Multinational Production and Innovation in Tandem

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The Age of Large-Scale Manufacturing Offshoring & Onshoring

- 1995 $\rightarrow$ 2010, goods supplied by foreign affiliates of U.S. escalated, \$1.45T $\rightarrow$ \$4T ‣ Trend1
- Foreign R&D expenditure of U.S. firms also increased rapidly, \$12.6B $\rightarrow$ \$40B ‣ Trend2
- In recent years, U.S. government made policies to reshore manufacturing

  Tax Cuts and Jobs Act, CHIPS and Science Act, Made in America Tax Plan ‣ Details

The Age of Large-Scale Manufacturing Offshoring & Onshoring

LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE
May 5th, 2018

When multinationals offshore production, where do they locate innovation?

Helena Vieira
July 10th, 2017

When companies stop offshoring, they may end up dying

Why Reshoring U.S. Manufacturing Could Be The Wave Of The Future Forbes

Nick Stonnington Forbes Councils Member
Forbes Business Council
COUNCIL POST | Membership (Fee-Based)

Sep 9, 2020, 04:00pm EDT

- 1995 $\rightarrow$ 2010, goods supplied by foreign affiliates of U.S. escalated, \$1.45T $\rightarrow$ \$4T ▸ Trend1
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IDE-JETRO Institute of Developing Economies, JETRO
September 2022

How Will the US-China Trade War Affect Asian Economies?

EPSNews News For Electronics Purchasing And The Supply Chain
December 14, 2013

Key to Innovation? Onshoring Manufacturing of Course

ArcStone

Offshoring vs Reshoring: The Great Debate

April 2012

Innovation Should Be Made in the U.S.A. THE WALL STREET JOURNAL.

Offshoring by American companies has destroyed our manufacturing base and our capacity to develop new products and processes. It's time for a national industrial policy.

Nov. 15, 2019 11:06 am ET

Research Questions

- When multinational firms relocate production, what happens to their innovation?
  - Do firms *colocate* them by moving innovation to where production goes, or choose high-return innovation locations independently from production?
  - Are firms' offshoring choices in different countries *correlated*?
- How do reshoring policies affect the global allocation of innovation?

  Employment, social benefits and local spillovers of R&D
  - When U.S. reshores production, can it also bring innovation back?
  - Does R&D stay in the host country, return to the U.S. , or flow to third-party countries?
  - Do bilateral trade policies have third-country effects?

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  - Do bilateral trade policies have third-country effects?
- **Two missing inputs**: colocation benefits + interdependencies

Factors Affecting Firms' Colocation Choice

- Forces pushing for colocation of production and innovation

  1. Synergy: direct interactions reduce communication and coordination costs, spur new ideas, speed up new product commercialization $\rightarrow$ innovation efficiency $\uparrow$

     E.g. Elon Musk's Gigafactories; product designers in biotech; Texas Instruments in Singapore

  2. Cost sharing: having local production reduces fixed cost of innovation

     E.g. share overhead expenses like rent, management, professional services

> At both Tesla and SpaceX, Musk put the design engineers in charge of production. . . . The 75 design engineers then moved their desks next to the assembly lines to reinforce the idea that product design and manufacturing must work hand-in-hand.
>
> — Elon Musk Ensures That Product Development Is Not Siloed
> Forbes, Oct 2023

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- Forces pushing for separation of production and innovation

  3 Countries's comparative advantages in production costs and returns to innovation

     E.g. FGPFs, Bernard & Fort (2015); Apple (US-CN), Dyson (UK-MY), Qualcomm (US-TW-KOR)

- **First input:** $\exists$ colocation benefits? How large are they?

  Separately quantify synergy and cost sharing mechanisms

More on Texas Instruments

Offshoring Choices Are Correlated Across Countries

- Quantifying within-country colocation benefits isn't enough
  - Firm activities move not only between home and host, but also to third-party countries
  - Regional complementarities: regional R&D centers, shared management & legal service ▸ More

Table 1.11. Diversification of production from China to ASEAN because of United States–China trade tensions and other reasons, 2019 and 2020 (Selected cases)

Company	Nationality	Industry/activity	Host country	Year	Remarks
Alpan Lighting	United States	Industrial products	Indonesia	2020	Shifting production from China to escape higher tariffs triggered by trade tensions
Dell	United States	Personal computer	Viet Nam	2019	Considered moving up to 30 per cent of production
Delta Electronics	Taiwan Province of China	Electronic components	Thailand	2019	Supplier to Microsoft and Huawei Technologies; moved some production back to home economy and some to Thailand amid the trade tensions
Ever Win International	United States	Electronic components	Philippines	2019	Opened a manufacturing facility in Laguna Technology Park to assist customers with transitioning production outside of China
Foxconn	Taiwan Province of China	Electronic components	Viet Nam	2020	Major supplier of Apple; moved manufacturing of some iPads and Macbooks from China to mitigate the risk of the trade tensions
Harley Davidson	United States	Automotive	Thailand	2019	Finalized location in Thailand

Due to US-China trade tension, MNEs relocate activities to Altasia

Source: ASEAN Investment Report 2020-2021

Offshoring Choices Are Correlated Across Countries

- Quantifying within-country colocation benefits isn't enough
  - Firm activities move not only between home and host, but also to third-party countries
  - Regional complementarities: regional R&D centers, shared management & legal service ▸ More
- Many previous studies simplify models by assuming independent choices across countries
  - Bilateral policies do not have flexible third-country effects
- **Second input:** cross-country interdependencies
  - Regional: overhead cost sharing [+]
  - Global: input substitutability [−], scale effect [+]

Causal Evidence For These Two Ingredients

- Plausibly exogenous variation in tariffs are used for identification
  - Based on firm import bundles (instrument) and trade policy shocks (event study)
  - Shift offshore production without directly affecting offshore innovation
- Findings: $\uparrow$ tariff $\rightarrow$ $\downarrow$ production & innovation
  - In the host country $\Rightarrow$ within-country colocation
  - In other countries of the region $\Rightarrow$ cross-country interdependence, positive

Empirical Model

- Goal: develop a quantitative framework that can evaluate trade policies, taking into account various mechanisms of colocation benefits and cross-country interdependencies
- Featuring: a dynamic knowledge production process + countries' comparative advantages
- Challenge: interdependence creates an NP-hard problem, even harder with dynamics
  large action and state spaces due to 2^N combinations of countries
  ▸ Lit Forefront
- Step 1: sign interdependencies + prove conditions for supermodularity
- Step 2: adapt a cutting-edge algorithm from Alfaro-Ureña et al. (2023)

Empirical Model Findings

- Estimation Results
  - Compared to offshoring only R&D to a host country, offshoring both production and R&D results in a 0.06% (0.2%) larger increase in firm productivity
- Counterfactuals to evaluate trade policies
  - Limited reshoring of innovation
  - Third-country effects: 11% increase in U.S. import tariff for China
    - Prob. production $\downarrow$ 9.4 p.p. (20%) in China, $\downarrow$ 0.8 p.p. (5.5%) in ROW
    - Prob. innovation $\downarrow$ 0.11 p.p. (9.4%) in China, $\downarrow$ 0.2 p.p. (10%) in ROW
  - Nonlinear effects on innovation shares, contingent on firm heterogeneity
    - Moderate shocks: $\uparrow$ China, $\downarrow$ ROW, $\uparrow$ US
    - Large shocks: $\downarrow$ China, $\uparrow$ ROW, $\uparrow$ US
  - Dynamic effects: negative trade shock $\rightarrow$ productivity loss accumulates over time

Related Work

1. **Empirical colocation of production and innovation**
   - ▷ Tecu (2013); Lan (2019); Delgado (2020); Fort et al. (2020); Branstetter et al. (2021)
   - ▷ Contribution: non-localized colocation + cross-location complementarities + causal evidence + quantifying mechanisms
2. **Models on multinational production, sourcing, and innovation**
   - ▷ Bøler et al. (2015); Antras et al. (2017); Arkolakis et al. (2018); Bilir & Morales (2020)
   - ▷ Contribution: direct synergy effect + solve dynamic location choices
3. **Interdependent discrete choices**
   - ▷ Lattice theory: Jia (2008); Arkolakis et al. (2021); Alfaro-Ureña et al. (2023)
   - ▷ Contribution: rich complementarities + conditions for supermodularity + dynamic algorithm
4. **R&D and firm performance**
   - ▷ Aw et al. (2011); Doraszelski & Jaumandreu (2013); Fan et al. (2022)
   - ▷ Contribution: multicountry innovation + direct interaction of production and innovation

Data and Descriptive Patterns

Data Sources

Administrative records from the U.S. Census Bureau spanning from 2008 to 2019

1. Business R&D Surveys (representative of for-profit, nonfarm firms) ▸ Form
   - ▷ A previously unused module: firm-level R&D expenses by foreign country ▸ Measure
2. Longitudinal Firm Trade Transactions Database (transactions at customs)
   - ▷ Firm ID, product code, partner country, value, quantity, duties, related parties/arm's length
3. Census of Manufacturing and Annual Survey of Manufactures
   - ▷ Location, employment, shipments, materials, energy use

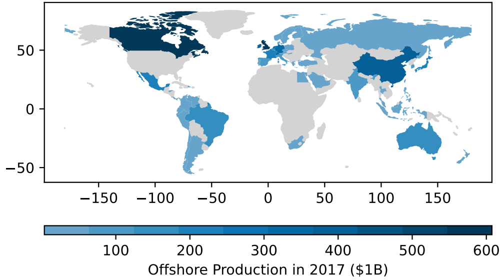
Data caveats

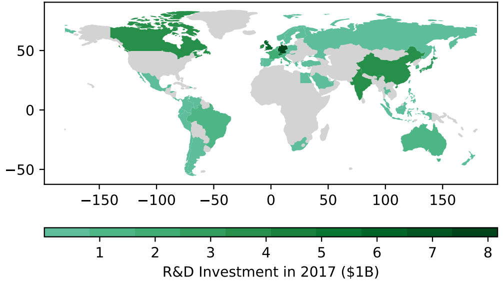
- Use imports to proxy for offshored production ▸ Accuracy
- Capture both production offshored to affiliates and outsourced to foreign firms

Descriptives of The Sample

1. Unbalanced panel, but large firms are surveyed nearly every year ‣ Survey Freq
2. For R&D firms, offshore R&D $\sim$ 23% of total firm-wide R&D ‣ Sum Stats
3. Multi-location firms account for the majority of offshored activities
   - Firms with $>$ 10 (1) R&D locations $\sim$ 71% (2.4%) of offshore R&D ‣ R&D Locations
   - Firms importing from $>$ 10 (1) country $\sim$ 95% (0.1%) of total import value ‣ Import Origins
4. 94% of foreign R&D is done in countries where the firm has imports ‣ Offshoring Modes

Colocation at the Country Level





- Similar geographical distributions of offshore production and innovation.

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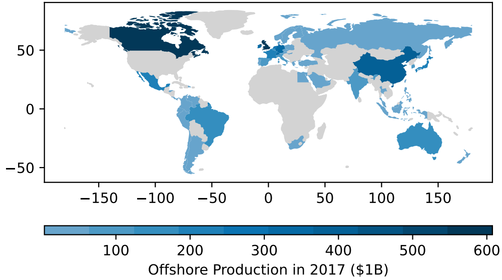
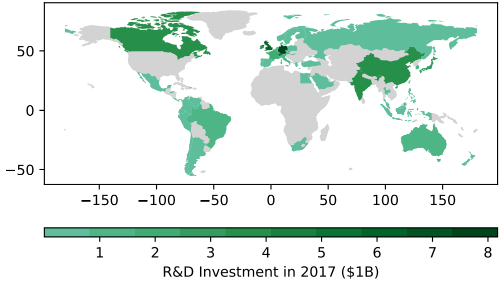
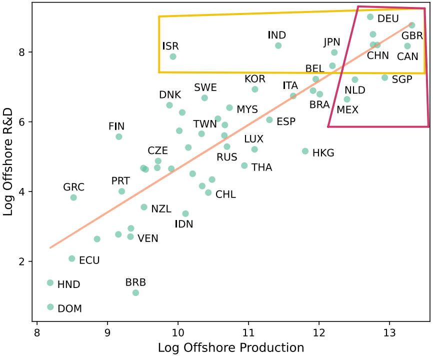




- Similar geographical distributions of offshore production and innovation.
- Big destinations of offshore R&D are big destinations of offshore production.



