Constructive Deconstruction: Evaluating Industrial Policies in Strategic Interactions and Production Networks

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Motivation

- Industrial policies are policies that purposefully promote/protect particular industries.
- Ex) Trump tariffs on steel, Biden's subsidy on semiconductor.
- Of great importance is to evaluate of the impacts of these policies on macroeconomic outcome such as GDP.

- There has been huge empirical literature on treatment-effects of industrial policies.
- The treatment effects of industrial policies are tailored for the targeted sectors.
- The literature compares those firms that received a policy and those that do not.

- These empirical estimates might not be informative for the policymaker for two reasons.

Motivation

- Production networks play a role of a transmission channel:
  - Ex) aggregate fluctuations, misallocations, inflation, etc.
  - This is assumed away in most of the treatment-effect literature.

- Firms' strategic interactions are the key to replicating many empirical regularities:
  - Ex) an incomplete pass-through of a price shock, markups, comparative advantage, etc.
  - This is assumed away in most of the treatment-effect literature.

- This paper develops a structural framework for policy evaluations of industrial policies in the presence of strategic interactions and production networks.
- The policy parameter of this paper allows for an causal interpretation.
- As byproducts, my model i) takes into account the general equilibrium effects, and ii) can be used for *ex ante* policy evaluations.

What I do

- I show that in this setup, the production network compounds firms' markup responses not only with respect to their own choices but also with respect to competitors' choices.
- The latter is absent in monopolistic competition models.

- To identify firms' markup responses, I exploit the control function approach of the industrial organization literature.
- To account for firms' strategic interactions, I impose three assumptions on firms' demand and production functions.

- I apply my framework to study a part of the Biden's subsidy on the semiconductor industry.
- Accounting for firms' strategic interactions nearly doubles the magnitude of the policy effect.

Setup

- Consider a simple input-output framework for a two-sector economy, Sector 1 and 2.
- These sectors are linked through a production network Ω.
- There is a final good consumer Y.

- There are sector-level markups: μ_1 and μ_2.
- (The sectoral markup arises from duopoly competition.)
- The markup is the sole source of the sectoral value added: VA_1 and VA_2.

- Under this setup,

$$GDP = VA_1 + VA_2.$$

Setup

- There is a subsidy specific to Sector 1, τ_1^0.
  - Sector 1's input cost is "discounted" by τ_1^0.
- The policymaker is interested in the effect on GDP of a policy reform from τ_1^0 to τ_1^1.
- The object of interest:

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

where $GDP(\tau_1)$ represents GDP under policy τ_1.

- This tells us the *ceteris paribus* change of GDP with respect to the subsidy.

Implications

- The integrand involves the expression:

$$\left\{ \sum_{n=1}^{\infty} \sum_{l=0}^{n-1} \underbrace{(\Omega M^{-1})^{l+1}}_{(A)} \frac{dM}{d\tau_1} M^{-1} \underbrace{(\Omega M^{-1})^{n-l-1}}_{(B)} \right\} Y,$$

where M is a diagonal matrix with the (i,i) entry equal to μ_i.

- (A): the extent of the sector's sales used as input in the $(l+1)$th round of the production process.
- (B): the extent of the sector's intermediate purchase in the $(n-l-1)$th round of the production process.

- The point is that the markup changes $(\frac{dM}{d\tau_1})$ accrue through the production network.

Implications

- Consider a simple Cournot-duopoly model, firm 1 and 2.
- In each sector, there is a sectoral aggregator ("demand function").
- The sector i's markup response takes the form of

$$\frac{d\mu_i}{d\tau_1} = \underbrace{\frac{\partial\mu_{i1}(\cdot)}{\partial q_{i1}}\frac{dq_{i1}}{d\tau_1} + \frac{\partial\mu_{i2}(\cdot)}{\partial q_{i2}}\frac{dq_{i2}}{d\tau_1}}_{\text{(a) change in markups with respect to own choices}} + \underbrace{\frac{\partial\mu_{i1}(\cdot)}{\partial q_{i2}}\frac{dq_{i2}}{d\tau_1} + \frac{\partial\mu_{i2}(\cdot)}{\partial q_{i1}}\frac{dq_{i1}}{d\tau_1}}_{\text{(b) change in markups with respect to competitors' choices}},$$

  where μ_{ik} is firm k's markup and q_{ik} is firm k's output quantity.
- Part (b) captures the strategic complementarities.

