The effect of trade liberalization on multinational production

A quantitative trade general equilibrium model with multinational production and input-output linkages

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Introduction

Abstract

What this study does

- This study constructs a quantitative trade general equilibrium model with multinational production and input-output linkages.
- This study simulates how the decrease in **import costs** in a host country changes the **multinational production** through foreign direct investment (FDI) in the host country.

Abstract

Main finding

When import costs in Ireland **decrease**, foreign firms will be less likely to locate their production bases in Ireland, while the output of the foreign firms that remain in Ireland will conversely **increase**.

Background

Horizontal and vertical FDI

- ▷ Horizontal FDI: FDI that aims to **avoid export costs**.
- ▷ Vertical FDI: FDI that aims to **reduce production costs**.

When import costs in a host country decrease...

- ▷ Horizontal FDI **decreases** (Markusen and Venables 1998).
- ▷ Vertical FDI **increases** (Yeaple 2003).

Motivation

Motivation

This study is motivated to quantify:

1. how the decrease in import costs in a host country changes the multinational production through horizontal and vertical FDI;
2. how the multinational production changes in aggregate.

Related studies

Quantitative trade general equilibrium model

- Alviarez (2019):

  MP + IO linkage

- Tintelnot (2017):

  MP + extensive & intensive margin

- **Our model**:

  MP + IO linkage + extensive & intensive margin

Contribution

Contribution

1. Our model can capture the effect on both horizontal and vertical FDI by considering multinational production and input-output linkages.
2. Our model allows us to see the change in the probability of a firm locating its production base abroad (**extensive margin**) and the change in output at the production base (**intensive margin**).

Theoretical framework

Key features

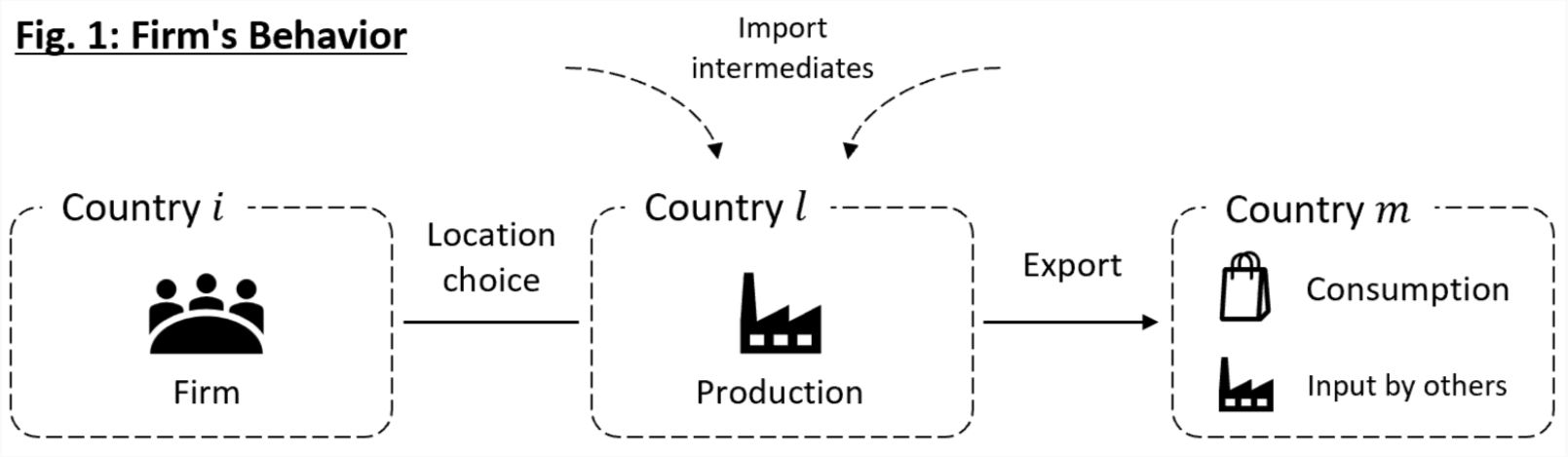
Key features

- ▷ Many countries & Many industries & Many firms

- ▷ Each firm behaves in following steps:
  1. **Location**: A firm chooses the set of countries in which to establish their production bases;
  2. **Input**: A firm determines the volume of inputs of labor and intermediate goods from each industry;
  3. **Export**: A firm determines the volume of production and exports of each production base.

- ▷ Three types of costs:
  1. Trade costs τ;
  2. Efficiency losses of a firm operating a production base abroad γ;
  3. Fixed costs of a firm establishing a production base abroad η.

Key features



Key features

Key features (cont'd)

- Horizontal and vetical FDI
  - We can capture horizontal FDI by assuming that firms can choose both export and multinational production.
  - We can capture vertical FDI by assuming that firms use intermediate goods in production.

- Firms are heterogenous in terms of productivity.
  - Combined with the assumption of fixed costs, this would result in a mix of firms that locate their production base abroad and those that do not.
  - Consequently, we can analyze both extensive and intensive margins of multinational production.

Basic settings

Basic settings

- ▷ The economy consists of N countries and S industries.
- ▷ Each firm belongs to one of the countries and industries, and is continuously distributed by country and industry.
- ▷ A firm determines:
  - ○ which countries to locate production bases;
  - ○ how to procure production factors and intermediate goods;
  - ○ how much goods to produce and export to each country.

- ▶ Each firm produces continuous goods $v \in [0, 1]$, which are heterogenous across firms.
- ▶ The markets of firm-level goods are monopolistically competitive.