- Countries have comparative advantages.

Causal Evidence

- Facts may be confounded by correlated country characteristics
- Target: causal impact of offshore production on offshore innovation
- Endogeneity arises from affiliate unobservables, e.g. better manager; R&D subsidy policy
- Strategy 1: Explore Trump Tariffs that affect production w/o directly affecting innovation
- Strategy 2: Instrument offshore production with firm-country-specific tariff rates

The Trump Tariffs Policy

- A series of tariff increases on specific goods & countries in 2018, 2019
  - ∼ To reduce US trade deficit
  - ∼ Tariff increases from 2.6% to 16.6% on a total of 12,043 goods
  - ∼ Cover $303B (12.7%) of US annual imports (Fajgelbaum et al., 2020)
- Major waves and products involved
  - ∼ Jan 2018, 30% to 50% on solar panels and washing machines
  - ∼ Mar 2018, 25% on steel and 10% on aluminum from many countries
  - ∼ Jun 2018, steel and aluminum tariffs extended to EU, CAN, Mex
  - ∼ Separate tariffs on Chinese goods
- 116 countries involved: 25.6K tariff lines for China, 19.3K for other countries

Treatment and Control Groups

- Define treated units
  1. Identify product-country pairs targeted during the Trump Tariffs
     $\sim$ Compiled by Fajgelbaum et al. (2020) based on USITC documents
  2. Identify goods that firm i had imported from country l
     $\sim$ During a five-year period prior to the Trump Tariffs
  3. $\text{Treat}_{il} = 1$ if any good the firm had imported was affected
     $\text{Treat}_{il} = 0$ if none of the firm's goods was affected
- Study sample: i-l pairs for which $\text{Imp}_{il} > 0$ in the prior period

Specification and Identification Assumption

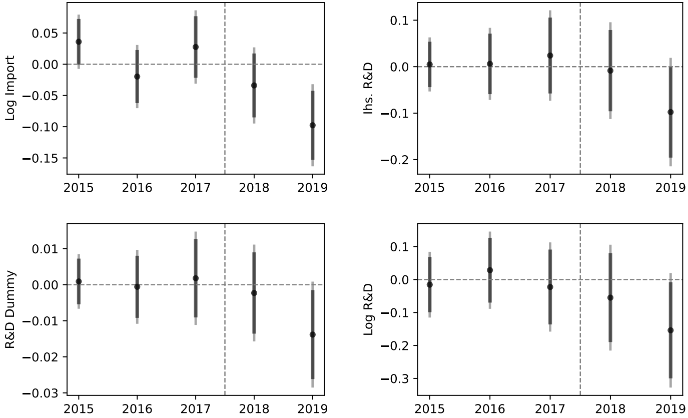
$$y_{ilt} = \sum_{t=2014:2019} \beta_t \cdot \text{Treat}_{il} \cdot \text{Year}_t + \gamma_{il} + \gamma_{lt} + z_{it} + \varepsilon_{ilt}$$

- Variation: affiliates of two US multinationals in the same host country
- Identification argument: random tariff shocks, based on firm's ex-ante import product mix, are orthogonal to affiliate-year specific shocks that affect *changes* in innovation

$$\text{Treat}_{il} = \left(\sum_{p} \mathbb{1}_{ipt} \cdot \text{Trump}_{pt} \right) > 0, \qquad \text{Treat}_{il} \perp \varepsilon_{ilt} \mid \gamma_{il}, \gamma_{lt}, z_{it}$$

▸ Section 301 Investigations

Event Study Results



- Treated units have 9.8% less imports, 1.4 p.p. lower likelihood of offshoring R&D, and 15.4% less R&D expenditure conditioning on innovating.
- Robust to excluding China/semiconductor and using only related-party imports.

▸ DID regressions ▸ Alternative treatment measures and robustness

Alternative Identification Strategy + More Results

- Second strategy: a shift-share style, firm-country-specific tariff rate as IV ‣ Construction
  - Less restrictive sample size
  - A specification with richer variations and firm-year fixed effects ‣ Specification
  - Potential identification concerns ‣ Discussion
- Result: Higher tariffs $\rightarrow$ less imports and less R&D within the host country ‣ Regressions
- Evidence for interdependence: Higher tariffs in other countries of the same region $\rightarrow$ less imports and less R&D within the host country ‣ Results
- Suggestive evidence for rich industry heterogeneity in colocation ‣ Figure
- Suggestive evidence for production offshoring vs outsourcing ‣ Table

Model

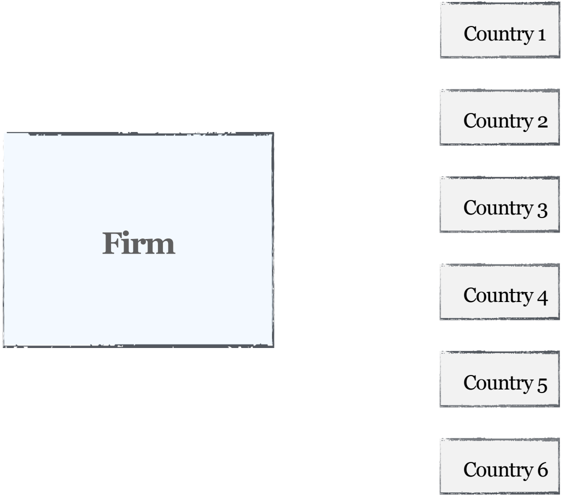
- Result 1: Offshore production positively affects offshore innovation in the host country.
  - Model Feature: Colocation benefits
  - Mechanisms: Synergy & Cost sharing

Separate Identification

- Result 2: Production in neighbor countries positively affects innovation in the host country.
  - Model Feature: Cross-country interdependence
  - Mechanisms: Input substitution & Cost sharing & Scale effect

- Purpose: quantify mechanisms + evaluate counterfactual policies.

Preview of Model



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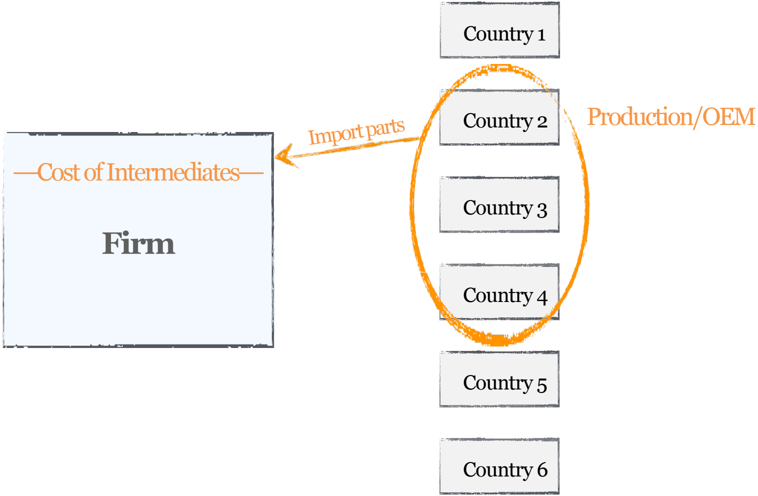

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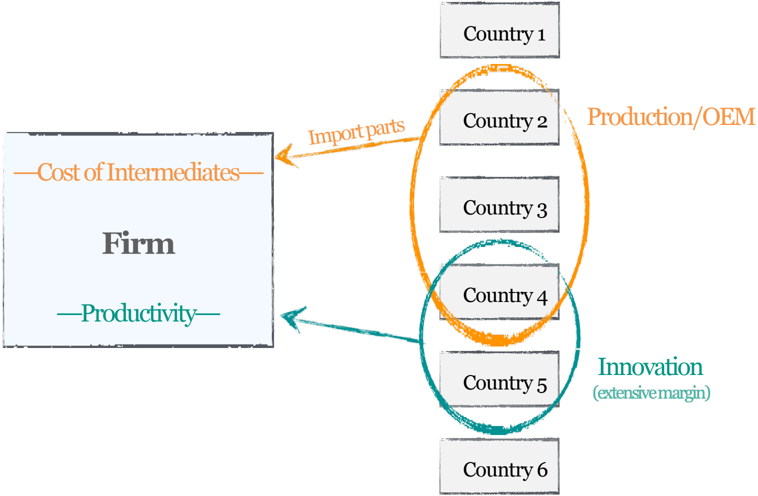

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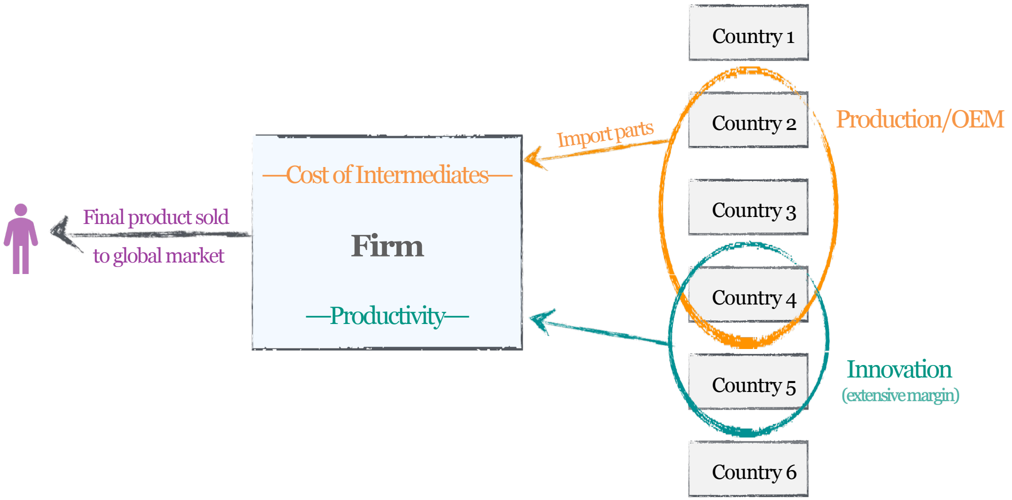


Demand and Marginal Cost

Denote each firm i, industry j, location l, and time period t.

Assume monopolistic competition structure where firm i's demand is

$$q_{it} = Q_{jt} \left(\frac{p_{it}}{P_{jt}} \right)^{\eta} = \Phi_{jt}(p_{it})^{\eta}.$$

Assume constant unit production cost that depends on cost shifters,

$$\ln c_{it} = \beta_0 + \beta_k \ln k_{it} + \beta_w \ln w_{jt} + \underbrace{\beta_m \ln p_{it}^m}_{\text{Intermediate Price}} - \omega_{it}.$$

Berry et al. (1995), Aw et al. (2011), Roberts et al. (2018), Piveteau (2021)

Foreign Production

- Intermediates from different locations are aggregated via CES,

$$m_{it} = \left(\sum_{l \in \mathcal{L}} m_{ilt}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}.$$

ρ elasticity of substitution between inputs from different countries.

- Unit cost of imported goods depends on local wage level, shipping cost, and tariff: $p_{m,ilt} = w_{lt}\tau_{lt}t_{lt}$.
- Price index of the aggregated intermediates depends on the set of production locations and the unit cost of product at each location.

$$p_{it}^{m} = \left(\underbrace{\sum_{l \in \mathcal{L}} y_{ilt} \overbrace{(w_{lt}\tau_{lt}t_{lt})^{1-\rho}}^{\theta_{lt}}}_{\Theta_{it}} \right)^{\frac{1}{1-\rho}}$$

$\theta_{lt} \equiv$ country l's production-offshoring potential; $\Theta_{it} \equiv$ firm i's production-offshoring capability.