- $\Delta Y(\tau_1^0, \tau_1^1)$ involves (a) and (b), both of which accrue through the production network.

Identification

- The identification of $\Delta Y(\tau_1^0, \tau_1^1)$ is not straightforward.

- A widely used approach assumes that firms are negligible at the aggregate.
- Under this assumption, $\Delta Y(\tau_1^0, \tau_1^1)$ can be written in terms of sectoral variables.

- In my case, however, firms are not negligible!
- My idea is to recover the firm-level markups at the cost of additional assumptions.

Identification

(i) The sectoral aggregators take the form of a demand system that is homothetic with a single aggregator.
   - Strategic interaction comes only through this single aggregate.
   - This class includes Cobb-Douglas, CES, etc.

(ii) The firm-level production functions exhibit constant returns to scale with Hicks-neutral productivity.

(iii) Competitors' productivities enter the firm's equilibrium outcome only through a single aggregate.

- These assumptions are already satisfied in the commonly used specifications.
- Under these assumptions, firms' markup responses can be recovered by using the control function approach.

Summary of My Approach

Top Layer Deconstruct the object of interest:

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

Middle Layer Express the integrand in terms of firm-level variables:

$$\frac{d\mu_i}{d\tau_1} = \frac{\partial \mu_{i1}(\cdot)}{\partial q_{i1}} \frac{dq_{i1}}{d\tau_1} + \frac{\partial \mu_{i2}(\cdot)}{\partial q_{i2}} \frac{dq_{i2}}{d\tau_1} + \frac{\partial \mu_{i1}(\cdot)}{\partial q_{i2}} \frac{dq_{i2}}{d\tau_1} + \frac{\partial \mu_{i2}(\cdot)}{\partial q_{i1}} \frac{dq_{i1}}{d\tau_1},$$

Bottom Layer Under the three assumptions, $\frac{\partial \mu_{ik}(\cdot)}{\partial q_{ik'}}$ can be recovered.

Identification Reconstruct $\Delta Y(\tau_1^0, \tau_1^1)$ by tracing this procedure backward.

Estimation The bottom layer can be nonparametrically estimated. Again by tracing this backward, a nonparametric estimator for $\Delta Y(\tau_1^0, \tau_1^1)$ can be obtained.

Policy Scenario

- In 2022, the CHIPS and Science Act (CHIPS) was enacted.
- This includes \$24.25 billion of tax credit for the next 10 years.
  - roughly \$2.43 billion per year.

- I consider a policy scenario of increasing the subsidy on the semiconductor industry from the 2021 level of 14.94% to an alternative ratio of 16.00% — equivalent to \$0.56 billion.
- Subsidies on other sectors are fixed constant.

- Q. How much will $\Delta Y(14.94\%, 16.00\%)$ be?
- I calculate the estimates for both cases of oligopolistic and monopolistic competition.

Results

Table: The estimates of the object of interest

(billion U.S. dollars)	Monopolistic competition	Oligopolistic competition
$\widehat{\Delta Y}(14.94\%, 16.00\%)$	-0.71	-1.34

- The estimate for oligopolistic competition is almost twice as large in magnitude as that for oligopolistic competition.
- Accounting for strategic interactions is empirically important!

Conclusion

- The empirical treatment effects do not always answer macroeconomic policy questions.

- I propose a framework for evaluating industrial policies in the presence of strategic interactions and production networks.
- I show that in this setup, the production network compounds firms' markup responses not only with respect to their own choices but also with respect to competitors' choices.

