2 \implies x_2 = (1-\mu_2^{-1})^{-1}(\omega_{1,2}\mu_1^{-1}x_1 + y_2)$

back

Value Added

- $VA_1 = (1-\mu_1^{-1})x_1 = (1-\mu_1^{-1})(1-\omega_{1,1}\mu_1^{-1})^{-1}y_1$
- $VA_2 = (1-\mu_2^{-1})x_2 = \omega_{1,2}\mu_1^{-1}x_1 + y_2 = \omega_{1,2}\mu_1^{-1}(1-\omega_{1,1}\mu_1^{-1})^{-1}y_1 + y_2$
- Hence,

$$\begin{aligned}
\frac{dVA}{d\tau} &= \frac{dVA_1}{d\tau} + \frac{dVA_2}{d\tau} \\
&= (1-\omega_{1,1}\mu_1^{-1})^{-1}\mu_1^{-2}[(1-\omega_{1,2}) - \omega_{1,1}(1-\omega_{1,1}\mu_1^{-1})\{1-(1-\omega_{1,2})\mu_1^{-1}\}]y_1\frac{d\mu_1}{d\tau} \\
&\quad + (1-\omega_{1,1}\mu_1^{-1})^{-1}\{1-(1-\omega_{1,2})\mu_1^{-1}\}\frac{dy_1}{d\tau} \\
&\quad + \frac{dy_2}{d\tau}.
\end{aligned}$$

- When there is no trade between sectors ($\omega_{1,1} = 1$, $\omega_{1,2} = 0$), then $\frac{dVA}{d\tau} = \frac{dy_1}{d\tau} + \frac{dy_2}{d\tau}$.

back

Sectoral Markup Response

- Sectoral markups:

$$\mu_i = \mathcal{D}_i(\mu_{i1}, \mu_{i2}) \qquad \text{with} \qquad \mu_{ik} = \mu_{ik}(q_{i1}, q_{i2}).$$

- Total differentiation:

$$d\mu_i = \frac{\partial \mathcal{D}_i(\cdot)}{\partial \mu_{i1}} d\mu_{i1} + \frac{\partial \mathcal{D}_i(\cdot)}{\partial \mu_{i2}} d\mu_{i2} \qquad \text{with} \qquad d\mu_{ik} = \frac{\partial \mu_{ik}(\cdot)}{\partial q_{i1}} dq_{i1} + \frac{\partial \mu_{ik}(\cdot)}{\partial q_{i2}} dq_{i2}.$$

- Substitution and dividing it by $d\tau$ yield

$$\frac{d\mu_i}{d\tau} = \frac{\partial \mathcal{D}_i(\cdot)}{\partial \mu_{i1}} \left(\frac{\partial \mu_{i1}(\cdot)}{\partial q_{i1}} \frac{dq_{i1}}{d\tau} + \frac{\partial \mu_{i1}(\cdot)}{\partial q_{i2}} \frac{dq_{i2}}{d\tau} \right) + \frac{\partial \mathcal{D}_i(\cdot)}{\partial \mu_{i2}} \left(\frac{\partial \mu_{i2}(\cdot)}{\partial q_{i1}} \frac{dq_{i1}}{d\tau} + \frac{\partial \mu_{i2}(\cdot)}{\partial q_{i2}} \frac{dq_{i2}}{d\tau} \right).$$

back

Open Economy

- The present paper considers a closed economy model.
- The model can be opened up for international trade by two steps.

Step 1. Reindex firms to accommodate foreign firms:

$$k = \underbrace{1, \ldots, N_i^0}_{\text{domestic firms}}, \underbrace{N_i^0 + 1, \ldots, N_i^1}_{\text{foreign country 1's firms}}, N_i^1 + 1, \ldots, N_i^2, \ldots$$

Step 2. Impose trade balance condition.

- Data on foreign firms are typically unavailable.
- This is left for future work.

back

Static or Dynamic?

- CHIPS and Science Act includes:
  - Tax credit for capital investments in semiconductor.
  - Investment in construction, expansion, or modernization of facilities producing semiconductors.
- As far as the tax credits and the static analysis are concerned, the empirical analysis of this paper is consistent to the model.
  - Capital endowment.
- To account for the investment, the model of this paper needs to be extended to include the firms' dynamic decisions.
  - Capital accumulation.

back

Static Model

- Conceptually, the present model could be viewed as a "steady state approximation" of a dynamic model.
- In terms of empirical analysis, there are two ways of treating capital endowment.

- Capital as observed heterogeneity:
  - Capital is observed in the Compustat data.
  - $\tilde{r}_{ik} = \tilde{\phi}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik}, \tilde{k}_{ik}) + \tilde{\eta}_{ik}$.

- Capital as unobserved heterogeneity:
  - This sidesteps potential errors inherent in the measurement of capital.
  - Under the timing assumption and the "Hicks-neutrality" assumption,

$$q_{ik} = \underbrace{h_i(k_{ik}) z_{ik}}_{\check{z}_{ik}} f_i(\ell_{ik}, m_{ik}) \qquad \text{for some function } h_i(\cdot).$$

  - The "firm-level productivity" $\check{z}_{ik}$ is understood as firm's overall capability of production.

back

Dynamic Model

- Firm's dynamic decisions take into account:
  - Which firms will or will not be in the market.
  - The firm's own future decisions and the competitors' future decisions.

- Accommodating these will require additional assumptions.
- This is left for future work.

back

Structural vs. Sufficient Statistics

Structural approach

Feature:

- Fully specify the model
  $\rightarrow$ deep parameters

Pros:

- behavioral interpretation

Cons:

- restrictive
- computationally hard

Sufficient statistics approach

Feature:

- Partially specify the model
  $\rightarrow$ sufficient statistics

Pros:

- less restrictive
- computationally easy

Cons:

- no behavioral interpretation

back

Price Takers in Input Markets

- **Fact:** If (i) the production function exhibits constant returns to scale, (ii) all inputs are variable and (iii) the firms are price takers in the input markets, then the marginal costs are constant.

- In this case,

$$
\begin{aligned}
&(\text{Sector } i) \qquad q_{ik}^* \in \max_{q_{ik}} \left\{ p_{ik}(q_{ik}) q_{ik} - mc_{ik} q_{ik} \right\} \\
&(\text{Sector } j) \qquad q_{jk}^* \in \max_{q_{jk}} \left\{ p_{jk}(q_{jk}) q_{jk} - mc_{jk} q_{jk} \right\}
\end{aligned}
$$

- Oligopolistic competition takes place in each sector.
  - Firms' strategic interactions are confined within each sector.
- This is in line with the literature.

back

Price Setters in Input Markets

- If otherwise,

$$\text{(Sector } i\text{)} \qquad q_{ik}^* \in \max_{q_{ik}} \left\{ p_{ik}(q_{ik})q_{ik} - mc_{ik}(q_{ik}, \{q_{nk'}\}_{n,k'})q_{ik} \right\}$$

$$\text{(Sector } j\text{)} \qquad q_{jk}^* \in \max_{q_{jk}} \left\{ p_{jk}(q_{jk})q_{jk} - mc_{jk}(q_{jk}, \{q_{nk'}\}_{n,k'})q_{jk} \right\}$$

- Oligopolistic competition takes place between firms across sectors.
  - Firms engage in a single big strategic interaction.
- This may not align with the motivating literature.

- The "perfectly competitive input markets" assumption restricts the strategic interaction within each sector.
- The input price indices coincide with the output price indices in the aggregate equilibrium.

back

CES Aggregator

- Consider the CES aggregator in sector i:

$$F_i(\{q_{ik}\}_{k=1}^{N_i}) := \left(\sum_{k=1}^{N_i} \delta_{ik}^{\sigma_i} q_{ik}^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}},$$

  where σ_i: the elasticity of substitution specific to sector i; and δ_{ik}: a demand shifter specific to firm k's product.

- The residual inverse demand curve faced by firm k: $p_{ik} = \frac{\delta_{ik} q_{ik}^{-\frac{1}{\sigma_i}}}{\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma_i}}} R_i$, where R_i: the total expenditure to sector i's good.

- Letting $R_i = \Phi_i$ and $A_i(\mathbf{q}_i) := (\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma_i}})^{\frac{\sigma_i}{\sigma_i - 1}}$, the HSA specification is satisfied with $\Psi_{ik}(x; \mathcal{I}_i) := \delta_{ik} x^{\frac{\sigma_i - 1}{\sigma_i}}$.

back

Counterexample

- Consider the smartphone market, in which iPhone (Apple) and Galaxy (Samsung) are close substitutes.
- The demand for iPhone might be very sensitive to that of Galaxy.
- Letting k and k'' denote Apple and Samsung, respectively.
- The inverse demand for iPhone (k):

$$p_{ik} = \kappa(q_{ik}, q_{ik''}) + \frac{\delta_{ik} q_{ik}^{-\frac{1}{\sigma_i}}}{\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma_i}}} R_i,$$

where $\kappa(\cdot)$ is a function of q_{ik} and $q_{ik''}$.

- The Apple's decision q_{ik} is directly affected by the Samsung's choice $q_{ik''}$ as well as through the quantity index.

Household

- There is a single representative utility-maximizing consumer.
- The consumer's utility function is strictly monotonic and continuously differentiable in the final consumption good.

- The consumer inelastically supplies labor.
- The consumer chooses the quantity of the final consumption good subject to the binding budget constraint:

$$C = WL + \Pi - T,$$

where Π is firm's total profit, and T indicates the tax payment to the government in the form of a lump-sum transfer.

- The price index of the final consumption good is set to be the numeraire.

back

Economy-Wide and Sectoral Aggregations

- The economy-wide aggregator $\mathcal{F}$ produces the final consumption good Y:

$$Y = \mathcal{F}(\{X_i\}_{i=1}^{N}),$$

where X_i: the sector i's good.

- The sectoral aggregator F_i produces sectoral good Q_i:

$$Q_i = F_i(\{q_{ik}\}_{k=1}^{N_i}),$$

where q_{ik}: firm k's product.

- **Assumption**: (i) $\mathcal{F}$ is increasing and concave in each of its arguments. (ii) F_i is a) twice continuously differentiable and b) increasing and concave in each of its arguments.

back

HSA Demand System

- In each sector $i \in \mathbf{N}$, the sectoral aggregator F_i exhibits an HSA inverse demand function; that is, the inverse demand function faced by firm $k \in \mathbf{N}_i$ is given by

$$p_{ik} = \frac{\Phi_i}{q_{ik}} \Psi_{ik}\left(\frac{q_{ik}}{A_i(\mathbf{q}_i)}; \mathcal{I}_i\right) \qquad \text{with} \qquad \sum_{k'=1}^{N_i} \Psi_{ik'}\left(\frac{q_{ik'}}{A_i(\mathbf{q}_i)}; \mathcal{I}_i\right) = 1,$$

  where Φ_i: a constant indicating the expenditure by sector i's aggregator; Ψ_{ik}: the share of firm k's good in the expenditure of sector i's aggregator; and $A_i(\mathbf{q}_i)$: the aggregate quantity index capturing interactions between firms' choices with $\mathbf{q}_i := \{q_{ik'}\}_{k'=1}^{N_i}$.