R&D and Productivity Evolution

Firm productivity follows a Markov process that depends on past productivity, a random shock, and offshoring choices at all locations.

$$\omega_{it} = \alpha_0 + \alpha_1 \omega_{it-1} + \sum_l \overbrace{\left[1 + X'_{lt-1}\mu\right]}^{\text{country-specific multiplier}} \cdot \underbrace{\left[\beta_1 r_{ilt-1} + \beta_2 y_{ilt-1} r_{ilt-1} + \beta_3 y_{ilt-1}\right]}_{\text{common return \& synergy}} + \xi_{it}.$$

- y_{ilt} Indicator for whether firm i produces in country l in year t.
- r_{ilt} Indicator for whether firm i conducts R&D in country l at t.
- β_2 Captures spillover from production to innovation, i.e. synergy effect.
- X_{lt} A vector of country characteristics.
- ξ_{it} Follows $N\left(0, \sigma_\xi^2\right)$ and captures the randomness in innovation.

Dynamic Costs and Bellman Equation

Firms incur fixed and sunk costs for offshoring production and innovation

- Sunk costs ϕ_s^p for production and ϕ_s^r for innovation
- Fixed cost ϕ_f^p for production and $\phi^r_{f,ilt} = \phi^r_f - \lambda_1 \max_{l'} \{c_{ll'} y_{il't}\}$ for innovation

Dynamic Costs and Bellman Equation

$$
\begin{aligned}
V_{it}\left(\boldsymbol{s}_{it}\right) = \max_{\boldsymbol{y}_{it},\boldsymbol{r}_{it}} \Bigg\{ & \underbrace{\pi_{it}(\boldsymbol{y}_{it},\omega_{it})}_{\text{static profit}} \\
& - \sum_{l} \underbrace{\left[(1-y_{ilt-1})\cdot y_{ilt}\cdot \phi_s^p + y_{ilt-1}\cdot y_{ilt}\cdot \phi_f^p\right]}_{\text{costs of production offshoring}} \\
& - \sum_{l} \underbrace{\left[(1-r_{ilt-1})\cdot r_{ilt}\cdot \phi_s^r + r_{ilt-1}\cdot r_{ilt}\cdot \phi_{f,ilt}^r\left(\boldsymbol{y}_{it}\right)\right]}_{\text{costs of innovation offshoring}} \\
& + \underbrace{\zeta \mathbb{E}_{\xi} V_{it+1}\left(\boldsymbol{s}_{it+1} \middle| \omega_{it},\boldsymbol{y}_{it},\boldsymbol{r}_{it}\right)}_{\text{continuation value}} \Bigg\}
\end{aligned}
$$

- Rich trade geography enters through $\pi_{it}\left(\boldsymbol{y}_{it},\omega_{it}\right)$, $\phi_{f,ilt}^r\left(\boldsymbol{y}_{it}\right)$, and state transition
- Computational challenge: $\boldsymbol{s}_{it}$, $\boldsymbol{y}_{it}$, $\boldsymbol{r}_{it}$

Supermodularity Property (first step to achieve solution)

Theorem.

- Let $\mathcal{L}$ denote the set of locations, $\mathcal{T}$ the collection of time periods, and Ω the set of all possible paths of shocks $\boldsymbol{z}$.
- Assume that sunk costs $\geq$ fixed costs, and β_1, β_2, β_3, and λ_1 are non-negative.
- If $(\eta - 1)\beta_m > \rho - 1$, $\Pi_0\left(\boldsymbol{o}_i | \boldsymbol{y}_{i,-1}, \boldsymbol{r}_{i,-1}, \omega_{i,-1}\right)$ is supermodular in $\boldsymbol{o}_i$ on $\{0,1\}^{2\mathcal{L}\mathcal{T}\Omega}$.

Behind supermodularity are static and dynamic complementarities.

1. y_{ilt} complements y_{ilt+1}; r_{ilt} complements r_{ilt+1}.

   $\sim$ Offshoring this period makes it cheaper to offshore next period (sunk cost $\geq$ fixed cost)

2. y_{ilt} complements r_{ilt}

   $\sim$ Synergy effect ($\beta_2 \geq 0$) and cost sharing effect ($\gamma_1 \geq 0$)

3. r_{ilt} complements $y_{il't}$

   $\sim$ Cost-sharing effect is allowed to cross borders ($\gamma_1 \geq 0$)

4. y_{ilt} complements $y_{il't}$ if $(\eta - 1)\beta_m > \rho - 1$

   $\sim$ Scale effect dominates substitution effect (Antras et al., 2017)

▸ Lifetime Problem

▸ Interpretation of Condition

Adapting Novel Algorithm (second step to achieve solution)

- Alfaro-Ureña et al. (2023) provides the cutting-edge algorithm to solve dynamic combinatorial discrete choices with supermodularity
- Complementarity helps rule out undesirable country combinations
- Adapting the algorithm to the following specificities
  - Two intertwining discrete choices
  - Rich static and dynamic complementarities
  - Endogenous process of unobserved state

Three Key Ideas of Algorithm

- Challenges from dynamics: a large state space, and thus a large policy function.
- Idea 1: Breakdown a multi-country problem into many single-country problems.
  - Solve single-country choices while fixing choices in other countries at their bounds.
- Idea 2: Partial info on other states can suffice for solving current-state problem.
  - Track bounds on optimal *discrete* choices, sparing the need to save the full policy function.
- Idea 3: Reduce # problems by focusing on specific paths of shocks, and therefore states.
  - Three relevant paths: most favorable path, least favorable path, simulated path of interest

▸ Static Squeezing ▸ Algorithm Details ▸ Comparison to Alfaro-Ureña et al. (2023)

Estimation Procedure and Results

Parameter Identification and Estimation Steps

Parameter	Source of Identification
η	Average markup.
ρ	Response of country production-offshoring potential to tariff change.
β_k, β_m	Relationship between output and input factors.
$\alpha_0, \alpha_1, \sigma_\xi$	Persistence and variation in firm productivity.
$\beta_1, \beta_2, \beta_3, \mu$	Relationship between productivity change and innovation efforts in each country.
$\phi_s^p, \phi_s^r, \phi_f^p, \phi_f^r$	Fraction of firms that offshore production and innovation (unconditional and conditional on past choices).
λ_1	Colocation of production and innovation in and out of the region.

Step 1. Use input shares to estimate each country's production-offshoring potential, θ_{lt}, and the elasticity of substitution between inputs, ρ.

Step 2. Use the control function approach to estimate the marginal cost function and productivity evolution parameters, β_k, β_m, α_0, α_1, β_1, β_2, β_3, μ, and σ_ξ.

Step 3. Use the MSM to estimate dynamic cost parameters, ϕ_s^p, ϕ_s^r, ϕ_f^p, ϕ_f^r, and λ_1.

Step 1 - Estimate production-offshoring potentials

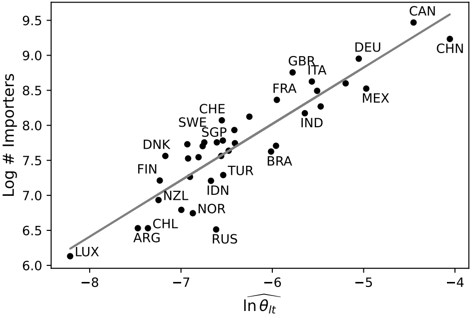
- Value share of firm i's input from country l is proportional to θ_l.

$$\chi_{ilt} = (w_{lt}\tau_{lt} T_{lt}/p_{it}^m)^{1-\rho} = \theta_{lt}/\Theta_{it}.$$

- Taking logs and normalizing by domestic shares (setting $\theta_{0t} = 1$),

$$\ln \chi_{ilt} - \ln \chi_{i0t} = \ln \theta_{lt} + \ln \epsilon_{ilt} \xrightarrow{\text{OLS}} \widehat{\ln \theta_{lt}}$$

- $\widehat{\ln \theta_{lt}}$, given firm's choice of production locations, makes $\ln p_{it}^m$ *firm-specific* and *observable* → identify β_m



‣ Estimate ρ

Step 2 - Control Function Approach

1. Endogeneity: serial correlation in productivity.

$$\ln R_{it} = \tilde{C} + \ln \Phi_{jt} + (1-\eta)\left(\beta_k \ln k_{it} + \beta_w \ln w_{jt} + \beta_m \ln p^m_{it} - \underbrace{g\left(\mathbf{r}_{it-1}, \mathbf{y}_{it-1}\right)}_{\text{location decisions}}\right) + \left[\underbrace{u_{it} - (1-\eta)\left(\alpha_1 \omega_{it-1} + \xi_{it}\right)}_{\text{composite error term}}\right].$$

2. Using insight from OP (1996) and ACF (2006), assume conditional energy input, $n_{it}\left(\omega_{it} | k_{it}, w_{jt}, p^m_{it}\right)$, strictly increases with ω_{it} so that an inversion exists.

$$\ln R_{it} = \psi_0 + \psi_{jt} + \underbrace{h\left(k_{it}, w_{jt}, p^m_{it}, n_{it}\right)}_{\text{obtain } \hat{\phi}_{it}} + \nu_{it}.$$

3. Combining it with the productivity evolution process to get an estimation equation.

$$\begin{aligned} \hat{\phi}_{it} &= \beta^*_k \cdot \ln k_{it} + \beta^*_m \cdot \ln p^m_{it} - \alpha^*_0 + \alpha_1 \cdot \left(\hat{\phi}_{it-1} - \beta^*_k \cdot \ln k_{it-1} - \beta^*_m \cdot \ln p^m_{it-1}\right) \\ &- \sum_l \left[1 + X_{lt-1}\rho\right] \cdot \left[\beta^*_1 r_{ilt-1} + \beta^*_2 r_{ilt-1} y_{ilt-1} + \beta^*_3 y_{ilt-1}\right] - \xi^*_{it}. \end{aligned}$$

Step 2 - Control Function Approach

1. Endogeneity: serial correlation in productivity.

$$\ln R_{it} = \tilde{C} + \ln \Phi_{jt} + (1-\eta)\left(\beta_k \ln k_{it} + \beta_w \ln w_{jt} + \beta_m \ln p_{it}^m - \underbrace{g\left(\mathbf{r}_{it-1}, \mathbf{y}_{it-1}\right)}_{\text{location decisions}}\right) + \left[\underbrace{u_{it} - (1-\eta)\left(\alpha_1 \omega_{it-1} + \xi_{it}\right)}_{\text{composite error term}}\right].$$

2. Using insight from OP (1996) and ACF (2006), assume conditional energy input, $n_{it}\left(\omega_{it} | k_{it}, w_{jt}, p_{it}^m\right)$, strictly increases with ω_{it} so that an inversion exists.

$$\ln R_{it} = \psi_0 + \psi_{jt} + \underbrace{h\left(k_{it}, w_{jt}, p_{it}^m, n_{it}\right)}_{\text{obtain } \hat{\phi}_{it}} + \nu_{it}.$$

3. Combining it with the productivity evolution process to get an estimation equation.

$$\begin{aligned}\hat{\phi}_{it} &= \beta_k^* \cdot \ln k_{it} + \beta_m^* \cdot \ln p_{it}^m - \alpha_0^* + \alpha_1 \cdot \left(\hat{\phi}_{it-1} - \beta_k^* \cdot \ln k_{it-1} - \beta_m^* \cdot \ln p_{it-1}^m\right) \\ &\quad - \sum_l \left[1 + X_{lt-1}\rho\right] \cdot \left[\beta_1^* r_{ilt-1} + \beta_2^* r_{ilt-1} y_{ilt-1} + \beta_3^* y_{ilt-1}\right] - \xi_{it}^*.\end{aligned}$$