- To identify firms' markup responses, I impose three assumptions on firms' demand and production functions.
- These assumptions are satisfied in the widely used specifications.

- I apply my framework to study a part of the Biden's subsidy on the semiconductor industry.
- Accounting for firms' strategic interactions nearly doubles the magnitude of the policy effect.

Contribution

- The literature has developed a trade model with production networks and a mass of infinitesimally small firms.
- The existing papers typically characterize policy effects in terms of a certain set of aggregate variables — aggregate sufficient statistics.

- My framework considers a finite number of firms.
- In my paper, policy effects are identified in terms of firm-level sufficient statistics.
- Idea: I am willing to impose assumptions to the extent that the commonly-used specifications are covered.

- The existing literature: "Micro to Macro"
- My paper: "Macro to Micro"

▸ Literature

Literature: Bird's Eye View

- Policy effects 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, Itskhoki and Vogler (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.
- Policy effects in a model of continuum of firms with a production network:
  - Liu (2019); Lashkaripour and Lugovskyy (2023), etc.

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

Literature

Setup

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

- $\Omega := [\omega_{i,j}]_{i,j}$ represents the production network.
- In this case,

$$GDP = VA_1 + VA_2 =: VA\ \iota,$$

where $VA := [VA_1\ \ VA_2]'$ and ι is a 2×1 vector of ones.

Aggregate Data

- **Aggregate data**: The U.S. Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA).
- The dataset provides the wage W, sectoral price index $\{P_i\}_{i=1}^N$ and input-output table Ω.

- The BEA input-output table contains 71 industries:
  - This is in line with the 3-digit NAICS (North American Industry Classification System).
- Following the literature, I segment the BEA industries into 38 industries.

- From this input-out table Ω, I can back out data on (net) subsidy $\boldsymbol{\tau}^0$.

Segmentation Subsidy

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

- f_i is only assumed to be neoclassical (i.e., increasing, concave, Inada condition, constant returns to scale).

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

Firms

Sectoral Aggregators / "Demand Functions"

- In each sector, the sectoral aggregator's cost minimization yields the demand function for individual firms.

- **Assumption 1**: The inverse demand function can be parametrized to exhibit a homothetic demand system with a single aggregator (HSA): i.e.,

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

  where Φ_i: the sectoral aggregator's expenditure, $\Psi_{ik}(\cdot)$: the share of firm k's good in Φ_i, $A_i(\cdot)$: some function of all firms' quantities, and $\mathcal{I}_i$: the information set.

- 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

Object of Interest

- Let Y be the (nominal) gross domestic product (GDP).
- Income accounting identity:

$$Y = \underbrace{WL}_{\text{labor income}} + \underbrace{\Pi}_{\text{total profit}} - \underbrace{\sum_{i=1}^{N} \tau_i \sum_{k=1}^{N_i} M_{ik}}_{\text{policy expenditure}} = \sum_{i=1}^{N} \underbrace{\sum_{k=1}^{N_i} \left(W\ell_{ik} + \pi_{ik} - \tau_i M_{ik} \right)}_{=:Y_i(\boldsymbol{\tau})},$$

where $W\ell_{ik}$: labor income from firm k, π_{ik}: firm k's profit, and M_{ik}: firm k's expenditure on intermediate goods.

- The object of interest: *the change in Y when the vector of current policy regime $\boldsymbol{\tau}^0$ is shifted to an alternative one $\boldsymbol{\tau}^1$*, i.e.,

$$\sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^1) - \sum_{i=1}^{N} Y_i(\boldsymbol{\tau}^0).$$

Firm-level Data

- **Firm-level data**: Compustat data.
- This data contains a detailed financial accounting data.
- 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.
- Under our setup, I can recover firm-level labor input ℓ_{ik}, material input m_{ik} and input demand for sectoral goods $\{m_{ik,j}\}$.
  - I can in turn recover firm-level expenditure on sectoral goods M_{ik}.