- For the sake of simplicity, this paper assumes that $\Psi_{ik}(\cdot) = \Psi_{ik'}(\cdot)$ for all $k \neq k'$.
- This assumption can be relaxed at the expense of technicalities.

back

Firm-Level Production: Assumption

- **Assumption**: $f_i(\cdot)$ (i) displays constant returns to scale, (ii) is twice continuously differentiable in all arguments, (iii) is increasing and concave in each of its arguments, and (iv) satisfies $f_i(0,0) = 0$.
- Moreover, (v) $\left(\frac{\partial f_i(\cdot)}{\partial \ell_{ik}}\right)^2 \frac{\partial^2 f_i(\cdot)}{\partial m_{ik}^2} + \left(\frac{\partial f_i(\cdot)}{\partial m_{ik}}\right)^2 \frac{\partial^2 f_i(\cdot)}{\partial \ell_{ik}^2} - 2\frac{\partial f_i(\cdot)}{\partial \ell_{ik}}\frac{\partial f_i(\cdot)}{\partial m_{ik}}\frac{\partial^2 f_i(\cdot)}{\partial \ell_{ik}\partial m_{ik}} < 0$ for all (ℓ_{ik}, m_{ik}).

- Conditions (i) – (iv) jointly state that the aggregators $f_i(\cdot)$ is neoclassical.
- Condition (v) guarantees an interior solution for the firm's cost minimization problem.

back

Firm-Level Production: Example

- The specification for the firm-level production function includes the nested Cobb-Douglas production function.

$$q_{ik} = z_{ik} \ell_{ik}^{\alpha_i} m_{ik}^{1-\alpha_i} \qquad \text{with} \qquad m_{ik} = \prod_{j=1}^{N} m_{ik,j}^{\gamma_{i,j}},$$

where α_i: labor share specific to the sector, and $\gamma_{i,j}$: the share of sector j's good in the material input used by sector i with $\sum_{j=1}^{N} \gamma_{i,j} = 1$.

- In this setup, $\omega_{i,L} = \alpha_i$ and $\omega_{i,j} = (1-\alpha_i)\gamma_{i,j}$.

back

Firm's Decisions

- Taking material input $\bar{m}_{ik}$ and sectoral price indices $\{P_j\}_j$ as given, the firm's optimal demand for sectoral intermediate goods $\{m^*_{ik,j}\}_j$ is given by

$$\{m^*_{ik,j}\}_{j=1}^N \in \underset{\{m_{ik,j}\}_{j=1}^N}{\arg\min} \quad \sum_{j=1}^N (1-\tau_i) P_j m_{ik,j} \qquad s.t. \quad \prod_{j=1}^N m_{ik,j}^{\gamma_{i,j}} \geq \bar{m}_{ik}.$$

- The associated unit cost condition defines the cost index of material input P_i^M gross of the policy $\boldsymbol{\tau}$.

back

Firm's Decisions

- Taking the output quantity $\bar{q}_{ik}$ and input prices W and P_i^M as given, the optimal input quantities ℓ_{ik}^* and m_{ik}^* are given by

$$\{\ell_{ik}^*, m_{ik}^*\} \quad \in \quad \underset{\ell_{ik}, m_{ik}}{\arg\min} \quad W\ell_{ik} + P_i^M m_{ik} \qquad s.t. \quad z_{ik} f_i(\ell_{ik}, m_{ik}) \geq \bar{q}_{ik},$$

back

Firm's Decisions

- The information set $\mathcal{I}_i$:

$$\mathcal{I}_i := \{Y, \{X_j\}_{j=1}^{N}, \{Q_j\}_{j\neq i}, W, P_i^M, \{z_{ik}\}_{k=1}^{N_i}, \boldsymbol{\omega}_L, \Omega, \boldsymbol{\tau}\}.$$

- The Cournot-Nash equilibrium quantities $\mathbf{q}_i^* := \{q_{ik}^*\}_{k=1}^{N_i}$ must satisfy the following system of equations:

$$q_{ik}^* = \arg\max_{q} \pi_{ik}(q, \mathbf{q}_{i,-k}; \mathcal{I}_i) \qquad \forall k \in \mathbf{N}_i.$$

- The existence of Cournot-Nash equilibria in each sector immediately follows from the Debreu-Glicksberg-Fan theorem (Debreu 1952; Fan 1952; Glicksberg 1952).

back

Government

- The government sets the level of subsidies $\boldsymbol{\tau}$ under the balanced budget:

$$G + \sum_{i=1}^{N} S_i = T \qquad \textit{where} \qquad S_i := \sum_{k=1}^{N_i} \sum_{j=1}^{N} \tau_i P_j m_{ik,j},$$

where G: public spending; S_i: the total policy expenditure in sector i; and T: a lump-sum tax on the consumer.

back

Market Clearing Conditions

- The final consumption good:

$$Y = C + G.$$

- Combined with the consumer's and government's budget constraints,

$$Y = WL + \Pi - \sum_{i=1}^{N} S_i.$$

- This is nothing but the income accounting identity of GDP.

back

Market Clearing Conditions

- Sectoral intermediate goods:

$$Q_j = X_j + \sum_{i=1}^{N} \sum_{k=1}^{N_i} m_{ik,j}.$$

- Labor:

$$L = \sum_{i=1}^{N} \sum_{k=1}^{N_i} \ell_{ik}.$$

back

Equilibria

- Under the invariance condition, the numbers of sectors N and firms N_i, firm's productivities z_{ik}, and the network structures $\boldsymbol{\omega}_L$ and Ω are invariant to a policy shift.
- Other aggregate variables as well as firm-level variables are endogenously determined.

- The general equilibria of this model are defined as fixed points in the endogenous firm-level and aggregate variables.

back

Equilibria

- **Sectoral Equilibria**: Given the information set $\mathcal{I}_i$, a vector of sectoral Cournot-Nash equilibrium quantities $\{q^*_{ik}\}_{k=1}^{N}$, the optimal labor and material inputs $\{\ell^*_{ik}, m^*_{ik}\}_{k=1}^{N_i}$, and input demand for sectoral intermediate goods $\{\{m^*_{ik,j}\}_{j=1}^{N}\}_{k=1}^{N_i}$ are determined so as to satisfy the firm-level problems.

- **Aggregate Equilibria**: Given sectoral equilibrium quantities $\{q^*_{ik}, \ell^*_{ik}, m^*_{ik}, \{m^*_{ik,j}\}_{j=1}^{N}\}_{i,k}$, an aggregate equilibrium is referenced by the set of aggregate quantities $\{Y^*, \{X^*_j, Q^*_j\}_{j=1}^{N}\}$ together with the set of aggregate prices $\{W^*, \{P^*_j\}_{j=1}^{N}\}$ that satisfy the market clearing conditions.

back

The Object of Interest

- Let $Y^{\boldsymbol{\tau}}$ be the country's GDP in equilibrium under policy regime $\boldsymbol{\tau}$.
- From the market clearing conditions,

$$Y^{\tau} = \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}) \qquad \textit{where} \qquad Y_i(\boldsymbol{\tau}) := \sum_{k=1}^{N_i} \left(W^* \ell_{ik}^* + \pi_{ik}^* - \sum_{j=1}^{N} \tau_i P_j^* m_{ik,j}^* \right),$$

  where π_{ik} stands for firm k's profit.
- $Y_i(\boldsymbol{\tau})$ can be viewed as sectoral i's GDP, with each of its summands corresponding to an individual firm's contribution.

back

Policy Invariance

- **Assumption**: Throughout the policy reform from $\boldsymbol{\tau}^0$ to $\boldsymbol{\tau}^1$, (i) the index set for sectors N, (ii) the index set for firms in each sector N_i, (iii) each sectoral aggregator, (iv) every firm-level production function in each sector, and (v) the shape of the input-output linkages $\boldsymbol{\omega}_L$ and $\boldsymbol{\Omega}$ do not change.

- Condition (i) excludes other competition interventions.
- Condition (ii) is implied by the short-run scope of this paper.
- Conditions (iii) and (iv) rule out both direct and indirect impacts of the policy reform on firms' productivities.
- Condition (v) states that the input-output linkages do not reshape in reaction to the policy reform.

back

Causal Effects

- This is an *intensive-margin causal effect* of the policy reform.
  - A *ceteris paribus* change in an outcome variable across different policy regimes.
- This policy parameter internalizes
  - firms' strategic interactions;
  - network spillovers;
  - general equilibrium effects.
- This policy parameter can answer
  - macroeconomic policy questions;
  - *ex ante* policy questions.

back

Empirical vs. Structural Approach

Empirical Approach

Advantages:

- less assumptions

Limitations:

- no general equilibrium effects
- no strategic interactions
- no peer effects
- *ex post* assessment
- policy parameters are locally defined

Structural Approach

Limitations:

- more assumptions

Advantages:

- general equilibrium effects
- strategic interactions
- peer effects
- *ex ante* assessment
- policy parameters are locally or globally defined

back

Consumption

- The policy effect on final consumption:

$$\Delta C(\tau_n^0, \tau_n^1) = \int_{\tau_n^0}^{\tau_n^1} \frac{dC}{d\tau_n} d\tau_n.$$

- Letting government spending G be fixed,

$$\frac{dC}{d\tau_n} = \frac{dY}{d\tau_n} = \sum_{i=1}^{N} \frac{dY_i}{d\tau_n},$$

where $\frac{dY_i}{d\tau_n}$ is identified in my framework.

back

Labor, Material and Output Quantity

- Labor employed in sector i:

$$L_i := \sum_{k=1}^{N_i} \ell_{ik}.$$

- The policy effect on labor employed in sector i:

$$\Delta L_i(\tau_n^0, \tau_n^1) = \int_{\tau_n^0}^{\tau_n^1} \sum_{k=1}^{N_i} \frac{d\ell_{ik}}{d\tau_n} d\tau_n,$$

where $\frac{d\ell_{ik}}{d\tau_n}$ is identified in my framework.

- The policy effects on material input and total quantity of output in sector i are analogous.

back

Unilateral and Bilateral Trade Flow

- The volume of unilateral trade flow from sector j to i:

$$U_{i,j} := \sum_{k=1}^{N_i} m_{ik,j}.$$

- The policy effect on the unilateral trade flow:

$$\Delta U_{i,j}(\tau_n^0, \tau_n^1) = \int_{\tau_n^0}^{\tau_n^1} \sum_{k=1}^{N_i} \frac{dm_{ik,j}}{d\tau_n} d\tau_n,$$

where $\frac{dm_{ik,j}}{d\tau_n}$ is identified in my framework.