Step 2 - Cost Function and Productivity Evolution

	Full Sample (1)	Firms with Foreign Employmees (2)	Excluding Tax Havens (3)	Excluding China (4)
Capital Coefficient, β_k	-0.164***	-0.172***	-0.164***	-0.164***
	(0.0017)	(0.0027)	(0.0017)	(0.0017)
Intermediate Price Coefficient, β_m^F	0.435***	0.412***	0.435***	0.435***
	(0.0049)	(0.0075)	(0.0049)	(0.0049)
Constant in AR(1): α_0	-0.0433***	-0.0521***	-0.0431***	-0.0433***
	(0.0027)	(0.0048)	(0.0027)	(0.0027)
Slope in AR(1): α_1	0.909***	0.907***	0.909***	0.909***
	(0.0038)	(0.0056)	(0.0038)	(0.0038)
Return to Innovation: β_1	-0.000803	-0.00095	-0.001	-0.000624
	(0.0021)	(0.0028)	(0.0019)	(0.0022)
Return to Colocation: β_2	0.0064**	0.0072*	0.0058**	0.0064**
	(0.0031)	(0.0038)	(0.0029)	(0.0031)
Return to Production: β_3	0.00463***	0.00666***	0.00418***	0.00491***
	(0.0010)	(0.0014)	(0.0011)	(0.0010)
Observations	28500	12500	28500	28500
Mean Elasticity	0.0006	0.0005	0.0007	0.0006
SD of Elasticity	0.0006	0.0005	0.0006	0.0006
Max of Elasticity	0.002	0.0017	0.0021	0.002

▸ Heterogeneous Synergy Effect by Country

Step 2 - Cost Function and Productivity Evolution

	Full Sample	Firms with Foreign Employmees	Excluding Tax Havens	Excluding China
	(1)	(2)	(3)	(4)
Capital Coefficient, β_k	-0.164***	-0.172***	-0.164***	-0.164***
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▸ Heterogeneous Synergy Effect by Country

Step 3 - MSM and Dynamic Costs

Parameter Estimates (unit = $1k)

ϕ_s^p	ϕ_f^p	ϕ_s^r	ϕ_f^r	λ_1
5039.31	3304.68	69196.30	41213.89	1058.63
(572.63)	(77.11)	(16403.78)	(4359.88)	(352.64)

Matched Moment

Moment	Data	Model
$E[y_{ilt}]$	0.16059	0.1601
$E[r_{ilt}]$	0.01303	0.01297
$E[y_{ilt} y_{ilt-1}]$	0.01901	0.01797
$E[r_{ilt} r_{ilt-1}]$	0.00182	0.00150
$E[y_{ilt} y_{il't} \mid c_{ll'} = 1] - E[y_{ilt} y_{il't} \mid c_{ll'} = 0]$	0.01115	0.01166
$E[r_{ilt} r_{il't} \mid c_{ll'} = 1] - E[r_{ilt} r_{il't} \mid c_{ll'} = 0]$	0.00048	0.00039

Model Validation Based On Trump Tariffs

- U.S. tariff for China increased from 4.07 p.p. in 2017 to 7.87 p.p. in 2019 (TRAINS Data)
- Reduced-Form Predictions
  - 3.8 p.p. increase in tariff ⇒ 7.2% decrease in imports from China
  - 3.8 p.p. increase in tariff ⇒ 0.1 p.p. decrease in R&D offshoring probability for China
- Model Simulated Effects
  - 3.8 p.p. increase in tariff is equivalent to production-offshoring potential dropping to 90%
  - Produced a 6.5% decrease in imports from China,
  - and a 0.06 p.p. decrease in R&D offshoring probability for China
- Model can generate the right magnitude of effects, matching reduced-form estimates.

Relative Importance of Model Mechanisms

1. Reduce the synergy effect (β_2) by half
   - ⇒ big impact ($> 85\%$) on innovation probability and colocation
2. Shut down the cost sharing effect (λ_1)
   - ⇒ minimal impact ($< 5\%$) on innovation probability and colocation

Synergy between production and innovation is the most important driver of colocation.

	(1) $\beta_2 = \hat{\beta}_2$	(2) $\beta_2 = \frac{1}{2}\hat{\beta}_2$	(3) Δ
$\mathbb{E}[y_{ilt}]$	0.160	0.159	0.001
	(100)	(99.5)	(0.5)
$\mathbb{E}[r_{ilt}]$	0.013	0.0018	0.0112
	(100)	(13.85)	(86.15)
$\mathbb{E}[r_{ilt} \mid y_{ilt} = 1]$	0.081	0.0116	0.069
	(100)	(14.32)	(85.68)

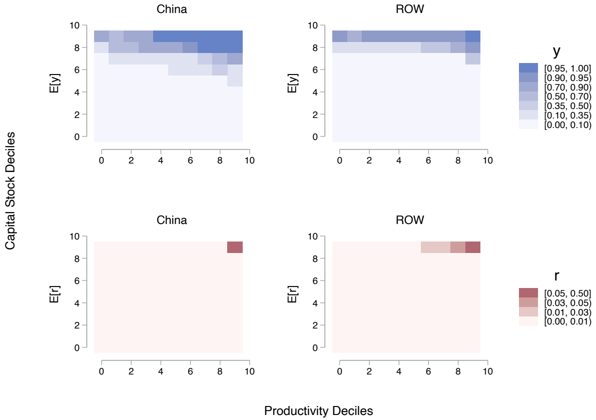
	(1) $\lambda_1 = \hat{\lambda}_1$	(2) $\lambda_1 = 0$	(3) Δ
$\mathbb{E}[r_{ilt}]$	0.0130	0.0125	0.0004
	(100)	(96.70)	(3.30)
$\mathbb{E}[r_{ilt} \mid y_{ilt} = 1]$	0.0810	0.0783	0.0028
	(100)	(96.59)	(3.41)
$\mathbb{E}[r_{iRt} \mid y_{iRt} = 1]$	0.0773	0.0736	0.0037
	(100)	(95.20)	(4.80)

Counterfactual Exercises

Counterfactual US-China Bilateral Policies

- Negative policy shocks to production offshoring toward China
  - U.S. imposes different levels of tariff increase on Chinese goods
  - The cost of production offshoring to China rises
- All countries lose production and innovation in absolute terms
- U.S. innovation share gains, but only moderately
  - Third-country effect: Large firms produce and innovate in China, but their R&D leaving China gets diverted to other countries Details
  - Scale effect: Medium-sized firms produce in China but innovate in U.S. despite colocation benefit; they scale down globally

Firms Are Heterogeneous in Where and What They Offshore

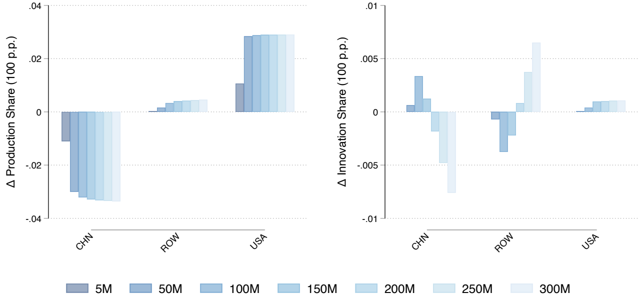


Firm Heterogeneity:

- China has the highest production-offshoring potential but moderate return to innovation.
- Many medium-sized firms produce in China but innovate elsewhere.
  - ∼ Struck by moderate shocks
- The largest firms both produce and innovate in China.
  - ∼ Struck by large shocks

Nonlinear Effects and Policy Intensity

Increasing Cost of Production Offshoring

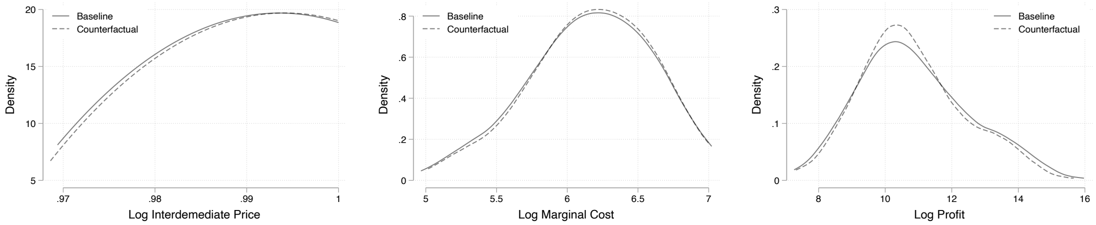


- The shares of production always flow from China to US and ROW.
- Nonlinear effects in the shares of innovation
  - (Current) Moderate shocks: from ROW to China and US
  - Larger shocks (e.g. decoupling): from China to ROW and US

‣ Effects of Tariff Changes ‣ Effects by Country 1 ‣ Effects by Country 2 ‣ US-China Decoupling

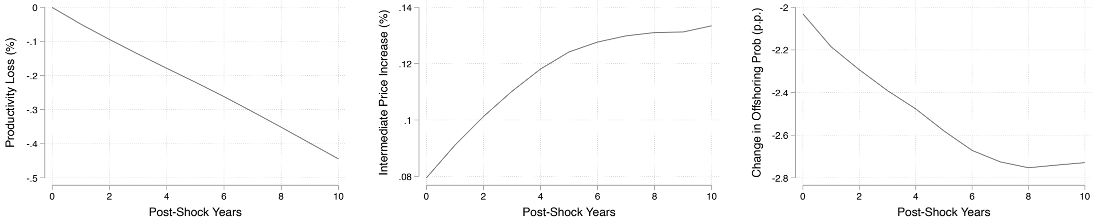
Dynamic Losses From Tariff Increases

- Exercise: a permanent 50% decrease in China's production-offshoring potential (29% ↑ tariff)
- Static losses from deteriorated production offshoring opportunities
  - Prob. of offshoring ↓ 1.8 p.p. for production and ↓ 0.26 p.p. for innovation
  - Higher intermediate price, higher marginal cost, lower profit



Dynamic Losses From Tariff Increases

- In a dynamic framework with endogenous R&D process, losses accumulate over time.
  - ▷ Less offshore production and R&D (immediately after the negative shock)
  - ▷ Lower future productivity (according to the productivity evolution equation)
  - ▷ Even less offshore production and R&D, etc (harder to overcome the fixed/sunk costs)



⇒ My framework can evaluate dynamic effects of worsened production offshoring opportunities, missing in static models of global production and sourcing.

Conclusion and Future Work

- Study multinational firms' location choices for offshore production and innovation
- Highlight within- and cross-country complementarities between production and innovation
- Demonstrate important aspects of trade policies
  - Third-country effects, nonlinear effects contingent on firm heterogeneity, dynamic effects
- **Further directions**
  - Proximity and the direction of innovation
  - How is trade policies' welfare calculation different w/ and w/o colocation benefits $\rightarrow$ GE framework
  - Perspective of developing-country governments
  - Firms may underestimate the synergy effect (Pisano & Shih, 2012)

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Thank you for listening!