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

Identification Strategy

- The object of interest:

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

$$\text{where} \qquad \frac{dY_i(s)}{ds} = \sum_{k=1}^{N_i} \left\{ \frac{d(W\ell_{ik})}{ds} + \frac{d\pi_{ik}}{ds} - \tau_i \frac{dM_{ik}}{ds} \right\}.$$

- If the firms are infinitesimally small, firm-level idiosyncrasies diminish in the aggregate.
- $\frac{dY_i(s)}{ds}$ = some aggregate outcome (observable or estimable).
- But, when firms are finite in number, as in my model, firm-level idiosyncrasies are not washed away even in the aggregate.
- My approach is to recover each of the firm-level components.

Big Picture

- The identification argument consists of two layers.
- Outer layer identifies the total derivatives, given inner layer.
- Inner layer identifies the partial derivatives and firm-level quantity and price.

$$\frac{dq_{ik}}{d\tau_n} = A_{ik} \begin{bmatrix} \frac{dW}{d\tau_n} \\ \frac{dP_i^M}{d\tau_n} \end{bmatrix}, \qquad \begin{bmatrix} \frac{d\ell_{ik}}{d\tau_n} \\ \frac{dm_{ik}}{d\tau_n} \end{bmatrix} = B_{ik} \begin{bmatrix} \frac{dW}{d\tau_n} \\ \frac{dP_i^M}{d\tau_n} \end{bmatrix}, \qquad \frac{dP_i}{d\tau_n} = C_i \begin{bmatrix} \frac{dW}{d\tau_n} \\ \frac{dP_i^M}{d\tau_n} \end{bmatrix}$$

$$\frac{dP_i^M}{d\tau_n} = \underbrace{D_{i,n} \frac{P_n^M}{1-\tau_n}}_{\text{network spillover effect}} + \underbrace{E \frac{dW}{d\tau_n}}_{\text{general equilibrium effect}}$$

where P_i^M: sector i's cost index for sectoral intermediate goods.

- A_{ik}, B_{ik}, C_i are matrices, and $D_{i,n}$, E are scalars:
  - These terms consist of 1) partial derivatives and 2) firm-level quantity and price, as well as 3) other observables.

Control Function Approach: Idea

- For the inner layer, I apply the control function approach of the industrial organization literature.
- Idea is to model the unobservable productivity in terms of observables.

- The literature considers perfectly or monopolistically competitive markets.
- The control function is given by $z_{ik} = \mathcal{M}_i(\ell_{ik}, m_{ik})$.

- In my case, strategic interactions take place over output and input quantities:
  - Firm's decision: $q_{ik} \to (\ell_{ik}, m_{ik})$.
- The control function will look like $z_{ik} = \mathcal{M}_{ik}(\{\ell_{ik'}, m_{ik'}\}_{k'=1}^{N_i}; \mathcal{I}_i)$.
- Idea: I restrict the way in which other firms' choices affect the firm's own decision.

Control Function Approach: Assumption

- **Assumption 2**: For each sector i, there exist some functions $H_i(\cdot)$ and $\chi_i(\cdot)$ such that (i) $q^*_{ik} = \chi_i(z_{ik}, H_i(\{z_{ik'}\}_{k'=1}^{N_i}); \mathcal{I}_i)$ and (ii) $\frac{\partial \chi_i(z_{ik}, \cdot)}{\partial z_{ik}} \neq 1$, for all k.

- Under this assumption, there exist some functions $\mathcal{H}_i$ and $\mathcal{M}_i$ such that $z_{ik} = \mathcal{M}_i(\ell_{ik}, m_{ik}, \mathcal{H}_i(\{z_{ik'}\}_{k'=1}^{N_i}); \mathcal{I}_i)$ for all firm k.
- The results of the existing literature can be applied.