- The policy effect on the bilateral trade flow is analogous, i.e., $B_{i,j} := U_{i,j} + U_{j,i}$.

back

Treatment Effects

- Multitudes of “treatment effects” can be considered about firm’s profit π_{ik}.
- Individual-level treatment effect:

$$\Delta\pi_{ik}(\tau_n^0, \tau_n^1) := \pi_{ik}(\tau_n^1) - \pi_{ik}(\tau_n^0) = \int_{\tau_n^0}^{\tau_n^1} \frac{d\pi_{ik}}{d\tau_n} d\tau_n,$$

where $\frac{d\pi_{ik}}{d\tau_n}$ is identified in my framework.
- Sectoral average treatment effect:

$$\Delta\Pi_i(\tau_n^0, \tau_n^1) = \frac{1}{N_i} \sum_{k=1}^{N_i} \Delta\pi_{ik}(\tau_n^0, \tau_n^1).$$

- Economy-wide average treatment effect (i.e., producer surplus):

$$\Delta\Pi(\tau_n^0, \tau_n^1) = \frac{1}{N} \sum_{i=1}^{N} \Delta\Pi_i(\tau_n^0, \tau_n^1).$$

back

Changing Multiple Subsidies

- Suppose that there are only two sectors.
- $\boldsymbol{\tau}^0 = (\tau_1^0, \tau_2^0) \longrightarrow \boldsymbol{\tau}^1 = (\tau_1^1, \tau_2^1)$, where $\boldsymbol{\tau}^0, \boldsymbol{\tau}^1 \in \mathscr{T}$ with $\mathscr{T}$: the observed support.
- The object of interest:

$$
\begin{aligned}
\Delta Y(\boldsymbol{\tau}^0, \boldsymbol{\tau}^1) &:= \sum_{i=1}^{N} Y_i((\tau_1^1, \tau_2^1)) - \sum_{i=1}^{N} Y_i((\tau_1^0, \tau_2^0)) \\
&= \underbrace{\sum_{i=1}^{N} Y_i((\tau_1^1, \tau_2^1)) - \sum_{i=1}^{N} Y_i((\tau_1^1, \tau_2^0))}_{\text{one-sector problem (the effect of } \tau_2^0 \to \tau_2^1)} + \underbrace{\sum_{i=1}^{N} Y_i((\tau_1^1, \tau_2^0)) - \sum_{i=1}^{N} Y_i((\tau_1^0, \tau_2^0))}_{\text{one-sector problem (the effect of } \tau_1^0 \to \tau_1^1)}
\end{aligned}
$$

- A multiple-subsidies problem can be broken down to multiple one-subsidy problems!

back

Three Views

1. The present paper studies merely a "**special case**" of the "full-fledged model."
   - This is enough as far as the short-run effects are concerned.
   - The "extension" will be studied in future work.

2. The short-run analysis *per se* is **useful** in practice.
   - The model prediction can be compared to the data.
   - If they are substantially different, the policymaker can/should revise the model.
   - If they are not substantially different, the policymaker is on the right track.

3. The short-run analysis is a **necessary** step to separately identify the intensive and extensive margin causal effects.
   - The long-run analysis identifies the total causal effect.
   - The short-run analysis identifies the intensive margin causal effect.
   - The extensive margin causal effect is identified as a residual.

back

Total, Intensive Margin and Extensive Margin Causal Effects

- The international trade literature studies the "trade elasticities" for the both intensive and extensive margins.
  - e.g., Chaney (2008), Adão et al. (2020), Boehm et al. (2023)
- Other works decompose the total growth/difference in the value of trade into the intensive and extensive margins.
  - e.g., Feenstra (1994), Hummels and Klenow (2005), Kehoe and Ruhl (2013)
- None of them admits an interpretation as a causal policy effect.

- My framework defines the intensive and extensive margin causal policy effects.

back

Total, Intensive Margin and Extensive Margin Causal Effects

- Consider a policy reform from $\boldsymbol{\tau}^0$ to $\boldsymbol{\tau}^1$.
- $\mathcal{N}_i^0$: the index set for firms in sector i under $\boldsymbol{\tau}^0$.
- $\mathcal{N}_i^1$: the index set for firms in sector i under $\boldsymbol{\tau}^1$.
- u: the competitiveness of the market under $\mathcal{N}_i^u$.

- $y_{ik}^u(\boldsymbol{\tau})$: the firm-level GDP of firm k in sector i under u and $\boldsymbol{\tau}$.

- The total causal effect of the policy reform:

$$\Delta Y(\boldsymbol{\tau}^0, \boldsymbol{\tau}^1) := \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^1} y_{ik}^1(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^0} y_{ik}^0(\boldsymbol{\tau}^0).$$

back

Total, Intensive Margin and Extensive Margin Causal Effects

- The total causal effect of the policy reform:

$$\underbrace{\Delta Y(\boldsymbol{\tau}^0, \boldsymbol{\tau}^1)}_{\text{the total causal effect}} = \underbrace{\sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^1} y_{ik}^1(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^0} y_{ik}^0(\boldsymbol{\tau}^1)}_{\text{the extensive margin causal effect}}$$

$$+ \underbrace{\sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^0} y_{ik}^0(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^0} y_{ik}^0(\boldsymbol{\tau}^0)}_{\text{the intensive margin causal effect}} .$$

- The long-run analysis identifies the total causal effect.
- The short-run analysis identifies the intensive margin causal effect.
- The extensive margin causal effect is identified as a residual.

back

Identification of the Total Causal Effects

- $\mathbf{a}^u \in \mathbb{R}$: the index of the market competitiveness corresponding to u.
- Under the assumption of the HSA demand system, I can write as

$$y_{ik}(\boldsymbol{\tau}, \mathbf{a}^u) = y_{ik}^u(\boldsymbol{\tau}) \qquad \text{for} \qquad \boldsymbol{\tau} \in \{\boldsymbol{\tau}^0, \boldsymbol{\tau}^1\}.$$

- Assume that the "within-the-support condition" holds for $[\mathbf{a}^0, \mathbf{a}^1]$ as well.

- The total causal effect can be rewritten as

$$\Delta Y(\boldsymbol{\tau}^0, \boldsymbol{\tau}^1) = \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^1} y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - \sum_{i=1}^{N} \sum_{k \in \mathcal{N}_i^0} y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0).$$

back

Identification of the Total Causal Effects

- The identification of the total causal effect:

$$\Delta Y(\boldsymbol{\tau}^0, \boldsymbol{\tau}^1) = \sum_{i=1}^{N} \Bigg\{ \underbrace{\sum_{k \in \mathcal{N}_i^0 \cap \mathcal{N}_i^1} \left(y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0) \right)}_{\text{continuing firms}}$$

$$+ \underbrace{\sum_{k \in \mathcal{N}_i^1 \setminus \mathcal{N}_i^0} \left(y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0) \right)}_{\text{new entrants}} + \underbrace{\sum_{k \in \mathcal{N}_i^0 \setminus \mathcal{N}_i^1} \left(y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0) \right)}_{\text{exiting firms}}$$

$$+ \underbrace{\sum_{k \in \mathcal{N}_i^1 \setminus \mathcal{N}_i^0} y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0) - \sum_{k \in \mathcal{N}_i^0 \setminus \mathcal{N}_i^1} y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1)}_{\text{a normalization constant}} \Bigg\}$$

back

Identification of the Total Causal Effects

- For continuing firms, new entrants and exiting firms,

$$y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0) = y_{ik}(\boldsymbol{\tau}^1, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^1) + y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^1) - y_{ik}(\boldsymbol{\tau}^0, \mathbf{a}^0)$$
$$= \int_{\boldsymbol{\tau}^0}^{\boldsymbol{\tau}^1} \frac{\partial y_{ik}(s, \mathbf{a}^1)}{\partial s} ds + \int_{\mathbf{a}^0}^{\mathbf{a}^1} \frac{\partial y_{ik}(\boldsymbol{\tau}^0, s)}{\partial s} ds,$$

  where the identification of $\frac{\partial y_{ik}(s,\mathbf{a}^1)}{\partial s}$ and $\frac{\partial y_{ik}(\boldsymbol{\tau}^0,s)}{\partial s}$ is left for future work.

- The identification of the normalization constant is left for future work as well.
  - This is tied with the formulation of the free entry condition (i.e., the determination of $\mathcal{N}_i^1$).

back

Welfare Gains from Trade Cost Shocks

- The common practice in the international trade literature proceeds in three steps.

  Step 1. Characterize the welfare gain $\%\Delta\mathcal{W}$ in terms of the "trade elasticity" ε and the domestic absorption share λ: e.g., $\%\Delta\mathcal{W} = 1 - \lambda^{1/\varepsilon}$.

  Step 2. Estimate the trade elasticity $\hat{\varepsilon}$, while λ is typically observed in data.

  Step 3. Plug in the estimate $\hat{\varepsilon}$ into the characterization: e.g., $\widehat{\%\Delta\mathcal{W}} = 1 - \lambda^{1/\hat{\varepsilon}}$.

- In Step 2, the literature assumes that the trade policy is a "random realization."
  - e.g., Arkolakis et al. (2012), Adão et al. (2020), Boehm et al. (2023).
- This is compatible with the analysis of "shocks to trade costs."
- But this is not compatible with the analysis of policy making.

- My paper proposes a conceptually consistent framework for the policymaker's problem.

back

More on Arkolakis et al. (2012)

- *Ex ante*, the policy shock is known only up to its probability distribution.
- The appropriate evaluation criteria should involve the probability distribution of the shocks: e.g.,

$$E[\%\Delta\mathcal{W}] \qquad \text{or} \qquad E[\Delta\mathcal{W}]$$

- The famous expression for the "*ex ante*" welfare gain from going to autarky $\%\Delta\mathcal{W} = 1 - \lambda^{1/\varepsilon}$ (Arkolakis et al. 2012) only corresponds to one possible realization of the shock.
- Any inference based solely on this expression is merely as useful as an *ex post* assessment.

back

Policy Evaluation to Policy Design

- My framework can naturally fit into an optimal policy design problem.
- One criterion for the optimal industrial policy ${\tau_n^1}^*$ is defined by

$$ {\tau_n^1}^* \in \max_{\tau_n^1} \Delta Y(\tau_n^0, \tau_n^1) $$

- The expression for $\%\Delta\mathcal{W}$ cannot be used in this way for the reason explained above.