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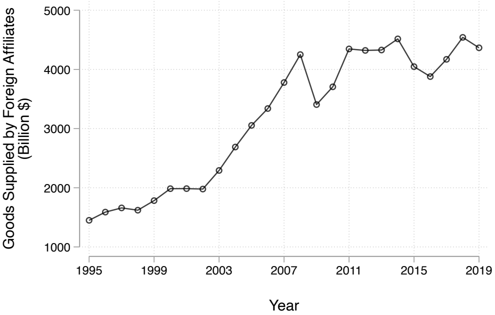
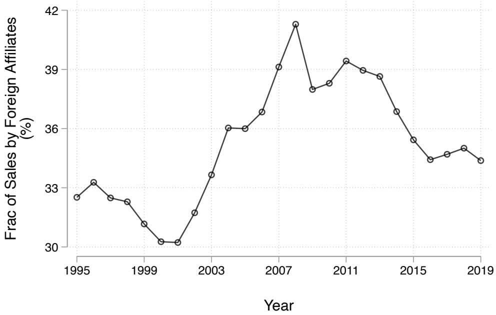
Appendix

Goods supplied by foreign affiliates

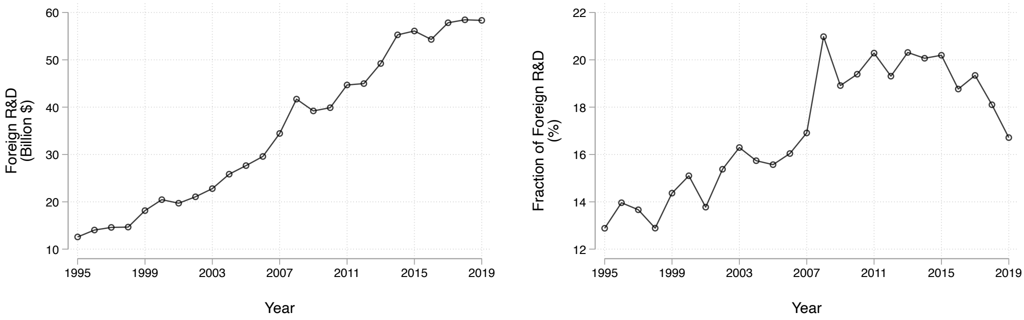




Data source: BEA.
The value of goods supplied by foreign affiliates increased from $1.45T in 1995 to $4.3T in 2011.

go back

Rise of Foreign R&D



- US foreign R&D expenditure increased from $10B to $60B during 1995 and 2019
- The share of foreign R&D for US MNEs ↑ from 13% in 1995 to 20% in 2015, and ↓ to 16% in 2020

go back

Reshoring Policies

The Tax Cuts and Jobs Act

- Signed on December 22, 2017 by Trump
- Lowered corporate tax rate from 35% to 21%, reducing incentive to offshore for tax reasons

The CHIPS and Science Act (White House, 2022)

- Signed on August 9, 2022 by Biden
- Allocated $280B to enhance domestic research & manufacturing of semiconductors
- Aimed to cut reliance on foreign sourcing, particularly from China

Made in America Tax Plan (U.S. Treasury, 2021)

- Proposed in March 2021 by Biden
- To eliminate incentives for offshore investment & discourage the offshoring of jobs and profits
- To end the tax exemption for the first 10% return on foreign assets, thereby removing the incentive to offshore tangible assets

go back

HP and Texas Instruments

"(R&D centers) . . . should be located close to large markets and manufacturing facilities in order to commercialize new products rapidly in foreign markets. A silicon-wafer plant, for example, has to interact closely with product development engineers during trial runs of a new generation of microchips. The same is true for the manufacture of disk drives and other complex hardware. For that reason, Hewlett-Packard and Texas Instruments both operate laboratories in Singapore, close to manufacturing facilities." (local + border effects)

Walter Kuemmerle, Harvard Business Review

▸ go back

Anecdotes: Regional Complementarity

"In 2016, Nissan expanded its R&D centre with a new test centre in Thailand that will be the main R&D hub for ASEAN. The R&D test centre will also serve Indonesia, the Philippines, Malaysia and Vietnam."

"(MNEs establish regional headquarters) to oversee operation of a portfolio of subsidiaries and to provide consolidated regional support so to increase efficiency in administrative functions, logistics and marketing."

ASEAN Investment Report, 2020-2021

▸ go back

Lit Forefront on Interdependent Choices, Large N^*

1. Static model + lattice structure and squeezing method + solution

   ∼ Jia (2008); Arkolakis et al. (2021); Antras et al. (2017)

2. Dynamic model + Euler method and moment inequalities + estimation

   ∼ Holmes (2011); Aguirregabiria & Magesan (2013); Morales et al. (2019)

3. Value function approximation (state space) + set limit on choices (action space)

   ∼ Parametric approx., Sweeting (2013)

   ∼ Interpolation, Aguirregabiria & Vicentini (2016)

4. Dynamic model + lattice structure and a NEW algorithm + solution

   ∼ Alfaro-Ureña et al. (2023)

▸ go back

*Exhaustive enumeration can deal with small-N problems.

BRDIS Survey Form – R&D Offshoring Module

2-11 Of the amount reported in Question 2-10, column 2, how much R&D was performed in the following locations? For full list of countries in each region see Question by Question Guidance at https://www.census.gov/programs-surveys/brds/information/brdshelp.html#q2-11.

	$Bil.	Mil.	Thou.
Canada			
Puerto Rico			

Europe	$Bil.	Mil.	Thou.
Austria.			
Belgium.			
Czech Rep			
Denmark			
Finland			
France			
Germany			
Hungary.			
Ireland.			
Italy			
Luxembourg . . .			
Netherlands. . . .			
Norway			
Poland.			
Russia			

Question continues on next page

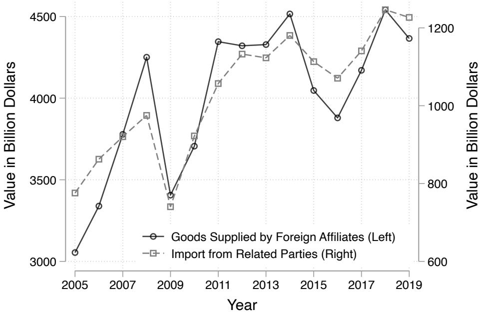
go back

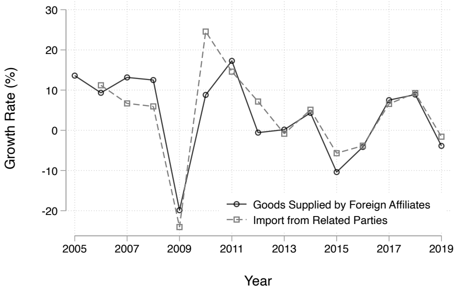
BRDIS Survey Form – R&D Measure

- Captures innovation performed by the firm.
- Direct costs such as salaries of researchers + administrative and overhead costs clearly associated with the firms R&D
- Basic R&D + applied R&D
- Product innovation + process innovation
- Does not account for spending on capital inputs, routine product testing and quality control, or market research

go back

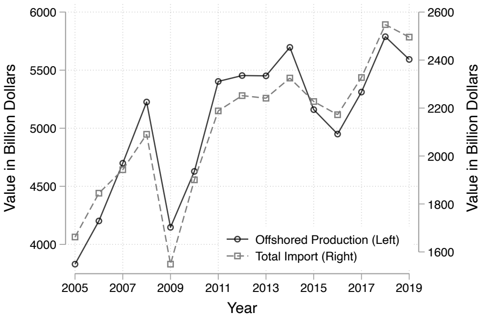
Within-Firm Production Offshoring

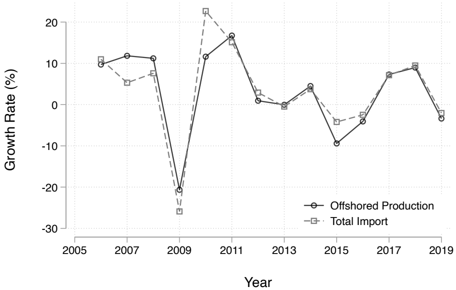




- Imports represent approximately half of total offshored production.
- Overall trends for imports and offshore production closely track each other in terms of both absolute value and growth rate.

Total Production Offshoring





- The same is true for the sum of within-firm offshored + across-firm outsourced production.
- Relative variations are used in regressions.

go back

Sample Structure and Survey Frequency

Sample: BRDIS ∩ ASM/CMF, 39 countries †

An Unbalanced Panel of Firms

Survey Freq.	# Firms	% Firms	% Sales	% VA
1-2	27500	76.39	3.05	3.50
3-5	5000	13.89	7.39	8.17
6-9	2500	6.94	22.42	16.24
10-12	1400	3.89	67.14	72.09
Total	36000	100	100	100

Large firms, representing a significant share of total sales, are surveyed nearly every year.

▸ go back

† Countries that are unimportant for R&D are grouped together as "other African countries" and etc.

Summary Statistics

Firm-Year Level	
Mean Sales ($K)	497700
Mean Emp	2945
Mean Domestic Emp	1797
Mean Foreign Emp	1145
Observations	85000
% Importing	83.40
Conditional on Importing	
# Imp Countries	8.007
Ave Imp Value ($K)	142800
% Performing R&D	57.95
Conditional on Performing R&D	
Mean R&D Expenditure ($K)	49400
Mean Domestic R&D Expenditure ($K)	38030
Mean Foreign R&D Expenditure ($K)	11380
% Performing Foreign R&D	19.65
Conditional on Doing Foreign R&D	
# Foreign R&D Countries	5.63
Mean Foreign R&D Expenditure ($1K)	61970

Firm-Country-Year Level	
% Importing	16.06
Conditional Imp Value ($1K)	17840
% Doing Foreign R&D	1.303
Conditional Foreign R&D Expenditure ($1K)	11010
Observations	3475000

Representativeness

$\sim$ 65% of annual total manufacturing shipment

go back

Is Multiple R&D Locations Important?

Why don't we just model a single R&D offshoring location?

# Foreign R&D Locations		% Obs	% Sales	% Worldwide R&D	% Foreign R&D
0	90.37	38.22	13.68	0	
1	2.83	6.39	4.40	2.37	
2-5		3.74	19.37	12.14	10.93
6-10		1.66	10.86	13.35	16.14
Above 10		1.40	25.16	56.44	70.56
Total		100	100	100	100

- Firms with more than 5 locations account for 87% of U.S. offshore R&D.
- R&D expenditure in the $(n+1)$-th largest location is substantial compared to that in the n-th largest location.

go back

Multiple Import Origins Even More Important

# Foreign Imp Locations	% Obs	% Sales	% Imp Value
0	16.60	0.52	0
1	13.18	0.88	0.09
2-10	48.26	14.18	4.97
11-20	14.39	29.10	19.55
Above 20	7.58	55.31	75.38
Total	100	100	100

- Firms importing from more than 10 countries represent 95% of total import value.

go back

Linkage at the Micro Level

Four Types of Offshoring Modes in Host Country

Mode	% Obs	% Import Value	% R&D Expenditure
None	83.75	0	0
Import Only	14.94	62.26	0
R&D Only	0.19	0	6.17
Both	1.12	37.74	93.83
Total	100	100	100

- 94% of foreign R&D is done in countries where the firm has production
- The return of offshoring only R&D is small; that of offshoring both can be substantial

go back

Top Offshoring Destinations

Top Five Offshoring Destinations

Top **R&D** Locations	% R&D Expenditure	Top **Imp** Locations	% Imp Value
Germany	14.76	Mexico	19.51
UK	11.32	Canada	17.76
China	8.25	China	12.58
India	6.78	Japan	8.18
Canada	5.38	Germany	7.16

- Germany, China, and Canada appear in both lists!

go back

Colocation of Production and Innovation at Firm Level

Fact 1: Firms engage in more offshore R&D activities in countries from which they import more, and vice versa.

$$\text{R\&D}_{il} = \beta \cdot \text{Imp}_{il} + \gamma_i + \gamma_{jl} + \varepsilon_{il}$$

	(1) R&D Dum	(2) R&D Dum	(3) Log R&D	(4) Log R&D	(5) Ihs. R&D
Imp Dum	0.0195*** (0.00109)		0.322*** (0.119)		
Log Imp		0.0150*** (0.000761)		0.212*** (0.0191)	
Ihs. Imp					0.0217*** (0.00102)
N	499000	41000	4100	3100	499000
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Ind-FE	Yes	Yes	Yes	Yes	Yes

The presence of production more than doubles the likelihood of conducting R&D in a country.

Δ = 1.95 p.p., Baseline = 1.3 p.p.