- Key: The firms' productivities are encapsulated in $H_i(\cdot)$ and $\mathcal{H}_i(\cdot)$.
  - Recall: Under the HSA demand function, strategic interactions are encapsulated in $A_i(\{q_{ik'}\}_{k'=1}^{N_i})$.

Example: Duopoly

- The CES sectoral aggregator and Cobb-Douglass firm-level production function:
- The Cournot-Nash equilibrium quantity for firm $k \in \{1, 2\}$:

$$q^*_{ik} = R_i \underbrace{\frac{\delta_{i1}\delta_{i2} mc_i(z_{i1})^{\frac{1-\sigma}{\sigma}} mc_i(z_{i2})^{\frac{1-\sigma}{\sigma}}}{\left(\delta_{i1} mc_i(z_{i1})^{\frac{1-\sigma}{\sigma}} + \delta_{i2} mc_i(z_{i2})^{\frac{1-\sigma}{\sigma}}\right)^{\frac{\sigma^2-\sigma+2}{\sigma}}}}_{=:H_i(\mathbf{z}_i)} z^{\sigma}_{ik} = \chi_i(z_{ik}, H_i(\mathbf{z}_i); \mathcal{I}_i),$$

where $mc_i(z_{ik})$: firm k's marginal cost, δ_{ik}: demand shifter for firm k, R_i: a constant specific to sector i.

- Input decision is constrained by the following production possibility frontier:

$$z_{ik}\ell_{ik}^{\alpha_i} m_{ik}^{1-\alpha_i} = q^*_{ik} = R_i \mathcal{H}_i(\mathbf{z}_i) z^{\sigma}_{ik}$$

$$\therefore z_{ik} = \{R_i H_i(\mathbf{z}_i)\ell_{ik}^{-\alpha_i} m_{ik}^{-(1-\alpha_i)}\}^{\frac{1}{1-\sigma}} = \mathcal{M}_i(\ell_{ik}, m_{ik}, \mathcal{H}_i(\mathbf{z}_i); \mathcal{I}_i),$$

unless $\sigma = 1$.

Main Results

1. I show that under Assumptions 1 and 2, firm-level quantity q_{ik}, price p_{ik} and partial derivatives of the firm-level production function can be recovered.
   $\longrightarrow$ Inner layer problem is solved.

2. This in turn identifies the responses of all firm-level variables and aggregate variables.
   $\longrightarrow$ Outer layer problem is solved.

3. Repeating these, we can identify $\left.\frac{dY_i(s)}{ds}\right|_{s=\boldsymbol{\tau}}$ for all $\boldsymbol{\tau} \in [\boldsymbol{\tau}^0, \boldsymbol{\tau}^1]$.

4. Integration recovers the object of interest as:

$$\underbrace{Y(\boldsymbol{\tau}^1) - Y(\boldsymbol{\tau}^0)}_{\text{object of interest}} = \sum_{i=1}^{N} \int_{\boldsymbol{\tau}^0}^{\boldsymbol{\tau}^1} \frac{dY_i(s)}{ds} ds.$$

Scenario: Biden's Subsidy

- I consider the recent policy by the Biden's administration:
  - In 2022, the CHIPS and Science Act (CHIPS) was passed.
  - Since then, a nearly $53 billion investment has been made in U.S. semiconductor manufacturing, research and development, and workforce.
- I view this as an additional subsidy targeted at semiconductor industry.
- Only subsidy on semiconductor industry (n) is increased: $\tau_n \to \tau_n + d\tau_n$.