- The welfare gain literature and the optimal trade policy literature are conceptually distinct.
- My framework bridges these two different strands of the literature.

back

Wage and Sectoral Price Indices

- Wage W^* is obtained from the U.S. Bureau of Labor Statistics (BLS) through the Federal Reserve Bank of St. Louis (FRED) at annual frequency.
- I use "average hourly earnings of all employees, total private"

- Sectoral price index data $\{P_i^*\}_{i=1}^N$ is available at the Bureau of Economic Analysis (BEA).
- I use "U.Chain-Type Price Indexes for Gross Output by Industry — Detail Level (A)"

back

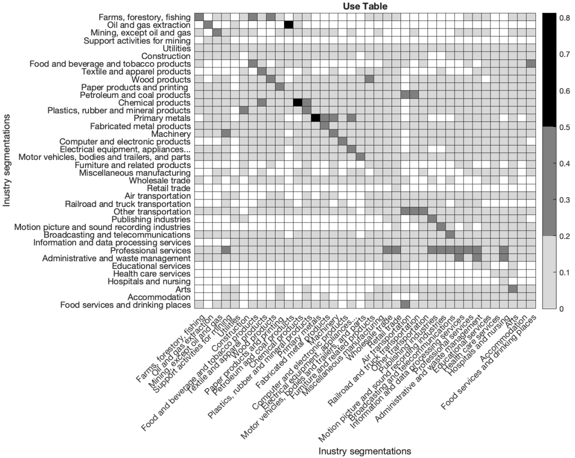
Input-Output Table

- The use table only records the uses of each commodity by each industry.
- I need to transform the table to the industry-by-industry table.

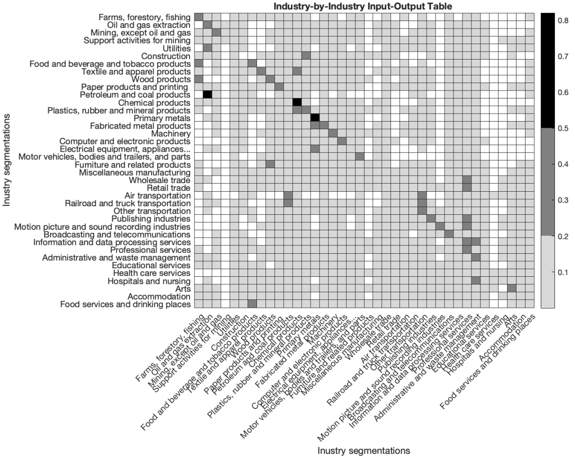
- **Assumption**: Each product has its own specific sales structure, irrespective of the industry where it is produced.
- The term "sales structure" refers to the shares of the respective intermediate and final users in the sales of a commodity.
- Each commodity is used at the constant rates regardless of in which industry it is produced.

back

Use Table vs. Industry-by-Industry Table



Use table



Transformed industry-by-industry table

Omit and Merge Sectors

1. I omit several industries following Baqaee and Farhi (2020) and Bigio and La'O (2020):
    - Finance, insurance, real estate, rental and leasing (FIRE) sectors;
    - Scrap, used and secondhand goods and Noncomparable imports and rest-of-the-world adjustment;
    - The government sectors.
2. I merge some of the BEA's industries following Gutiérrez and Philippon (2017):
    - I am left with 38 industries.

back

Mapping of BEA Industry Codes to Segments I

BEA code	Industry	Mapped segment
111CA	Farms	Farms, forestry, fishing, and related activ
113FF	Forestry, fishing, and related activities	Farms, forestry, fishing, and related activ
211	Oil and gas extraction	Oil and gas extraction
212	Mining, except oil and gas	Mining, except oil and gas
213	Support activities for mining	Support activities for mining
22	Utilities	Utilities
23	Construction	Construction
311FT	Food and beverage and tobacco products	Food and beverage and tobacco products
313TT	Textile mills and textile product mills	Textile and apparel products
315AL	Apparel and leather and allied products	Textile and apparel products
321	Wood products	Wood products
322	Paper products	Paper products, printing, and related act
323	Printing and related support activities	Paper products, printing, and related act
324	Petroleum and coal products	Petroleum and coal products
325	Chemical products	Chemical products
326	Plastics and rubber products	Plastics, rubber and mineral products

Mapping of BEA Industry Codes to Segments II

327	Nonmetallic mineral products	Plastics, rubber and mineral products
331	Primary metals	Primary metals
332	Fabricated metal products	Fabricated metal products
333	Machinery	Machinery
334	Computer and electronic products	Computer and electronic products
335	Electrical equipment, appliances, and components	Electrical equipment, appliances, and cor
3361MV	Motor vehicles, bodies and trailers, and parts	Motor vehicles, bodies and trailers, and p
33640T	Other transportation equipment	Motor vehicles, bodies and trailers, and p
337	Furniture and related products	Furniture and related products
339	Miscellaneous manufacturing	Miscellaneous manufacturing
42	Wholesale trade	Wholesale trade
441	Motor vehicle and parts dealers	Retail trade
445	Food and beverage stores	Retail trade
452	General merchandise stores	Retail trade
4A0	Other retail	Retail trade
481	Air transportation	Air transportation
482	Rail transportation	Railroad and truck transportation
483	Water transportation	Other transportation
484	Truck transportation	Railroad and truck transportation

Mapping of BEA Industry Codes to Segments III

485	Transit and ground passenger transportation	Other transportation
486	Pipeline transportation	Other transportation
4870S	Other transportation and support activities	Other transportation
493	Warehousing and storage	Other transportation
511	Publishing industries, except internet (includes software)	Publishing industries
512	Motion picture and sound recording industries	Motion picture and sound recording indu
513	Broadcasting and telecommunications	Broadcasting and telecommunications
514	Data processing, internet publishing, and other information services	Information and data processing services
521CI	Federal Reserve banks, credit intermediation, and related activities	Omitted
523	Securities, commodity contracts, and investments	Omitted
524	Insurance carriers and related activities	Omitted
525	Funds, trusts, and other financial vehicles	Omitted
HS	Housing	Omitted
ORE	Other real estate	Omitted
532RL	Rental and leasing services and lessors of intangible assets	Omitted
5411	Legal services	Professional services
54120P	Miscellaneous professional, scientific, and technical services	Professional services
5415	Computer systems design and related services	Professional services
55	Management of companies and enterprises	Omitted

Mapping of BEA Industry Codes to Segments IV

561	Administrative and support services	Administrative and waste management
562	Waste management and remediation services	Administrative and waste management
61	Educational services	Educational services
621	Ambulatory health care services	Health care services
622	Hospitals	Hospitals and nursing
623	Nursing and residential care facilities	Hospitals and nursing
624	Social assistance	Health care services
711AS	Performing arts, spectator sports, museums, and related activities	Arts
713	Amusements, gambling, and recreation industries	Arts
721	Accommodation	Accommodation
722	Food services and drinking places	Food services and drinking places
81	Other services, except government	Omitted
GFGD	Federal general government (defense)	Omitted
GFGN	Federal general government (nondefense)	Omitted
GFE	Federal government enterprises	Omitted
GSLG	State and local general government	Omitted
GSLE	State and local government enterprises	Omitted
Used	Scrap, used and secondhand goods	Omitted
Other	Noncomparable imports and rest-of-the-world adjustment	Omitted

Value Added in Use Table

Table 1.2 Use table: Commodities used by industries and final uses

		INDUSTRIES																FINAL USES (GDP)							TOTAL COMMODITY
		Agriculture, forestry, fishing, and hunting	Mining	Utilities	Construction	Manufacturing	Wholesale trade	Retail trade	Transportation and warehousing	Information	Finance, insurance, real estate, rental, and leasing	Professional and business services	Educational services, health care, and social assistance	Arts, entertainment, recreation,	Other services, except government	Government	Total Intermediate	Personal consumption expenditures	Private fixed investment	Change in private inventories	Exports of goods and services	Imports of goods and services	Government consumption expenditures and gross	Total final uses (GDP)	
COMMODITIES	Agriculture, forestry, fishing, and hunting																								
	Mining																								
	Utilities																								
	Construction																								
	Manufacturing																								
	Wholesale trade																								
	Retail trade																								
	Transportation and warehousing																								
	Information																								
	Finance, insurance, real estate, rental, and leasing																								
	Professional and business services																								
	Educational services, health care, and social assistance																								
	Arts, entertainment, recreation, accommodation, and food services																								
	Other services, except government																								
	Government																								
	Other																								
	Scrap, used and secondhand goods																								
	Total Intermediate																								
VALUE ADDED	Compensation of employees																								
	Taxes on production and imports, less subsidies																								
	Gross operating surplus																								
	Total value added																								
TOTAL INDUSTRY OUTPUT																									

Total industry output

Total commodity output

back

Subsidies

- By the construction of the input-output table,

$$Profits_i = (Revenue_i + TaxSubsidy1_i) - (LaborCost_i + MaterialCost_i + TaxSubsidy2_i)$$

$$\therefore \underbrace{Revenue - MaterialCost_i}_{\text{Value-added}} = \underbrace{Profits_i}_{\text{Gross operating profits}} + \underbrace{LaborCost_i}_{\text{Compensation of employees}}$$

$$- \underbrace{(TaxSubsidy1_i - TaxSubsidy2_i)}_{\text{Value-added taxes less subsidies}},$$

where $TaxSubsidy1_i$ is taxes less subsidies on revenues, and $TaxSubsidy2_i$ those on input costs.

- The term $(TaxSubsidy1_i - TaxSubsidy2_i)$ is available in the data.

back

Subsidies

- The theory counterpart is

$$\sum_{k=1}^{N_i} \pi_{ik}^* = \sum_{k=1}^{N_i} p_{ik}^* q_{ik}^* - \left\{ W^* \ell_{ik}^* + (1-\tau_i) \sum_{j=1}^{N} P_i^{M*} m_{ik,j}^* \right\}$$

$$\therefore \underbrace{\sum_{k=1}^{N_i} p_{ik}^* q_{ik}^* - \sum_{j=1}^{N} P_i^{M*} m_{ik,j}^*}_{\text{Value-added}} = \underbrace{\sum_{k=1}^{N_i} \pi_{ik}^*}_{\text{Gross operating profits}} + \underbrace{W^* \ell_{ik}^*}_{\text{Compensation of employees}} - \underbrace{\tau_i \sum_{j=1}^{N} P_i^{M*} m_{ik,j}^*}_{\text{Value-added taxes less subsidies}} .$$

back

Subsidies

- Total expenditure on material input by sector i:

$$(1-\tau_i)\sum_{j=1}^{N}\sum_{k=1}^{N_i} P_j^* m_{ik,j}^* = \sum_{j=1}^{N} IntermExpend_{i,j},$$

  where $IntermExpend_{i,j}$ is reported in the (i,j) entry of the industry-by-industry input-output table.
- Total amount of subsidy to sector i:

$$\tau_i \sum_{j=1}^{N}\sum_{k=1}^{N_i} P_j^* m_{ik,j}^* = TaxSubsidy1_i - TaxSubsidy2_i,$$

- Rearranging these,

$$\tau_i = \frac{VAT_i}{VAT_i + \sum_{j=1}^{N} IntermExpend_{i,j}}.$$

back

Compustat

- The coverage is limited to publicly traded firms.
- But, publicly traded firms tend to be much larger than private firms.
- Thus, it account for the dominant part of the industry dynamics.
- I use the following data:
  - Sales ($SALES$)
  - Costs of Goods Sold ($COGS$)
  - Selling, General & Administrative Expense (SGA)
  - Number of Employees (EMP)
- I drop observations with missing data at any item.
- I drop observations corresponding to
  - top and bottom 5% of $COGS/SALES$;
  - top and bottom 5% of $SGA/SALES$.

back

Data Cleaning

- EMP is used for both variable and fixed costs.