‣ Excl. Region Terms ‣ Reg Imp on R&D ‣ Panel Reg ‣ Industry Heterogeneity ‣ Offshoring vs outsourcing

Cross-Country Interdependence

Fact 2: Offshoring decisions are interdependent across countries.

$$\text{R\&D}_{il} = \beta \cdot \text{Imp}_{il} + \beta' \cdot \text{ImpRegion}_{il} + \gamma_i + \gamma_{jl} + \varepsilon_{il}$$

	(1) R&D Dum	(2) R&D Dum	(3) Log R&D	(4) Log R&D	(5) Ihs. R&D
Imp Dum	0.0195***		0.322***		
	(0.00109)		(0.119)		
Region Imp Dum	0.00147***		-0.00580		
	(0.000338)		(0.143)		
Log Imp		0.0150***		0.212***	
		(0.000761)		(0.0191)	
Log Region Imp		0.00167***		0.0105	
		(0.000626)		(0.0211)	
Ihs. Imp					0.0217***
					(0.00102)
Ihs. Region Imp					0.000936***
					(0.000233)
N	499000	41000	4100	3100	499000
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Ind-FE	Yes	Yes	Yes	Yes	Yes

Firms have more R&D activities in a country if they have more imports from nearby countries.

Facts: Without Region Terms

Panel A: R&D Offshoring on Imp.

	(1) R&D Dum	(2) R&D Dum	(3) Log R&D	(4) Log R&D	(5) Ihs. R&D
Imp Dum	0.0196***		0.322***		
	(0.000697)		(0.117)		
Log Imp		0.0134***		0.211***	
		(0.000448)		(0.0167)	
Ihs. Imp					0.0218***
					(0.000546)
N	499000	57000	4100	3400	499000
R-squared	0.392	0.478	0.569	0.595	0.419
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Ind-FE	Yes	Yes	Yes	Yes	Yes

Panel B: Imp on R&D Offshoring.

	(1) Imp Dum	(2) Imp Dum	(3) Log Imp	(4) Log Imp	(5) Ihs. Imp
R&D Dum	0.210***		1.755***		
	(0.00675)		(0.0529)		
Log R&D		0.00711***		0.309***	
		(0.00261)		(0.0254)	
Ihs. R&D					0.578***
					(0.0118)
N	499000	4100	57000	3400	499000
R-squared	0.420	0.612	0.475	0.661	0.470
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Ind-FE	Yes	Yes	Yes	Yes	Yes

go back

Facts: Regressing Imp on R&D

	(1) Imp Dum	(2) Imp Dum	(3) Log Imp	(4) Log Imp	(5) Ihs. Imp
R&D Dum	0.210***		1.763***		
	(0.00909)		(0.0546)		
Region R&D Dum	0.0591***		0.239***		
	(0.00634)		(0.0498)		
Log R&D		0.00498		0.325***	
		(0.00329)		(0.0308)	
Log Region R&D		0.000284		0.106***	
		(0.00428)		(0.0403)	
Ihs. R&D					0.576***
					(0.0161)
Ihs. Region R&D					0.126***
					(0.0100)
N	499000	2800	57000	2300	499000
R-squared	0.421	0.608	0.476	0.681	0.471
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Ind-FE	Yes	Yes	Yes	Yes	Yes

go back

Facts: Full Panel

$$y_{ilt} = \beta \cdot x_{ilt} + \beta' \cdot x_{iRt} + \gamma_{it} + \gamma_{jlt} + \varepsilon_{ilt}.$$

Panel A: R&D Offshoring on Imp.

	(1) R&D Dum	(2) R&D Dum	(3) Log R&D	(4) Log R&D	(5) Ihs. R&D
Imp Dum	0.0180***		0.391***		
	(0.000844)		(0.0625)		
Region Imp Dum	0.00169***		-0.0482		
	(0.000261)		(0.0682)		
Log Imp		0.0134***		0.208***	
		(0.000539)		(0.0134)	
Log Region Imp		0.00100***		0.00734	
		(0.000376)		(0.0147)	
Ihs. Imp					0.0213***
					(0.000862)
Ihs. Region Imp					0.000927***
					(0.000200)
N	3387000	400000	39000	30000	3387000
R-squared	0.389	0.483	0.568	0.593	0.414
Firm-Year FE	Yes	Yes	Yes	Yes	Yes
Country-Year-Ind-FE	Yes	Yes	Yes	Yes	Yes

Panel B: Imp on R&D Offshoring.

	(1) Imp Dum	(2) Imp Dum	(3) Log Imp	(4) Log Imp	(5) Ihs. Imp
R&D Dum	0.171***		1.639***		
	(0.00652)		(0.0371)		
Region R&D Dum	0.0442***		0.171***		
	(0.00367)		(0.0298)		
Log R&D		0.00838***		0.296***	
		(0.00172)		(0.0190)	
Log Region R&D		0.00228		0.0431*	
		(0.00166)		(0.0229)	
Ihs. R&D					0.502***
					(0.0121)
Ihs. Region R&D					0.0968***
					(0.00655)
N	3387000	25500	536000	22000	3387000
R-squared	0.449	0.637	0.467	0.689	0.501
Firm-Year FE	Yes	Yes	Yes	Yes	Yes
Country-Year-Ind-FE	Yes	Yes	Yes	Yes	Yes

▸ go back

Discussing Exclusion Restriction

Section 301 Investigations

- Claiming IP theft and forced technology transfers by China
- Resulted in a around of tariffs on innovation-intensive products

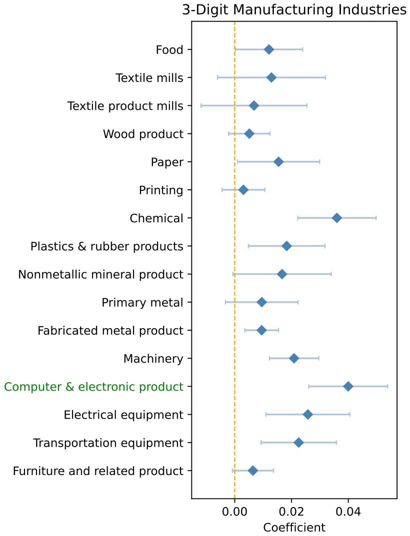
How to think about **selection**?

- Tariffs could target products that have higher initial R&D intensity, as long as the growth rate of R&D is the same for high vs low R&D intensity products absent Trump tariffs.
- The direction of potential bias is towards zero.

go back

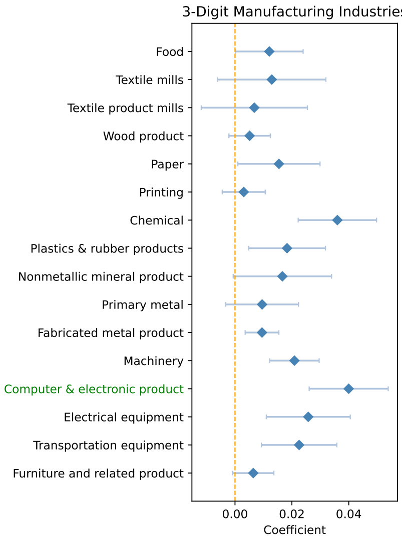
Industry Heterogeneity

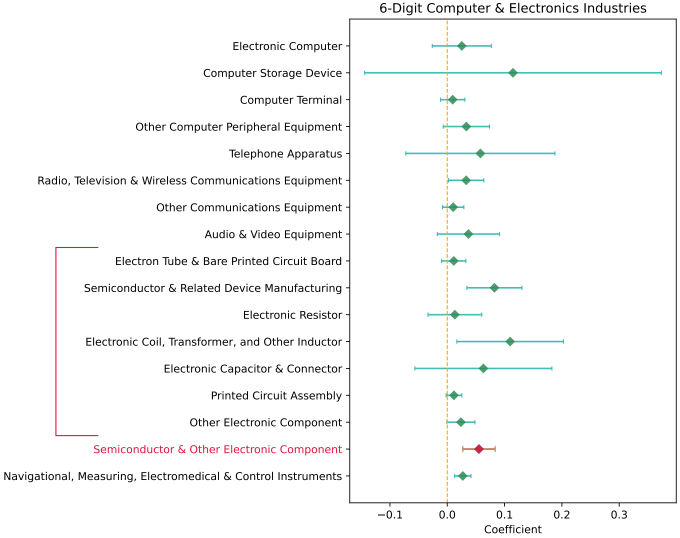
$$\text{IhsR\&D}_{ilt} = \beta \cdot \text{IhsImp}_{ilt} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}.$$



Industry Heterogeneity

$$\text{IhsR\&D}_{ilt} = \beta \cdot \text{IhsImp}_{ilt} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}.$$





go back

Within-Firm Offshoring vs Outsourcing

	(1) R&D Dum	(2) R&D Dum	(3) Log R&D	(4) Log R&D	(5) Ihs. R&D	(6) Ihs. R&D
Imp Dum: Non-related	0.00401***		0.116**		0.0206***	
	(0.000510)		(0.0492)		(0.00427)	
Imp Dum: Related	0.0692***		0.661***		0.555***	
	(0.00248)		(0.0483)		(0.0206)	
Region Imp Dum: Non-related	0.000158		-0.0650		0.00114	
	(0.000245)		(0.0618)		(0.00189)	
Region Imp Dum: Related	0.00113**		0.0572		0.0138***	
	(0.000523)		(0.0514)		(0.00408)	
Log Imp: Non-related		0.00254***		0.0284**		0.0256***
		(0.000857)		(0.0139)		(0.00710)
Log Imp: Related		0.0212***		0.214***		0.203***
		(0.00105)		(0.0151)		(0.0103)
Log Region Imp: Non-related		0.0000565		-0.0282		-0.000212
		(0.00117)		(0.0174)		(0.0101)
Log Region Imp: Related		0.000702		0.00731		0.0109
		(0.000826)		(0.0147)		(0.00794)
N	3387000	128000	39500	21000	3387000	128000
R-squared	0.402	0.567	0.573	0.611	0.422	0.584
Firm-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-Ind FE	Yes	Yes	Yes	Yes	Yes	Yes

go back

Constructing Firm-Country-Specific Tariff Rate

Weighted average tariff over a firm-specific, fixed set of goods

$$T_{ilt} = \sum_g s_{igt_0} T_{glt}$$

- ▷ g: Goods defined at 10-digit HS code level
- ▷ t: Study period, 2013–2019; t_0: Five-year prior period, 2008–2012
- ▷ T_{glt}: tariff rate for good g from country l in year t
- ▷ s_{igt_0}: value share of g among goods imported by firm i during t_0, regardless of origin

Why fix the set of goods?

- × the firm's selection of import product bundle for each country
- × potential endogenous response of import product bundle to tariff changes

go back

Specification and Identification Argument

$$y_{ilt} = \beta \cdot T_{ilt} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}$$

- Two sources of variations
  - Within-firm, cross-country: two affiliates of the same firm but in different countries;
  - Cross-firm, within-country: affiliates of two firms in the same home country, but initially producing different products.
- Relevance: Tariff $\rightarrow$ costs of shipping goods $\rightarrow$ production offshoring.
- Exclusion: Tariff doesn't affect innovation offshoring through mechanisms other than production offshoring, conditioning on fixed effects.

go back

Potential Concerns For Identification

1. Tariff changes (e.g. from FTAs) may be anticipated by firms

   Possibly responding with investment, hiring of manager, etc

2. Tariffs schedules in FTAs may come with IP terms, Santacreu (2021)

   No new trade agreements or major revisions in the study period

   Only relevant if IP terms differ at the product or firm level[‡]

Advantages of the quasi-experiment from the Trump Tariffs

- Product-country-specific tariff changes were unanticipated
- IP issues are much less relevant during the trade war (export control; sanctions)

go back

[‡] Firm-specific tariff rates are constructed based on product-level variations; country-year fixed effects are controlled in regressions.