Setup: The Object of Interest

- I revisit Liu (2019), who study the policy effect on GDP net of firms profits, $\Upsilon := Y - \Pi$:

$$\Upsilon \quad = \quad WL - \sum_{i}^{N} \tau_i M_i \quad =: \quad \Upsilon(\boldsymbol{\tau}).$$

- Using data on cross section of year 2021, I compute:

$$\left.\frac{d\Upsilon(s)}{ds}\right|_{s=\boldsymbol{\tau}} = \underbrace{\sum_{i=1}^{N}\sum_{k=1}^{N_i} \left.\frac{d(W\ell_{ik})}{ds}\right|_{s=\boldsymbol{\tau}}}_{\text{labor income}} - \underbrace{\sum_{k=1}^{N_n} M_{nk}}_{\text{policy expenditure}} - \underbrace{\sum_{i=1}^{N} \tau_i \sum_{k=1}^{N_i} \left.\frac{dM_{ik}}{ds}\right|_{s=\boldsymbol{\tau}}}_{\text{input reallocations}}$$

- He considers a model of continuum of monopolistic firms with a production network.
- He characterizes $\left.\frac{d \ln \Upsilon_i(s)}{ds}\right|_{s=0}$, relying on i) aggregation, and ii) $\boldsymbol{\tau} = \mathbf{0}$.

Results: Marginal Change in Υ and Its Breakdown

- Three specifications are examined:

  (1) Liu's model: aggregation & $\boldsymbol{\tau} = \mathbf{0}$

  (2) My model A: $\boldsymbol{\tau} = \mathbf{0}$

  (3) My model B: $\boldsymbol{\tau} = \boldsymbol{\tau}^0 \neq \mathbf{0}$ cf) subsidy for semiconductor industry: 14.94%.

			labor income		policy expenditure		input reallocations
	$\frac{d \ln \Upsilon(s)}{ds}$	$=$	$\frac{1}{\Upsilon}\frac{d(WL)}{ds}$	$-$	$\frac{1}{\Upsilon}\sum_{k=1}^{N_n} M_{nk}$	$-$	$\frac{1}{\Upsilon}\sum_{i=1}^{N} \tau_i \sum_{k=1}^{N_i} \frac{dM_{ik}}{ds}$
Liu's model	-0.0388		—		—		0
My model A	-0.3034		≈ 0		0.3030		0
My model B	-0.8369		≈ 0		0.7234		0.1135

▸ $\tau = 0$

Conclusion

- This paper considers counterfactual policy evaluations for models of production networks and oligopolistic competitions between a finite number of firms.
- The existing method of aggregation is not valid because firm-level idiosyncrasies are not washed away.
- I show that under a certain set of standard conditions, firm-level responses to an industrial policy can be recovered.
  - Macro to Micro! (not Micro to Macro)
- My paper, moreover, studies the comovements of sectoral variables.
  - Macro & micro complementarities
- A future work will be recovering the object of interest $Y(\boldsymbol{\tau}^1) - Y(\boldsymbol{\tau}^0)$.
- Also, i) multiple equilibria and ii) extrapolation will be studied.

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Literature

- Lane (2021); Juhász, Lane, Oehlsen and Pérez (2022); Juhász and Steinwender (2023), and references therein.

back

Literature

- Concentration in terms of sales share:
  - Head and Spencer (2017): In the U.S. 2012 data, there are 76 industries (out of 364) where the top four firms account for 60%+ of sales.
  - Autor, Dorn, Katz, Patterson and Van Reenen (2017, 2020): In the U.S. data, there has been a remarkable upward trend in concentration in each sector for the past few decades.
  - Gaubert and Itskhoki (2020): In French data, he largest firm in a typical manufacturing industry has a market share of 20%.
  - Freund and Pierola (2015): Among 32 countries, the top five firms make up 30% of a country's export.
  - Covarrubias, Gutiérrez and Philippon (2020); Gutiérrez and Philippon (2017); Grullon, Larkin and Michaely (2019), etc.
- Production networks:
  - Carvalho (2010); Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012): Microeconomic idiosyncratic productivity shocks accrue through intersectoral input-output linkages, and may lead to sizable aggregate fluctuations. Network topology matters.

back

Literature

- Oligopolistic competition & Production networks:
  - A change in competition intensity affects i) marginal costs of downstream sectors, and ii) sector's profit share of an upstream sector, which in turn changes the sector's demand for input.
  - The sign of this upstream propagation mechanism is determined by the interaction b/w oligopolistic competition (i.e., incomplete pass-through) and an I-O network.