- Under this assumption,

$$\begin{aligned} TotalCosts_{ik} &= TotalLaborCost_{ik} + TotalMaterialCost_{ik} \\ &= \underbrace{VariableLaborCost_{ik} + VariableMaterialCost_{ik}}_{COGS_{ik}} \\ &\quad + \underbrace{FixedLaborCost_{ik} + FixedMaterialCost_{ik}}_{SGA_{ik}}. \end{aligned}$$

back

Data Cleaning

- Also,

$$\begin{aligned} TotalLaborCosts_{ik} &= VariableLaborCosts_{ik} + FixedLaborCosts_{ik} \\ &= W \times AverageHoursWorked \times \underbrace{Employees_{ik}}_{EMP_{ik}} \\ &= W \times \frac{TotalHours}{TotalEmployees} \times EMP_{ik}. \end{aligned}$$

- Moreover,

$$TotalMaterialCosts_{ik} = TotalCosts_{ik} - TotalLaborCosts_{ik}.$$

back

- **Assumption**: For each sector $i \in \mathbf{N}$ and each firm $k \in \mathbf{N}_1$, $VariableLaborCost_{ik}$: $VariableMaterialCost_{ik} = FixedLaborCost_{ik} FixedMaterialCost_{ik} = \delta_{ik} : 1 - \delta_{ik}$, where $\delta_{ik} \in [0, 1]$ is a constant specific to firm k.
- Under this assumption,

$$VariableLaborCost_{ik} = \frac{1 - \delta_{ik}}{\delta_{ik}} VariableMaterialCost_{ik}$$
$$FixedLaborCost_{ik} = \frac{1 - \delta_{ik}}{\delta_{ik}} FixedMaterialCost_{ik},$$

- Then,

$$\delta_{ik} = \frac{TotalMaterialCost_{ik}}{TotalLaborCost_{ik} + TotalMaterialCost_{ik}}.$$

back

- Hence,

$$VariableLaborCost_{ik} = \delta_{ik} COGS_{ik},$$
$$VariableMaterialCost_{ik} = (1 - \delta_{ik}) COGS_{ik},$$

- Since W and P_i^M are available in data, I can back out ℓ_{ik}^* and m_{ik}^*.
- Before doing so, I eliminate outliers based on two criteria: leverage points, influence points.

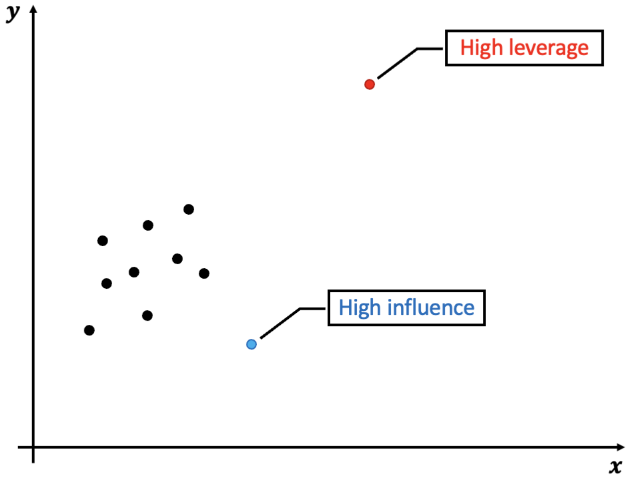
back

Leverage and Influence Points

- Consider a linear regression model: $y = x'\beta + \varepsilon$.
  - $Revenue_{ik} = \beta VariableLaborCost_{ik} + \varepsilon_{ik}$
  - $Revenue_{ik} = \beta VariableMaterialCost_{ik} + \varepsilon_{ik}$
- A leverage point is an observation that has an unusual predictor value.
  - An observation that is very different from the bulk of the observation.
- An influence point is an observation whose removal from the dataset would cause a large change in the estimated regression model coefficients.
- I treat both high leverage points and high influence points to be outliers.

back

An Illustrative Example



Leverage Points

- The observation's leverage on the regression model is determined by the location of points in x-space.
- This is measured by the diagonal elements h_{ii} of $H := X(X'X)^{-1}X$: i.e., $h_{ii} = x_i'(X'X)^{-1}x_i$.
- Let k be the number of variables and n the number of observations.
- The average value of h_{ii} is $\bar{h} = \frac{k+1}{n}$.
- I consider any observation with $h_{ii} > 1.8\bar{h}$ to be a leverage point.

back

Influence Points

- The observation's influence on the regression model is determined by (i) the location of the point in the x-space, and (ii) the response variable in measuring its influence.
- This is measured by a scalar D_i, where

$$D_i := \frac{\|\hat{y}_{(i)} - \hat{y}\|^2}{p \ MS_{Res}} = \frac{(\hat{\beta}_{(i)} - \hat{\beta})' X' X (\hat{\beta}_{(i)} - \hat{\beta})}{p \ MS_{Res}},$$

where

  - $\hat{\beta}$: least-squares estimate of regression coefficients based on all n points.
  - $\hat{\beta}_{(i)}$: least-squares estimate obtained by deleting the ith point.
  - p: the number of coefficients.
  - MS_{Res}: the mean squared error.

back

Influence Points

- For each $i \in \{1, 2, \ldots, n\}$,

$$D_i = \frac{r_i^2}{k+1} \frac{h_{ii}}{1-h_{ii}},$$

  where
  - r_i: the ith studentized residual.
  - $\frac{h_{ii}}{1-h_{ii}}$: the distance from x_i to the centroid of the remaining data.
- D_i is made up of
  (i) a component that reflects how well the model fits the ith observation y_i;
  (ii) a component that measures how far that point is from the rest of the data.
- I consider any observation for which $D_i > 1$ to be an influence point.

back

Input Demand

- Under the model, the input share of the Cobb-Douglas material aggregator is

$$\gamma_{i,j} = \frac{\omega_{i,j}}{\sum_{j'=1}^{N} \omega_{i,j'}},$$

where $\{\omega_{i,j}\}_{i,j}$ are observed in data.

- The cost index for material input:

$$P_i^M = \prod_{j=1}^{N} \frac{1}{\gamma_{i,j}^{\gamma_{i,j}}} \{(1-\tau_i)P_j\}^{\gamma_{i,j}}.$$

- The input demand for sector j's good:

$$m_{ik,j} = \gamma_{i,j} \frac{P_i^M}{(1-\tau_i)P_j} m_{ik}.$$

back

Construction of Control Functions

Perfect and monopolistic competition:

- Implicit in the existing literature is the timing assumption about input choices.
- Labor input is chosen before material input is chosen:

$$
\begin{aligned}
m_{ik}^* &\in \max_{\ell_{ik}} \max_{m_{ik}|\ell_{ik}} \pi_{ik}(\ell_{ik}, m_{ik}; z_{ik}) \\
&\Longrightarrow m_{ik}^* = \mathbb{M}(z_{ik}, \ell_{ik}^*) \\
&\Longrightarrow z_{ik} = \mathbb{M}^{-1}(\ell_{ik}^*, m_{ik}^*) \qquad \text{(under the invertibility assumption)}
\end{aligned}
$$

Oligopolistic competition:

- Input choices are constrained be the production possibility frontier:

$$
\begin{aligned}
z_{ik} f_i(\ell_{ik}^*, m_{ik}^*) &= q_{ik}^* = \chi_i(z_{ik}, \{z_{ik'}\}_{k' \neq k}) \\
\Longrightarrow z_{ik} &= \mathcal{M}_i(\ell_{ik}^*, m_{ik}^*, \{z_{ik'}\}_{k' \neq k})
\end{aligned}
$$

Sketch of Kasahara and Sugita (2020)

- Step 1: Identify revenue as a nonparametric function $\tilde{\phi}_i(\cdot)$ of labor and material

$$\tilde{r}_{ik} = \tilde{p}_{ik} + \tilde{q}_{ik} + \tilde{\eta}_{ik} = \tilde{\varphi}_i(\tilde{q}_{ik}) + \tilde{\eta}_{ik} = \tilde{\phi}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik}) + \tilde{\eta}_{ik},$$

  where $\tilde{x} = \ln(x)$ and $\tilde{q}_{ik} = \tilde{f}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik}; \tilde{z}_{ik})$.
- Step 2: $\frac{d\tilde{\varphi}_i^{-1}(\cdot)}{d\tilde{r}_{ik}}$ can be identified as the firm's markup.
- Step 3: Identify $\tilde{q}_{ik}$ according to

$$\tilde{q}_{ik} = \tilde{f}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik}; \tilde{z}_{ik}) = \int_{\tilde{\ell}_{ik}^{\circ}}^{\tilde{\ell}_{ik}} \frac{d\tilde{\varphi}_i^{-1}}{d\tilde{r}_{ik}} \frac{\partial \tilde{\phi}_i}{\partial \tilde{\ell}_{ik}}(s, \tilde{m}_{ik}) ds + \int_{\tilde{m}_{ik}^{\circ}}^{\tilde{m}_{ik}} \frac{d\tilde{\varphi}_i^{-1}}{d\tilde{r}_{ik}} \frac{\partial \tilde{\phi}_i}{\partial \tilde{m}_{ik}}(\tilde{\ell}_{ik}^{\circ}, s) ds,$$

  where $\tilde{f}_i(\tilde{\ell}_{ik}^{\circ}, \tilde{m}_{ik}^{\circ}; \tilde{z}_{ik}) = 0$ (normalization).

back

Sketch of Gandhi, Navarro and Rivers (2019)

- Step 1: $s^{\ell}_{ik} := \frac{W\ell_{ik}}{p_{ik}q_{ik}}$ and $\mu_{ik} := \frac{p_{ik}}{mc_{ik}}$ are observed in data.
- Step 2: From the firm's one-step profit maximization problem:

$$\ln s^{\ell}_{ik} = \ln \frac{\partial \tilde{g}_i(\cdot)}{\partial \tilde{\ell}_{ik}} - \ln \mu_{ik},$$

  where $\tilde{q}_{ik} = \tilde{f}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik}; \tilde{z}_{ik}) = \tilde{z}_{ik}\tilde{g}_i(\tilde{\ell}_{ik}, \tilde{m}_{ik})$.
- Step 3: Specify the share regression:

$$\tilde{s}^{\ell,\tilde{\mu}}_{ik} = \ln \mathcal{E}^{\ell}_i + \ln \frac{\partial \tilde{g}_i}{\partial \tilde{\ell}_{ik}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) - \tilde{\varepsilon}^{\ell}_{ik},$$

  where $\tilde{s}^{\ell,\tilde{\mu}}_{ik} := \ln s^{\ell}_{ik} + \ln \mu_{ik}$.
- Step 4: $\frac{\partial f_i(\cdot)}{\partial \ell_{ik}} = \frac{\partial \tilde{g}_i(\cdot)}{\partial \tilde{\ell}_{ik}} \frac{f_i(\cdot)}{\ell_{ik}}$. To obtain $\frac{\partial f_i(\cdot)}{\partial m_{ik}}$, apply the same procedure with respect to m_{ik}, or use the property of CRS.