Reduced-Form Regression

$$y_{ilt} = \beta \cdot T_{ilt} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}$$

	(1) Ihs. Imp	(2) Imp Dum	(3) Log Imp	(4) Ihs. R&D	(5) R&D Dum	(6) Log R&D
T_{ilt}	-1.906***	-0.0643*	-5.163***	-0.239***	-0.0281***	-0.728
	(0.504)	(0.0357)	(0.712)	(0.0811)	(0.0104)	(1.531)
N	1516000	1516000	317000	1516000	1516000	27500
Firm-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes

- Higher tariffs lead to less imports and less R&D within the host country.

  $\Delta T_{ilt} = 0.1$ (i.e. 10 p.p.) $\rightarrow$ 19% decrease in imports + 2.4% decrease in R&D

go back

IV Regression

$$\text{R\&D}_{ilt} = \beta \cdot \text{Imp}_{ilt} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}$$
$$\text{Imp}_{ilt} = \rho \cdot T_{ilt} + \gamma_{it} + \gamma_{lt} + \nu_{ilt}$$

	(1) Ihs. Imp	(2) Ihs. R&D	(3) Ihs. R&D	(4) R&D Dum	(5) R&D Dum
Ihs. Imp		0.0252***	0.125**	0.00315***	0.0147**
		(0.00111)	(0.0493)	(0.000131)	(0.00616)
T_{ilt}	-1.906***				
	(0.504)				
Method	OLS	OLS	IV	OLS	IV
1st-stage F	**61.93**				
N	1516000	1516000	1516000	1516000	1516000
Firm-Year-FE	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes

- Twice imports $\rightarrow$ 12.5% more R&D.

go back

Further Evidence On Interdependence

- Does tariff in neighboring countries affect R&D in the host country?
- If so, offshoring decisions are correlated across locations.

$$y_{ilt} = \beta \cdot T_{ilt} + \beta' \cdot T_{iR(l)t} + \gamma_{it} + \gamma_{lt} + \varepsilon_{ilt}$$

$T_{iR(l)t}$ is the leave-one-out ave tariff in the region, $T_{iR(l)t} = \frac{1}{\sum_{l' \neq l} c_{ll'} M_{l'}} \sum_{l' \neq l} c_{ll'} M_{l'} T_{il't}$.

	(1) Ihs. Imp	(2) Imp Dum	(3) Log Imp	(4) Ihs. R&D	(5) R&D Dum	(6) Log R&D
T_{ilt}	-2.817***	-0.124***	-5.689***	-0.226**	-0.0240**	-1.108
	(0.531)	(0.0373)	(0.723)	(0.0890)	(0.0113)	(1.590)
T_{iRt}	-1.666***	-0.119***	-1.638*	-0.461***	-0.0612***	1.985
	(0.555)	(0.0398)	(0.886)	(0.135)	(0.0182)	(2.395)
N	1238000	1238000	272000	1238000	1238000	23500
Firm-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes	Yes	Yes

- Higher tariffs in the region lead to less imports and less R&D in the host country.

go back

Comparison of Two Identification Strategies

1. Sample is more restricted for the Trump Tariffs quasi-experiment, because treatment is only defined for firm-country pairs that had positive imports.

2. The Trump Tariffs quasi-experiment is less subject to validity concerns, i.e. firms' anticipation of tariff changes and IP terms in trade agreements.

3. They use different tariff variations
   - IV strategy uses a broader spectrum of tariff variations, including tariff changes from built-in tariff reduction schedules, such as those within the U.S. Free Trade Agreements with Chile, Dominican Republic, Morocco, Peru, and Singapore.
   - Reassuring if two identification strategies produce consistent and robust results.

go back

Difference-In-Differences Regression Results

$$y_{ilt} = \beta \cdot \text{Treat}_{il} \cdot \text{Post}_t + \gamma_{il} + \gamma_{lt} + \varepsilon_{ilt}{}^{\S}$$

	(1) Log Imp	(2) Ihs. R&D	(3) R&D Dum	(4) Log R&D
Treat × Post	-0.106***	-0.0945*	-0.0130**	-0.151**
	(0.0263)	(0.0494)	(0.00637)	(0.0659)
N	187000	187000	187000	16500
Firm-Country-FE	Yes	Yes	Yes	Yes
Country-Year-FE	Yes	Yes	Yes	Yes

- Tariff increases lead to less import and less R&D.

go back

§Post dummy is set to 1 in 2019 and 0 between 2014 and 2017. Year 2018 is excluded in DID to (1) abstract away from middle waves, and (2) allow sufficient time for R&D decisions to respond.

DID Regression - Robustness

1. Robustness to alternative measures of treatment size

	(1) Log Imp	(2) Ihs. R&D	(3) R&D Dum	(4) Log R&D
% Products Affected × Post	-0.258*	-0.189***	-0.0207***	-0.250
	(0.137)	(0.0567)	(0.00757)	(0.518)
% Product Value Affected × Post	-0.161*	-0.160***	-0.0175**	-0.243
	(0.0861)	(0.0596)	(0.00772)	(0.250)
Product-Count Weighted	-1.686**	-0.758**	-0.101**	3.031
Effective Tariff Increase × Post	(0.845)	(0.318)	(0.0421)	(2.958)
Product-Value Weighted	-1.098**	-0.642**	-0.0807**	0.119
Effective Tariff Increase × Post	(0.540)	(0.313)	(0.0394)	(1.760)

2 Robust to regressions excluding China or the semiconductor industry

go back

Separately Identify Two Colocation Forces

1. Synergy between production to innovation
   - Control function approach to obtain a proxy for firm productivity
   - Use the relationship between productivity, R&D, and R&D interacted with production to identify the synergy effect
2. Shared overhead costs between production to innovation
   - Form moments based on colocation patterns in data
   - The fraction of colocation patterns that cannot be explained by the synergy effect will be attributed to the cost-sharing mechanism

go back

Reformulation of Firm Problem

Firms' lifetime optimization problem

- Firm's expected lifetime payoff Π_0 is a function of its decision rules $\boldsymbol{o}_i$:

$$\Pi_0\left(\boldsymbol{o}_i | \boldsymbol{y}_{i,-1}, \boldsymbol{r}_{i,-1}, \omega_{i,-1}\right) = \mathbb{E}_{\boldsymbol{z}} \sum_{t=0}^{\infty} \Pi_t\left(\omega_{it}\left(z^t, \left\{\boldsymbol{o}_i\left(z^{\tau}\right)\right\}_{\tau=0}^{t-1}\right), \boldsymbol{o}_i\left(z^t\right), \boldsymbol{o}_i\left(z^{t-1}\right)\right).$$

$\boldsymbol{o}_i \in \{0,1\}^{2\mathcal{L}\mathcal{T}\Omega}$ is a decision rule that specifies the optimal location choices for all countries and all periods, under all possible histories of productivity shocks.

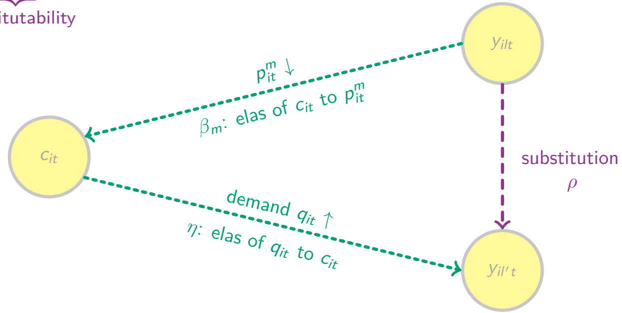
$\boldsymbol{z} = \{\xi_t\}_{t=0}^{\infty}$ represents a full history of productivity shocks, living in space Ω.

go back

Interpreting The Last Condition

Similar intuition as in Antras et al. (2017).

$$\underbrace{(\eta - 1) \cdot \beta_m}_{\text{complementarity}} > \underbrace{\rho - 1}_{\text{substitutability}}$$



- y_{ilt} and $y_{il't}$ are complementary when scale effect dominates input substitution effect.
- This condition holds empirically.

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Squeezing Under Complementarity — Static Case

$y_1 = 1$	$y_2 = 1$	$y_l = 1$	$y_L = 1$
$r_1 = 1$	$r_2 = 1$	$r_l = 1$	$r_L = 0$

go back

Squeezing Under Complementarity — Static Case

$y_1 = 1$	$y_2 = 1$	$y_l = 1$	$y_L = 1$
$r_1 = 1$	$r_2 = 1$	$r_l = 1$	$r_L = 0$

$$\downarrow$$

$y_1 = ?$	$y_2 = ?$	$y_l = ?$	$y_L = ?$
$r_1 = ?$	$r_2 = ?$	$r_l = ?$	$r_L = 0$

go back

Squeezing Under Complementarity — Static Case

$y_1 = 1$	$y_2 = 1$	$y_l = 1$	$y_L = 1$
$r_1 = 1$	$r_2 = 1$	$r_l = 1$	$r_L = 0$

$$\downarrow$$

$y_1 = ?$	$y_2 = ?$	$y_l = ?$	$y_L = ?$
$r_1 = ?$	$r_2 = ?$	$r_l = ?$	$r_L = 0$

$y_1 = 1$	$y_2 = 0$	$y_l = 0$	$y_L = 0$
$r_1 = 0$	$r_2 = 0$	$r_l = 0$	$r_L = 0$

▸ go back

Squeezing Under Complementarity — Static Case

$y_1 = 1$	$y_2 = 1$	$y_l = 1$	$y_L = 1$
$r_1 = 1$	$r_2 = 1$	$r_l = 1$	$r_L = 0$

$$\downarrow$$

$y_1 =?$	$y_2 =?$	$y_l =?$	$y_L =?$
$r_1 =?$	$r_2 =?$	$r_l =?$	$r_L = 0$

$$\vdots$$

$y_1 = 1$	$y_2 =?$	$y_l =?$	$y_L =?$
$r_1 =?$	$r_2 =?$	$r_l =?$	$r_L =?$

$$\uparrow$$

$y_1 = 1$	$y_2 = 0$	$y_l = 0$	$y_L = 0$
$r_1 = 0$	$r_2 = 0$	$r_l = 0$	$r_L = 0$

go back

Full Dynamic Problem and Constant Bound

- Recall the bellman equation for the full dynamic problem

$$V_{it}(\boldsymbol{s}_{it}) = \max_{\boldsymbol{y}_{it},\boldsymbol{r}_{it}} \{ \text{ obj } \},$$

  the solution for which is the following policy function,

$$\boldsymbol{o}_i : \left(\underbrace{t}_{T}, \underbrace{\boldsymbol{y}_{it-1}}_{2^L}, \underbrace{\boldsymbol{r}_{it-1}}_{2^L}, \underbrace{\omega_{it}}_{N_\omega} \right) \longrightarrow \left(\underbrace{\boldsymbol{y}_{it}}_{2^L}, \underbrace{\boldsymbol{r}_{it}}_{2^L} \right).$$

- Begin the algorithm with a "constant bound"

$$\overline{b}_i \equiv \{\overline{y}_{ilt}, \overline{r}_{ilt}\}_{l,t} = \mathbf{1}^{2TL} \in \{0,1\}^{2TL}$$

  that bounds the optimal choices regardless of the path of productivity shocks (& past states) and contemporary choices in other countries.

Single-Country Problem, Policy Function Bound, and Three Key Ideas

- Solve single-country problem, fixing choices in other countries at the constant bound,

$$\overline{V}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) = \max_{y_{ilt}, r_{ilt}} \left\{ \text{obj} \;\middle|\; \overline{b}_{i,-l,t} \right\},$$

Idea I: Breakdown

and obtain the solution $\overline{o}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) \in \{0,1\}^{2\times 4N_\omega}$.