back

Literature

- Oligopolistic competition:
  - Positive: Atkeson and Burstein (2008); Amiti, Itskhoki and Konings (2019); Gaubert and Itskhoki (2020); Wang and Werning (2022)
  - Normative: Gaubert et al. (2021)
- Production network:
  - Positive: Baqaee and Farhi (2020, 2022); Bigio and La'O (2020)
  - Normative: Liu (2019); Lashkaripour and Lugovskyy (2023)
- Oligopolistic competition & Production network:
  - Positive: Grassi (2017); Grassi and Sauvagnat (2019)
  - Normative: Sugiura (2023)?

back

Literature

- Oligopolistic competition:
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  - Positive: Grassi (2017); Grassi and Sauvagnat (2019)
  - Normative: Sugiura (2023)?

back

Consumer

- The household provides labor L inelastically and consumes a final consumption good C, which is a basket of sectoral intermediate goods.
- The household derives its utility only form consumption.
  - There exists a one-to-one mapping between utility level and consumption of the final good.
  - Monotone, concave, Inada condition, etc.
- The household chooses the utility-maximizing quantity of the final consumption good subject to the binding budget constraint:

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

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

- We let the price index of the final consumption good be the numeraire.

back

Government

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

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

where G represents the government purchase of the final consumption good, S_i denotes the policy expenditure in sector i, and T a lump-sum transfer from the representative consumer

back

Firms

- (Step 1) Output quantity decision:

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

- (Step 2) Input quantity decision:

$$\{\ell_{ik}^*, m_{ik}^*\} \quad \in \quad \arg\min_{\ell_{ik}, m_{ik}} \quad W\ell_{ik} + P_i^M m_{ik} \qquad s.t. \quad z_{ik} f_i(\ell_{ik}, m_{ik}) \geq q_{ik}^*,$$

where W denotes the wage and P_i^M is the cost index for material input.

- (Step 3) Sectoral intermediate goods:

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

back

Example: Constant Elasticity of Substitution (CES) Aggregator

- The CES aggregator in sector i:

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

where σ: 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:

$$p_{ik} = \frac{\delta_{ik} q_{ik}^{-\frac{1}{\sigma}}}{\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma}}} \Phi_i = \frac{\Phi_i}{q_{ik}} \delta_{ik} \left\{ \frac{q_{ik}}{(\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma}})^{\frac{\sigma_i}{\sigma-1}}} \right\}^{\frac{\sigma-1}{\sigma}},$$

where $A_i(\{q_{ik'}\}_{k'=1}^{N_i}) := (\sum_{k'=1}^{N_i} \delta_{ik'} q_{ik'}^{-\frac{1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$ and $\Psi_{ik}(x; \mathcal{I}_i) := \delta_{ik} x^{\frac{\sigma-1}{\sigma}}$.

back

Market Clearing

- Final Consumption Good:

$$Y = C + G$$

- Combining this with the household's and government's budget constraints:

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

- Sectoral intermediate goods:

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

- Labor:

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

Value-Added Tax/Subsidy

- Gutiérrez and Philippon (2017); Baqaee and Farhi (2020); Bigio and La'O (2020), etc.

back

Value-Added Tax/Subsidy

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

		Industries																Final uses (GDP)							
		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)	Total commodity
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

Value-Added Tax/Subsidy

- In data,

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

$$\therefore \underbrace{Revenue_i - MaterialCost_i}_{\text{Value-added}} = \underbrace{Profits_i}_{\text{Gross operating profits}} + \underbrace{LaborCost_i}_{\text{Compensation of employees}} - \underbrace{(TaxSubsidy1_i - TaxSubsidy2_i)}_{\text{Value-added taxes less subsidies}}.$$

- In my model,

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

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

back

Literature

- Unobservable firm-level prices and quantities:
  - I follow Kasahara and Sugita (2020).
  - Idea: express the firm-level revenue in two ways.