back

Intuition: Sufficient Statistics

- Suppose there are only three firms ($k = 1, 2, 3$) in sector i.
- Suppose: $q^*_{ik} = \chi_i(z_{ik}, H_i(\{z_{ik'}\}_{k'}))$ where $H_i(\{z_{ik'}\}_{k'}) := \sum_{k' \in \{1,2,3\}} z_{ik'}$.
- Suppose:

	z_{ik}
Firm 1	0.5
Firm 2	2.0
Firm 3	1.5
$H_i(\{z_{ik'}\}_{k'})$	4.0

- Firm 1 only cares its own productivity ($z_{i1} = 0.5$) and the aggregate ($H_i(\{z_{ik'}\}_{k'}) = 4.0$).
- Firm 1 does not care Firm 2 and 3 as an individual competitor.

back

Intuition: Sufficient Statistics

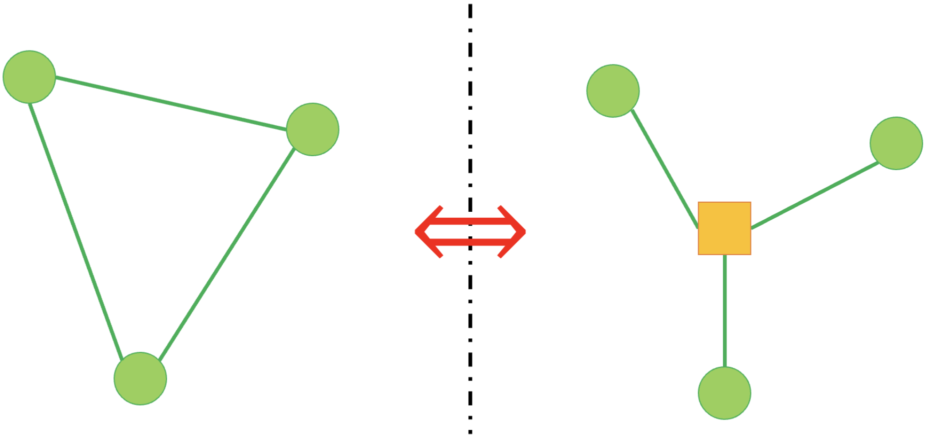
- Fix Firm 1 (i.e., stand at the Firm 1's perspective).
- Consider two scenarios:

	z_{ik}	
	Scenario 1	Scenario 2
Firm 1	0.5	0.5
Firm 2	2.0	1.0
Firm 3	1.5	2.5
$H_i(\{z_{ik'}\}_{k'})$	4.0	4.0

- The value of $H_i(\{z_{ik'}\}_{k'})$ is the same.
- From the Firm 1's perspective, Scenario 1 and 2 are the same. i.e., "Who are in the market" does not matter.

back

Equivalence Class



Derivation of Control Functions

- Input choices are constrained be the production possibility frontier.

$$z_{ik} f_i(\ell_{ik}^*, m_{ik}^*) = q_{ik}^* = \chi_i(z_{ik}, H_i(\{z_{ik'}\}_{k'}))$$
$$\implies z_{ik} = \mathcal{M}_i(\ell_{ik}^*, m_{ik}^*; \bar{\mathcal{H}}_i),$$

where $\bar{\mathcal{H}}_i = \mathcal{H}_i(\{z_{ik'}\}_{k'})$ with $\mathcal{H}_i(\cdot)$ being some function.

- $\bar{\mathcal{H}}_i$ can be interpreted as an index of market competitiveness and is known to all firms.

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Estimators for Price and Quantity I

- Step 1. Approximate $\tilde{\phi}(\cdot)$ by a second order Taylor polynomial:

$$\begin{aligned}\tilde{r}_{ik} &= b_{i,0} + b_{i,1}\tilde{\ell}_{ik} + b_{i,2}\tilde{m}_{ik} + b_{i,3}\tilde{\ell}_{ik}^2 + b_{i,4}\tilde{m}_{ik}^2 + b_{i,5}\tilde{\ell}_{ik}\tilde{m}_{ik} + \tilde{\eta}_{ik} \\ &= \tilde{x}_{ik}\boldsymbol{b}_i + \tilde{\eta}_{ik}\end{aligned}$$

- Step 2. Apply OLS

$$\hat{\mathbf{b}}_i = (\tilde{\mathbf{x}}_i'\tilde{\mathbf{x}}_i)^{-1}\tilde{\mathbf{x}}_i'\tilde{\mathbf{r}}_i,$$

so that $\hat{\tilde{\phi}}_i(\tilde{x}_{ik}) := \tilde{x}_{ik}\hat{\mathbf{b}}_i$.

Estimators for Price and Quantity II

- Step 3. Estimator for the first order partial derivatives of $\tilde{\phi}_i(\cdot)$

$$\widehat{\frac{\partial \tilde{\phi}_i}{\partial \tilde{\ell}_{ik}}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \hat{b}_{i,1} + 2\hat{b}_{i,3}\tilde{\ell}_{ik} + \hat{b}_{i,5}\tilde{m}_{ik}$$
$$\widehat{\frac{\partial \tilde{\phi}_i}{\partial \tilde{m}_{ik}}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \hat{b}_{i,2} + 2\hat{b}_{i,4}\tilde{m}_{ik} + \hat{b}_{i,5}\tilde{\ell}_{ik}.$$

- Step 4. $\frac{d\tilde{\varphi}_i^{-1}}{d\tilde{r}_{ik}} = \mu_{ik}$ is observed in data.
- Step 5. Estimate for $\tilde{q}_{ik}$ is obtained as

$$\hat{\tilde{q}}_{ik} = \int_{\tilde{\ell}^{\circ}_{ik}}^{\tilde{\ell}_{ik}} \frac{d\tilde{\varphi}_i^{-1}}{d\tilde{r}_{ik}} \widehat{\frac{\partial \tilde{\phi}_i}{\partial \tilde{\ell}_{ik}}}(s, \tilde{m}_{ik})ds + \int_{\tilde{m}^{\circ}_{ik}}^{\tilde{m}_{ik}} \frac{d\tilde{\varphi}_i^{-1}}{d\tilde{r}_{ik}} \widehat{\frac{\partial \tilde{\phi}_i}{\partial \tilde{m}_{ik}}}(\tilde{\ell}^{\circ}_{ik}, s)ds.$$

back

Estimators for Production Elasticities I

- Step 1. Consider a second order Taylor polynomial and solve

$$\hat{\zeta} \in \arg\min_{\zeta^\circ} \sum_{k=1}^{N_i} \left\{ \tilde{s}_{ik}^{\ell,\tilde{\mu}} - \ln\left\{ \zeta_{i,0}^\circ + \zeta_{i,1}^\circ \tilde{\ell}_{ik} + \zeta_{i,2}^\circ \tilde{m}_{ik} + \zeta_{i,3}^\circ \tilde{\ell}_{ik}^2 + \zeta_{i,4}^\circ \tilde{m}_{ik}^2 + \zeta_{i,5}^\circ \tilde{\ell}_{ik} \tilde{m}_{ik} \right\} \right\}^2.$$

- Step 2.

$$\widehat{D}_{ik}^{\ell}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \hat{\zeta}_{i,0} + \hat{\zeta}_{i,1}\tilde{\ell}_{ik} + \hat{\zeta}_{i,2}\tilde{m}_{ik} + \hat{\zeta}_{i,3}\tilde{\ell}_{ik}^2 + \hat{\zeta}_{i,4}\tilde{m}_{ik}^2 + \hat{\zeta}_{i,5}\tilde{\ell}_{ik} m_{ik}.$$

and

$$\widehat{\mathcal{E}}_i^{\ell} := \frac{1}{N_i}\sum_{k=1}^{N_i} \exp\{\hat{\varepsilon}_{ik}\} \qquad \text{where} \qquad \hat{\varepsilon}_{ik}^{\ell} := \ln \widehat{D}_{ik}^{\ell}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) - \tilde{s}_{ik}^{\ell,\tilde{\mu}}.$$

Estimators for Production Elasticities II

- Step 3.

$$\widehat{\frac{\partial \tilde{g}_i}{\partial \tilde{\ell}_{ik}}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \frac{\widehat{D}^{\ell}_{ik}(\tilde{\ell}_{ik}, \tilde{m}_{ik})}{\widehat{\mathcal{E}}^{\ell}_i}$$
$$= \frac{1}{\widehat{\mathcal{E}}^{\ell}_i}\left(\hat{\zeta}_{i,0} + \hat{\zeta}_{i,1}\tilde{\ell}_{ik} + \hat{\zeta}_{i,2}\tilde{m}_{ik} + \hat{\zeta}_{i,3}\tilde{\ell}^2_{ik} + \hat{\zeta}_{i,4}\tilde{m}^2_{ik} + \hat{\zeta}_{i,5}\tilde{\ell}_{ik}\tilde{m}_{ik}\right),$$

and

$$\widehat{\frac{\partial^2 \tilde{g}_i}{\partial \tilde{\ell}^2_{ik}}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \frac{1}{\widehat{\mathcal{E}}^{\ell}_i}\left\{(\hat{\zeta}_{i,1} + 2\hat{\zeta}_{i,3})\tilde{\ell}_{ik} + \hat{\zeta}_{i,5}\tilde{m}_{ik}\right\},$$
$$\widehat{\frac{\partial^2 \tilde{g}_i}{\partial \tilde{\ell}_{ik}\tilde{m}_{ik}}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) := \frac{1}{\widehat{\mathcal{E}}^{\ell}_i}\left\{(\hat{\zeta}_{i,2} + 2\hat{\zeta}_{i,4})\tilde{m}_{ik} + \hat{\zeta}_{i,5}\tilde{\ell}_{ik}\right\}.$$

back

Presence of a Timing Assumption

- Implicit in the existing literature is the timing assumption about input choices.
- Labor input is chosen before material input is chosen (e.g., Ackerberg, Caves and Frazer 2015; Gandhi et al. 2019):

$$
\begin{aligned}
& m_{ik}^{*} \in \max_{\ell_{ik}} \max_{m_{ik}|\ell_{ik}} \pi_{ik}(\ell_{ik}, m_{ik}; z_{ik}) \\
& \Longrightarrow m_{ik}^{*} = \mathbb{M}(z_{ik}, \ell_{ik}^{*}) \\
& \Longrightarrow z_{ik} = \mathbb{M}^{-1}(\ell_{ik}^{*}, m_{ik}^{*}) \qquad \text{(under the invertibility assumption)}
\end{aligned}
$$