Single-Country Problem, Policy Function Bound, and Three Key Ideas

- Solve single-country problem, fixing choices in other countries at the constant bound,

$$\overline{V}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) = \max_{y_{ilt}, r_{ilt}} \left\{ \text{obj} \;\middle|\; \overline{b}_{i,-l,t} \right\},$$

Idea 1: Breakdown

and obtain the solution $\overline{o}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) \in \{0,1\}^{2\times 4N_\omega}$.

- Repeat for all periods and countries to get a "policy function bound",

Idea 2: partial info

$$\overline{o}_i = \{\overline{o}_{ilt}\}_{l,t} \in \{0,1\}^{2TL\times 4N_\omega}$$

which bounds the optimal choices regardless of contemporary choices in other countries.

Single-Country Problem, Policy Function Bound, and Three Key Ideas

- Solve single-country problem, fixing choices in other countries at the constant bound,

$$\overline{V}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) = \max_{y_{ilt}, r_{ilt}} \left\{ \text{obj} \,\middle|\, \overline{b}_{i,-l,t} \right\},$$

  and obtain the solution $\overline{o}_{ilt}(y_{ilt-1}, r_{ilt-1}, \omega_{it}) \in \{0,1\}^{2\times 4N_\omega}$.

  Idea 1: Breakdown

- Repeat for all periods and countries to get a "policy function bound",

  Idea 2: partial info

$$\overline{o}_i = \{\overline{o}_{ilt}\}_{l,t} \in \{0,1\}^{2TL\times 4N_\omega}$$

  which bounds the optimal choices regardless of contemporary choices in other countries.

- Evaluate the policy function bound $\overline{o}_i$ on the most favorable path of productivity shocks to obtain a new constant bound $\overline{b}_i'$.

  Idea 3: ↓ # problems

- Iterate until constant bound converges and save converged policy function bound as $\overline{o}_i^*$.

Wrap Up the Algorithm

- Following the same logic and starting from $\underline{b}_i = \mathbf{0}^{2TL}$ to get the converged lower bound policy function $\underline{o}_i^*$.
- Evaluate the policy function bounds, $\overline{o}_i^*$ and $\underline{o}_i^*$, on the simulated path of shocks (i.e. the path of interest) to get bounds on firm choices along this shock path.
- If they coincide, the solution is found. If not, do further refinement by repeating the algorithm for a subset of non-converging periods and groups of countries.
- Supermodularity guarantees that the constant and policy function bounds remain to be proper bounds on the true policy function during iterations.

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Comparison to Alfaro-Urena et al. (2023)

1. Incorporate *two* interrelated dynamic choices with rich complementarities.
2. Accommodate a more general context where the static profit function isn't additively separable across countries but only supermodular.
3. Allow the evolution of the unobserved state to be endogenously affected by choices.

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Step 1 - Estimate Input Elasticity of Substitution

$$\widehat{\ln \theta_{lt}} = -(\rho - 1) \cdot \ln(1 + T_{lt}) + \nu_{lt}.$$

	(1) $\ln \hat{\theta}_{lt}$	(2) $\ln \hat{\theta}_{lt}$	(3) $\ln \hat{\theta}_{lt}$
$\ln(1 + T_{lt})$	-2.739*	-2.952***	-3.697***
	(1.567)	(1.123)	(1.110)
Log Population		0.358***	0.580***
		(0.0203)	(0.0252)
Common Language Dum		0.0246	-0.109*
		(0.0820)	(0.0601)
Colony Dum		0.0622	-0.210***
		(0.0712)	(0.0535)
Human Capital Index			0.657***
			(0.0840)
Control of Corruption Index			0.230***
			(0.0467)
N	450	450	450

- Elasticity of production-offshoring potential to tariff rate identifies ρ.

  When inputs are more substitutable, input demand is more responsive to tariff changes.

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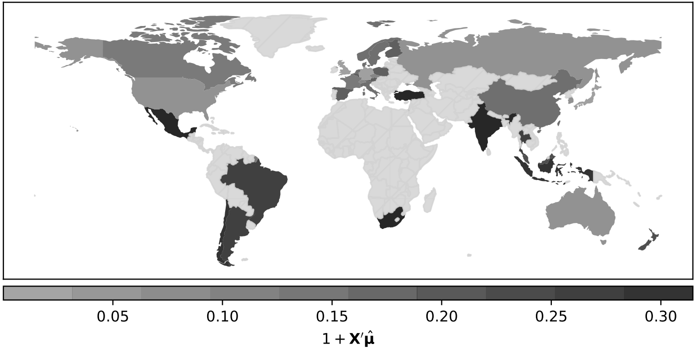
Step 2 - Heterogeneous Synergy Effect by Country



- ▷ Masking rich industry heterogeneity, e.g. chemicals for India, electronics for Japan, transportation equipment for Canada.
- ▷ Immersion to exotic cultures spark new idea and require product customization.
- ▷ Intensive margin of offshoring is larger when fixed costs are higher.

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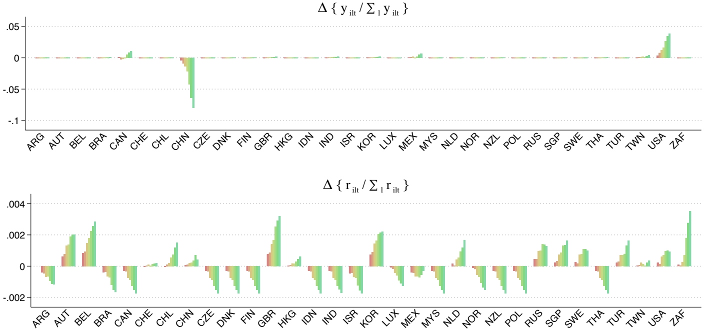
Third-Country Effects Are Nontrivial and Robust

- In two years after China's production-offshoring potential drops by 25% (tariff ↑ by 11%)
  - Prob. of production offshoring: ↓ 9.4 p.p. (20%) in China, ↓ 0.8 p.p. (5.5%) in ROW
  - Prob. of innovation offshoring: ↓ 0.11 p.p. (9.4%) in China, ↓ 0.2 p.p. (10%) in ROW
- Innovation shares get diverted to countries like the UK, South Korea, and Belgium.



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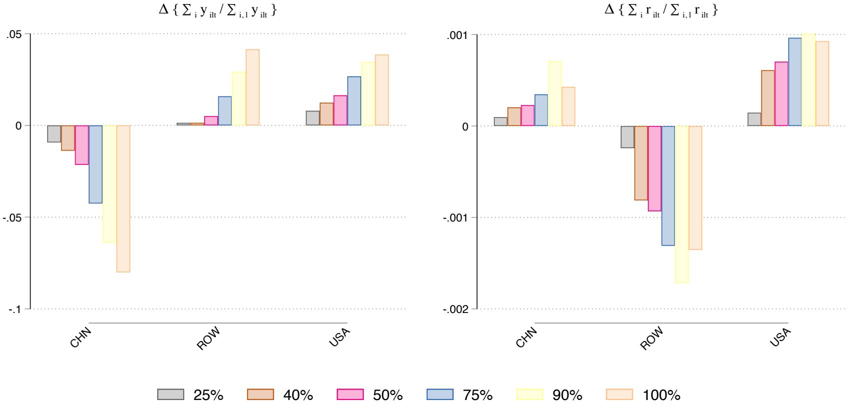
Effects of Tariff Changes



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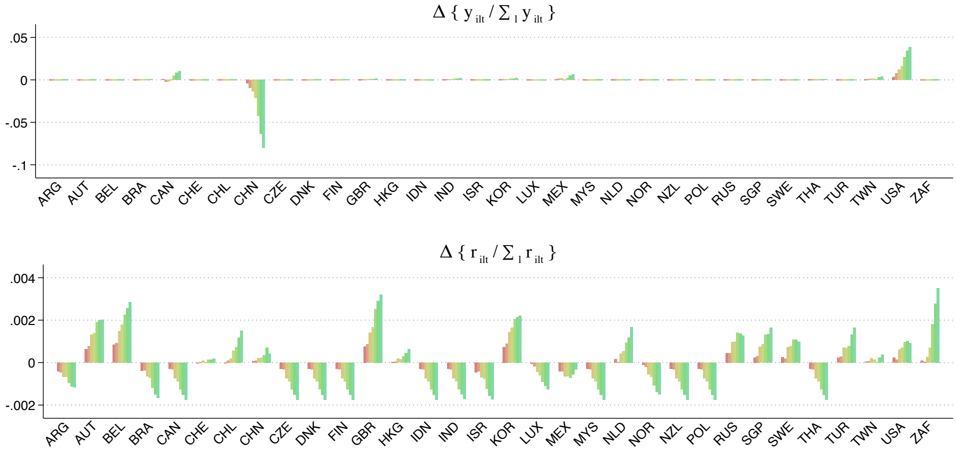
Effects of Counterfactual Policies By Country

Increasing Tariffs



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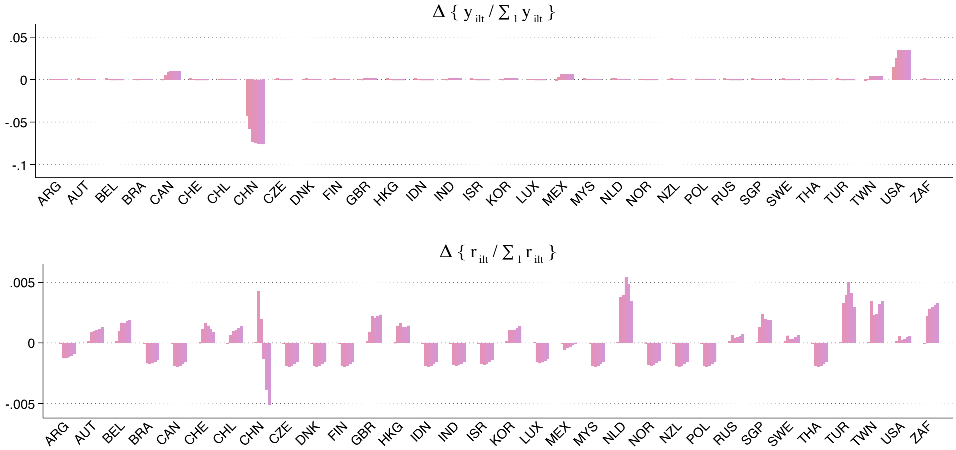
Effects of Counterfactual Policies By Country

Increasing Costs of Production Offshoring



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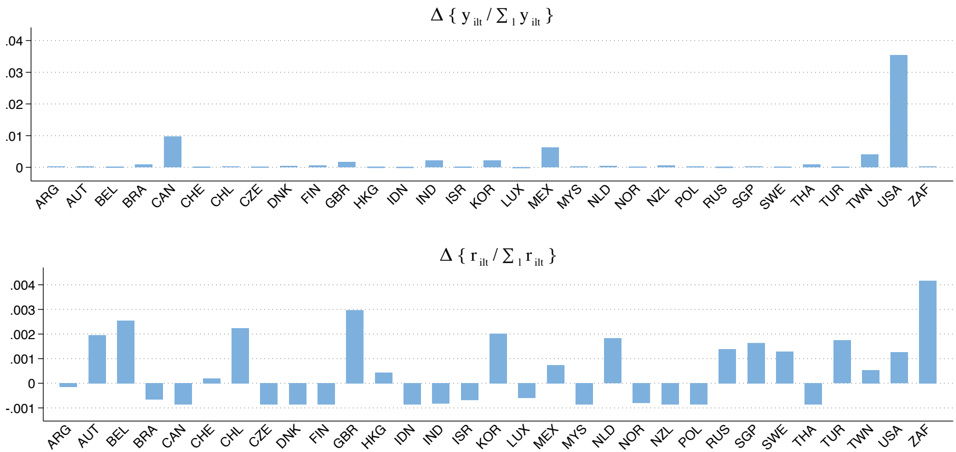
Simulated Effect of U.S-China Decoupling



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