(i) estimate the revenue function in terms of labor and material

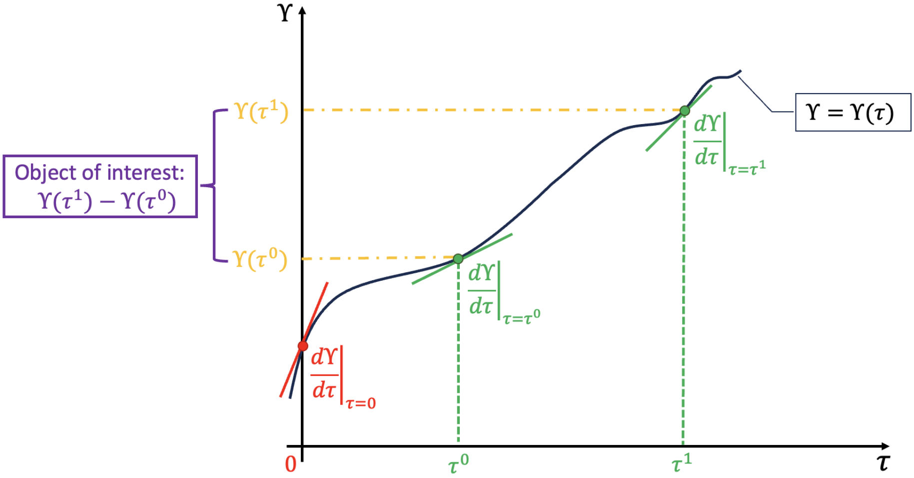
(ii) consider the revenue as a function quantity.

(iii) connect (i) and (ii) to identify the firm-level quantity.

- Unobservable firm-level productivities.
  - I follow Olley and Pakes (1996); Levinsohn and Petrin (2003); Ackerberg, Caves and Frazer (2015); Gandhi, Navarro and Rivers (2019).
  - I also follow the approach of De Loecker and Warzynski (2012); De Loecker, Goldberg, Khandelwal and Pavcnik (2016); De Loecker, Eeckhout and Unger (2020)
  - These methods only consider the case of monopolistic competition (Doraszelski and Jaumandreu 2019, 2021)
  - The scaler unobservability assumption is a type of an exclusion restriction.

back

Hypothetical Example of Υ as a Function of Subsidy



back

Recovering Markups

- Three assumptions on firm's production:
  1. The production function exhibits constant returns to scale.
  2. Inputs (both labor and material) are flexible.
  3. Input markets are perfectly competitive.
- Under these assumptions, the firm-level markup μ_{ik} is obtained by

$$\mu_{ik} = \frac{Revenue_{ik}}{TotalVariableCost_{ik}},$$

- e.g., Baqaee and Farhi (2020); De Loecker et al. (2020); Kasahara and Sugita (2020)

back

Recovering m_{ik}, $m_{ik,j}$ & $\gamma_{i,j}$

- From the revenue-based input-output linkages:

$$\omega_{i,j} = \frac{\sum_{k=1}^{N_i}(1-\tau_{i,j})P_j m_{ik,j}}{\sum_{k=1}^{N_i} p_{ik} q_{ik}}.$$

  - We can recover $\sum_{k=1}^{N_i} m_{ik,j}$.

- From the cost-based input-output linkages:

$$\tilde{\omega}_{i,j} = \frac{\sum_{k=1}^{N_i}(1-\tau_{i,j})P_j m_{ik,j}}{\sum_{k=1}^{N_i}\left\{\sum_{n'=1}^{N}(1-\tau_{ik,n'})P_{n'} m_{ik,n'} + (1-\tau_{i,L})W\ell_{ik}\right\}}$$

  - We can recover $\gamma_{i,j}$, P_i^M and $m_{ik,j}$.

- From the cost minimization:

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

  - We can recover $m_{ik,j}$.

back