- Under this setup, the share regression can be derived only with respect to material input:

$$
\tilde{s}_{ik}^{m,\tilde{\mu}} = \ln \mathcal{E}_i^m + \ln \frac{\partial \tilde{g}_i}{\partial \tilde{m}_{ik}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) - \tilde{\varepsilon}_{ik}^m.
$$

back

Absence of a Timing Assumption

- In my case, the control function comes from the production possibility frontier:

$$
\begin{aligned}
&z_{ik} f_i(\ell^*_{ik}, m^*_{ik}) = q^*_{ik} = \chi_i(z_{ik}, H_i(\{z_{ik'}\}_{k'})) \\
&\implies z_{ik} = \mathcal{M}_i(\ell^*_{ik}, m^*_{ik}; \bar{\mathcal{H}}_i),
\end{aligned}
$$

  where $\bar{\mathcal{H}}_i = \mathcal{H}_i(\{z_{ik'}\}_{k'})$ with $\mathcal{H}_i(\cdot)$ being some function.
- The timing assumption is not needed.
- The share regression can be derived both with respect to labor and material inputs:

$$
\begin{aligned}
[\ell_{ik}] : \quad & \tilde{s}^{\ell,\tilde{\mu}}_{ik} = \ln \mathcal{E}^{\ell}_i + \ln \frac{\partial \tilde{g}_i}{\partial \tilde{\ell}_{ik}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) - \tilde{\varepsilon}^{\ell}_{ik} \\
[m_{ik}] : \quad & \tilde{s}^{m,\tilde{\mu}}_{ik} = \ln \mathcal{E}^{m}_i + \ln \frac{\partial \tilde{g}_i}{\partial \tilde{m}_{ik}}(\tilde{\ell}_{ik}, \tilde{m}_{ik}) - \tilde{\varepsilon}^{m}_{ik}.
\end{aligned}
$$

back

Use of the Both Share Regressions

- There are two ways of using these two share regressions.

  1. Put aside one of them as an overidentification restriction.
     $\longrightarrow$ This can be used for a validation/test purpose.

  2. Incorporate both of them into estimation.
     $\longrightarrow$ It improves the accuracy of the estimates.

- I Incorporate the both regressions to mitigate inaccuracies due to computational issues.
  - e.g., The estimates are less prone to the choice of initial values in the optimization algorithm.

back

Robustness

- My framework is self-contained in the sense that it does not require external information.
  - e.g., parameter estimates from the preexisting literature
- My estimates are free from errors coming through the estimates for different contexts.
- There can be two sources for the estimation errors.
  1. Choices of polynomials in estimating i) firm-level prices and quantities, and ii) firm-level production elasticities and demand elasticities.
  2. Data cleaning (e.g., criteria for outliers).
- Examining the robustness is left for future work.

back

Assumptions

- **Assumption**: (i) The observations in the data are generated from a single equilibrium; (ii) The equilibrium that is played does not change over the course of the policy reform.
- The equilibrium selection probability is degenerated to a single equilibrium, which will be chosen in the policy counterfactuals.

- **Assumption**: $[\tau_n^0, \tau_n^1] \subseteq \mathscr{T}_n$ where $\mathscr{T}_n$ is the observed support of τ_n.
- This excludes a policy that has never been implemented before.

- Extrapolation is not trivial in my framework.

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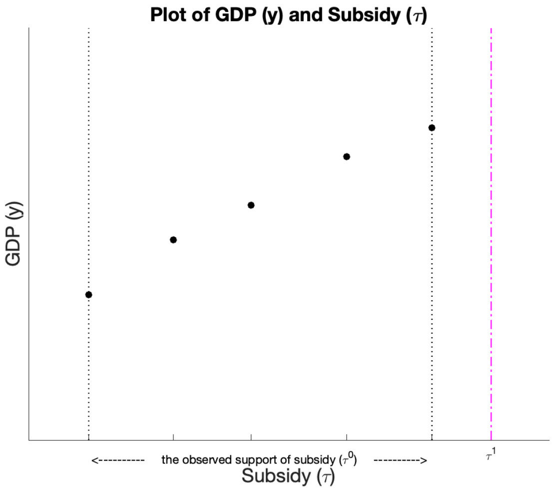
An Illustrative Example



Setup:

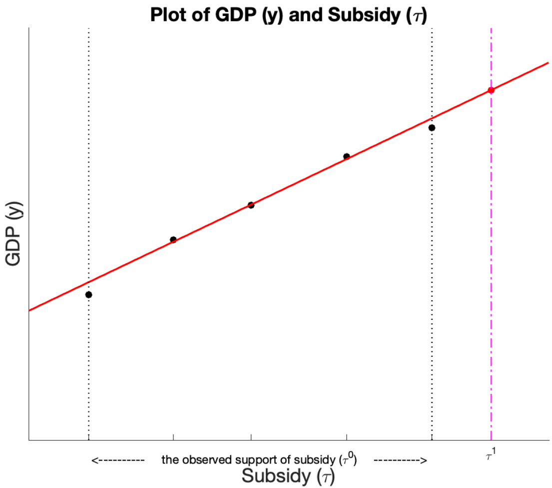
- I want to predict GDP (y) by subsidy (τ).
- Five data points (τ, y) are available.
- The data points are indicated by •.

Question:

- τ^1 is very large and has never been implemented.
- How can I predict the value of y corresponding to τ^1?

back

Empirical Reduced-Form Approach



Specification:

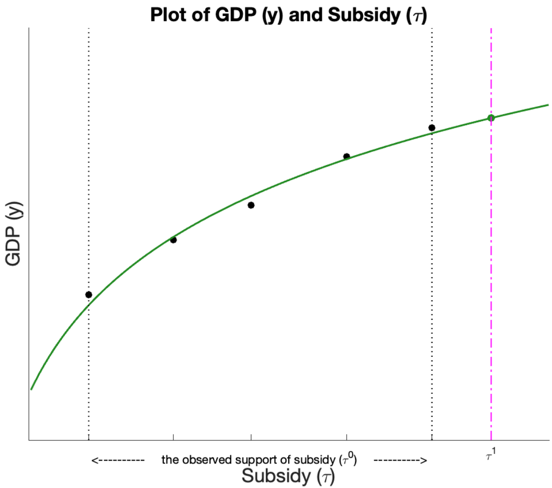
- $E[y \mid \tau] := \alpha + \beta\tau$ for $\tau \in \mathbb{R}$.
- α and β are regression coefficients.

Prediction:

- A simple linear extrapolation gives the prediction ●.

back

(Parametric) Structural Approach



Specification:

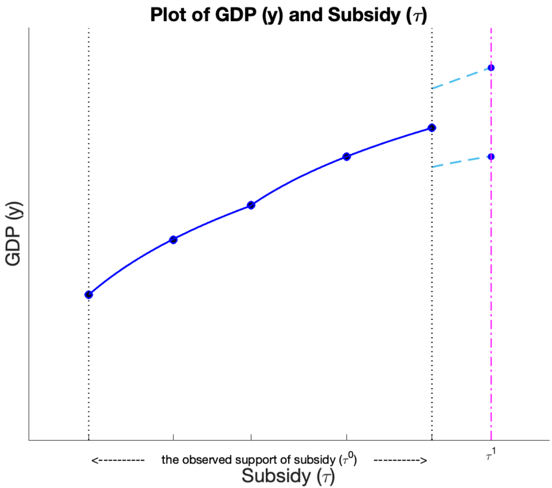
- $E[y \mid \tau] := g_\theta(\tau)$ for $\tau \in \mathbb{R}$.
- $g_\theta(\cdot)$ is a known function with θ the structural (or "deep") parameters.

Prediction:

- A simple (nonlinear) extrapolation gives the prediction •.

back

Nonparametric Structural Approach



Specification:

- $E[y \mid \tau] := h(\tau)$ for $\tau \in \mathscr{T}$.
- $h(\cdot)$ is an unknown function.

Prediction:

- Simple extrapolation is not possible.
- Canen and Song (2022) show that the upper and lower bounds – – ● can be identified.
- This is left for future work.

back

Source of Variation

- Empirical reduced-form approach directly identifies the regression function $E[y \mid \tau]$.
- This exploits the variation in τ.

- Structural approach first recovers the *value* of the regression function at $\bar{\tau}$, i.e., $E[y \mid \tau = \bar{\tau}]$.
- This exploits the variation in firm-level productivities (or labor and material inputs).
- This is repeated for all possible $\bar{\tau}$, recovering the "regression function" $E[y \mid \tau]$.

- Structural approach does not rely on variation in the observed policy variables.
  $\longrightarrow$ It can be used for *ex ante* policy evaluations (Todd and Wolpin 2008).

back

Design

- The estimator for the policy effect:

$$\widehat{\Delta Y}(\tau_n^0, \tau_n^1) = \sum_{i=1}^{N} \int_{\tau^0}^{\tau^1} \widehat{\frac{dY_i(s)}{ds}} ds$$

- The estimates are compared along two dimensions.
  1. I approximate $\widehat{\frac{dY_i(s)}{ds}}$ by a constant and non-constant function.
  2. I consider monopolistic competition and oligopolistic competition behind $\widehat{\frac{dY_i(s)}{ds}}$.

Approximation
back

Main Result

- The value of $\widehat{\Delta Y}(\tau_n^0, \tau_n^1)$:

(billion U.S. dollars)	Monopolistic competition	Oligopolistic competition
Non-constant approximation	-0.71	-1.34
Constant approximation	1.76	-2.93

- Non-constancy of $\widehat{\frac{dY_i(s)}{ds}}$ is empirically relevant.
- Strategic interaction in $\widehat{\frac{dY_i(s)}{ds}}$ is empirically relevant.

Plots
back

Constant and Non-Constant Approximation

- Non-constant approximation: I divide this interval evenly into a fixed number of segments and calculate the estimate according to

$$\widehat{\Delta Y}(\tau_n^0, \tau_n^1) \approx \sum_{v=0}^{\bar{v}-1} \sum_{i=1}^{N} \widehat{\frac{dY_i(s)}{ds}\bigg|_{s=\tau_n^0+v\Delta\tau_n}} \times \Delta\tau_n,$$

where $\Delta\tau_n := \frac{\tau_n^1-\tau_n^0}{\bar{v}}$ with $\bar{v}$: the number of bins equally segmenting the interval $[\tau_n^0, \tau_n^1]$.

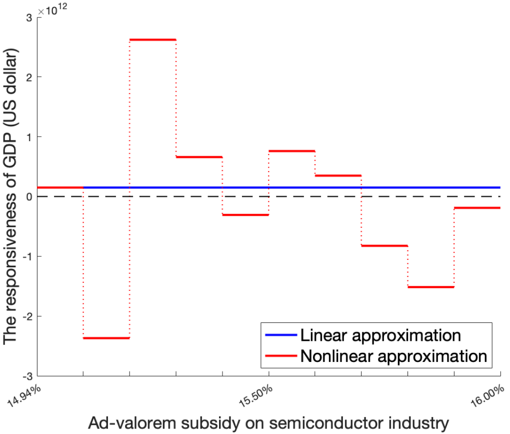
  - In this analysis, I set $\bar{v} = 10$.

- Constant approximation:

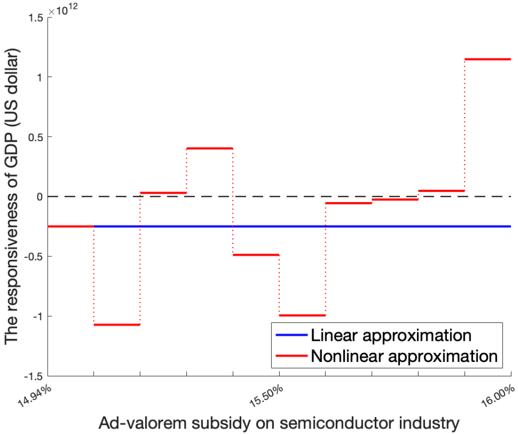
$$\widehat{\Delta Y}(\tau_n^0, \tau_n^1) \approx \sum_{i=1}^{N} \widehat{\frac{dY_i(s)}{ds}\bigg|_{s=\tau_n^0}} \times (\tau_n^1 - \tau_n^0).$$

back

Total Derivative of Y with respect to τ_n



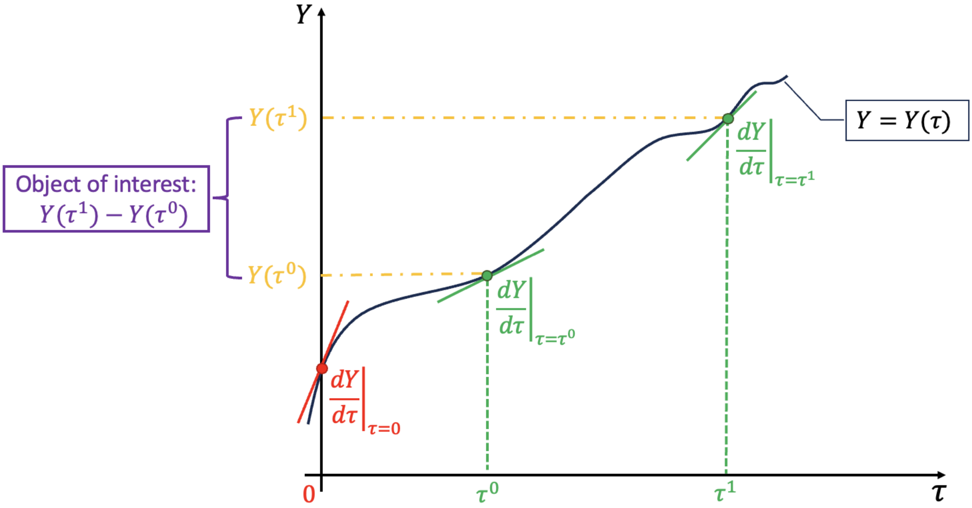
(a) Monopolistic Competition



(b) Oligopolistic Competition

back

Y as a Function of τ



Breakdown

- The marginal change in sectoral GDP:

$$\underbrace{\frac{dY_i(s)}{ds}}_{\text{total effect}} = \underbrace{\sum_{k=1}^{N_i} \frac{dp_{ik}^*}{ds} q_{ik}^*}_{\text{price effect}} + \underbrace{\sum_{k=1}^{N_i} p_{ik}^* \frac{dq_{ik}^*}{ds}}_{\text{quantity effect}} - \left(\underbrace{\sum_{k=1}^{N_i} \sum_{j=1}^{N} \frac{dP_j^*}{ds} m_{ik,j}^*}_{\text{wealth effect}} + \underbrace{\sum_{k=1}^{N_i} \sum_{j=1}^{N} P_j^* \frac{dm_{ik,j}^*}{ds}}_{\text{switching effect}} \right),$$

- The breakdown at $\tau_n^0 (= 14.94\%)$ for the semiconductor industry:

(billions U.S. dollars)	Total Effects	p.effect	q.effect	w.effect	s.effect
Monopolistic competition	196.76	-538.04	1098.37	-152.90	516.47
Oligopolistic competition	-94.70	-251.29	252.58	-59.75	155.74

- In monopolistic competition, the semiconductor industry "benefits" from the policy change.
- In oligopolistic competition, it "loses" due to the policy change.

back

Responsiveness of Sectoral GDP: Monopolistic Competition

Industry	Total Effects	Effects on Revenue		Effects on Material Cost	
		p.effect	q.effect	w.effect	s.effect
Wholesale trade	2679.40	3129.08	-14997.04	2900.08	-17447.44
Computer and electronic products	196.76	-538.04	1098.37	-152.90	516.47
Hospitals and nursing	87.26	-13.15	77.68	31.92	-54.64
Food services and drinking places	79.37	-27.08	117.76	19.42	-8.11
	⋮				
Broadcasting and telecommunications	-369.96	1079.64	-1948.26	597.88	-1096.54
Petroleum and coal products	-551.58	740.38	-462.15	2091.71	-1261.90
Motor vehicles, bodies and trailers, and parts	-720.69	626.73	-2963.23	687.48	-2303.29
Retail trade	-725.91	2993.65	-8432.83	2989.46	-7702.73
Total	150.74				

back

Responsiveness of Sectoral GDP: Oligopolistic Competition

Industry	Total Effects	Effects on Revenue		Effects on Material Cost	
		p.effect	q.effect	w.effect	s.effect
Accommodation	0.73	-2.15	3.38	-1.28	1.77
Wood products	0.59	0.83	-1.26	-0.47	-0.56
Plastics, rubber and mineral products	0.47	-6.35	6.26	-4.89	4.32
Railroad and truck transportation	0.44	-1.29	1.53	-1.35	1.15
⋮					
Wholesale trade	-14.28	-70.76	71.60	-78.28	93.40
Miscellaneous manufacturing	-44.50	43.98	-125.57	0.66	-37.75
Petroleum and coal products	-58.79	-186.41	187.48	-104.18	164.04
Computer and electronic products	-94.70	-251.29	252.58	-59.75	155.74
Total	-250.23				

back

Structural vs. Sufficient Statistics

Structural approach

Feature:

- Fully specify the model
  $\rightarrow$ deep parameters

Pros:

- behavioral interpretation

Cons:

- restrictive
- computationally hard

Sufficient statistics approach

Feature:

- Partially specify the model
  $\rightarrow$ sufficient statistics

Pros:

- less restrictive
- computationally easy

Cons:

- no behavioral interpretation

back

Example of $h_{i,n}$

- Suppose: there are only three sectors.

- The $(1,3)$ entry of $(I-\Gamma)^{-1}$ is

$$h_{1,3} = \underbrace{\gamma_{1,3}\frac{P_1^{M*}}{P_3^*}\lambda_3}_{\text{direct link}} + \underbrace{\gamma_{1,2}\gamma_{2,3}\frac{P_1^{M*}}{P_2^*}\frac{P_2^{M*}}{P_3^*}\lambda_2\lambda_3 + \ldots}_{\text{indirect links}}.$$

back

Comovements/Pass-Through (Full Description)

(Firm-level cost-price pass-through) $$\frac{dq^*_{ik}}{d\tau_n} = \bar{\lambda}^M_{ik}\frac{dP^{M*}_i}{d\tau_n} + \bar{\lambda}^L_{ik}\frac{dW^*}{d\tau_n}$$

(Sector-level cost-price pass-through) $$\frac{dP^*_i}{d\tau_n} = \bar{\lambda}^M_{i\cdot}\frac{dP^{M*}_i}{d\tau_n} + \bar{\lambda}^L_{i\cdot}\frac{dW^*}{d\tau_n}$$

(Sector-level policy-cost pass-through) $$\frac{dP^{M*}_i}{d\tau_n} = -h^M_{i,n}\frac{P^{M*}_n}{1-\tau_n} + h^L_i\frac{dW^*}{d\tau_n}$$

- $\bar{\lambda}^L_{ik}$, $\bar{\lambda}^M_{ik}$: firm k's contributions to the sector's overall markup response weighted by labor and material inputs, respectively.
- $\bar{\lambda}^L_{i\cdot}$, $\bar{\lambda}^M_{i\cdot}$: weighted averages of $\bar{\lambda}^L_{ik}$'s and $\bar{\lambda}^M_{ik}$'s.
- $h^M_{i,n}$: the (i,n) entry of $(I-\Gamma)^{-1}$, with $\Gamma := \left[\gamma_{i,j}\frac{P^{M*}_i}{P^*_j}\bar{\lambda}^M_{j\cdot}\right]^N_{i,j=1}$. ($h^L_i$ is analogous.)
    - The total strength of the direct and indirect links from sector n to sector i.

back

Sectoral Comovements: Monopolistic Competition

Industry (i)	h_i^L	$h_{i,n}^M$	$\frac{dP_i^{M*}}{d\tau_n}$	$\bar{\lambda}_{i\cdot}^L$	$\bar{\lambda}_{i\cdot}^M$	$\frac{dP_i^*}{d\tau_n}$
Wholesale trade	-65.37	-1.11	6567.20	1.71	0.63	4013.97
Computer and electronic products	-13.19	4.12	-2268.93	1.51	0.24	-667.05
Hospitals and nursing	-29.05	-0.97	3312.98	15.19	0.31	-285.32
Food services and drinking places	-22.46	-0.63	2460.67	7.34	0.11	-360.25
⋮						
Broadcasting and telecommunications	-52.00	0.42	4140.84	1.12	0.16	567.66
Petroleum and coal products	-5.51	0.00	471.62	-0.07	0.05	28.53
Motor vehicles, bodies and trailers, and parts	-12.35	-0.60	1560.55	3.67	0.60	618.57
Retail trade	-69.60	-1.46	7218.48	2.63	0.22	1372.51

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Sectoral Comovements: Oligopolistic Competition

Industry (i)	h_i^L	$h_{i,n}^M$	$\frac{dP_i^{M*}}{d\tau_n}$	$\bar{\lambda}_{i\cdot}^L$	$\bar{\lambda}_{i\cdot}^M$	$\frac{dP_i^*}{d\tau_n}$
Accommodation	13.13	0.12	-110.80	-1.70	0.11	-10.58
Wood products	3.95	0.06	-50.19	-1.55	-0.21	11.59
Plastics, rubber and mineral products	12.50	0.16	-140.44	1.05	0.06	-9.21
Railroad and truck transportation	14.48	0.12	-112.13	0.82	0.07	-8.94
$\vdots$						
Wholesale trade	15.44	0.20	-177.26	0.30	0.11	-19.16
Miscellaneous manufacturing	-30.04	-0.05	60.67	119.47	4.86	203.32
Petroleum and coal products	2.44	0.03	-23.49	0.05	0.49	-11.57
Computer and electronic products	13.34	1.67	-1391.01	0.68	0.11	-153.40

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