Settings on compound goods

Settings on compound goods

- Firm-level goods are consumed as final goods or used as intermediate goods only when they are aggregated by country and industry (**compound goods**, Caliendo and Parro (2015)).
  - ▷ There are numerous and homogeneous producers of compound goods in each country and industry.
  - ▷ Compound goods are non-tradable and the compound goods markets are perfectly competitive.

- We can obtain the demand function for firm-level goods by solving cost minimization problem of compound goods producers.

Behavior of compound goods producers

Production function of compound goods

- The production function of compound goods of industry s in country m:

$$Q_{ms} \equiv \left(\int_{\omega \in \Omega_{ms}} \int_0^1 q_{ms}(\omega, v)^{\frac{\sigma_s - 1}{\sigma_s}} dv d\omega \right)^{\frac{\sigma_s}{\sigma_s - 1}}. \tag{1}$$

  - ω and v: a firm and type of goods produced by the firm, respectively.
  - Ω_{ms}: a set of firms in industry s whose goods are demanded in country m.
  - $q_{ms}(\omega, v)$: demand of compound goods producers in country m for the goods v of firm ω in industry s.
  - $\sigma_s (> 1)$: elasticity of substitution in industry s.

Behavior of compound goods producers

Cost minimization problem

- Compound goods producers minimize the production cost in achieving certain levels of Q_{ms}:

$$\min_{q_{ms}(\omega)} \int_{\omega \in \Omega_{ms}} \int_0^1 p_{ms}(\omega, v) q_{ms}(\omega, v) dv d\omega$$

$$s.t. \quad \left(\int_{\omega \in \Omega_{ms}} \int_0^1 q_{ms}(\omega, v)^{\frac{\sigma_s - 1}{\sigma_s}} dv d\omega \right)^{\frac{\sigma_s}{\sigma_s - 1}} = Q_{ms}. \qquad (2)$$

  - $p_{ms}(\omega, v)$: price of goods v in country m.

Behavior of compound goods producers

Demand function for firm-level goods

- By solving this problem, we can obtain the demand function for firm-level goods:

$$q_{ms}(\omega, v) = p_{ms}(\omega, v)^{-\sigma_s} P_{ms}^{\sigma_s} Q_{ms}. \tag{3}$$

- P_{ms} is the **industry-level** price index:

$$P_{ms} \equiv \left(\int_{\omega \in \Omega_{ms}} p_{ms}(\omega)^{1-\sigma_s} d\omega \right)^{\frac{1}{1-\sigma_s}}. \tag{4}$$

  - $p_{ms}(\omega)$ is the **firm-level** price index of firm ω:

$$p_{ms}(\omega) \equiv \left(\int_0^1 p_{ms}(\omega, v)^{1-\sigma_s} dv \right)^{\frac{1}{1-\sigma_s}}. \tag{5}$$

  - The production cost of compound goods becomes $P_{ms}Q_{ms}$. Since the compound goods markets are perfectly competitive, the price of coupound goods becomes P_{ms}.

Consumer's behavior

Preference

- We can obtain the demand for compound goods as final goods by solving utility maximization problem.

  - The preference of the representative consumer is represented as follows:

$$C_m \equiv \prod_{s=1}^{S} C_{ms}^{\beta_{ms}}. \tag{6}$$

    - C_{ms}: consumption of compound goods.
    - β_{ms}: a parameter satisfying $\beta_{ms} \geq 0$ and $\sum_{s=1}^{S} \beta_{ms} = 1$.

Consumer's behavior

Utility maximization problem

- The utility maximization problem is given by:

$$\max_{C_{ms}} \prod_{s=1}^{S} C_{ms}^{\beta_{ms}} \quad s.t. \quad \sum_{s=1}^{S} P_{ms} C_{ms} = Y_m. \tag{7}$$

  - Y_m: total income of country m.

- By solving this problem, we can obtain the optimal consumption of compound goods:

$$C_{ms} = \frac{\beta_{ms} Y_m}{P_{ms}}. \tag{8}$$

Firm's behavior – Key settings

Decision-making process

- Each firm behaves in following steps:
  0. Upon entry, a firm knows the **core productivity**, which represents the productivity common across the production bases of the firm and stochastically determined.
  1. A firm chooses the countries in which to establish their production bases and knows the **local productivity**, which is specific to each production base and stochastically determined.
  2. A firm determines the volume of inputs of production factors and intermediate goods.
  3. A firm determines the volume of production and exports.

Three types of costs

1. Iceberg-type trade costs of exporting goods to foreign countries.
2. Marginal costs of operating a production base in a foreign country.
3. Fixed costs of establishing a production base in a foreign country.

Firm's behavior – Distribution of productivity

Distribution of productivity

- The local productivity ν_{ls} when a firms produces in country l follows Fréchet distribution:

$$\Pr\left(\nu_{ls} \leq a\right) = \exp\left(-\left(\frac{\phi_s \epsilon_{ls}}{a}\right)^{\theta}\right). \tag{9}$$

  - ϕ_s: core productivity of the firm.
  - ϵ_{ls}: local productivity shifter.
  - θ: a shape paremeter of the distribution.

Firm's behavior – Distribution of productivity

Distribution of unit supply cost

- Let $\gamma_{ils}\tau_{lms}c_{ls}/\nu_l$ be the unit supply cost for a firm of industry s in country i to produce in country l and supply to country m.
  - γ_{ils}: efficiency loss of country i's firm operating in country l.
  - τ_{lms}: iceberg-type trade cost of exporting goods from country l to country m.
  - c_{ls}: unit input cost of production in country l.

▷ From Eq. (9), the distribution of this unit cost is given by:

$$\Pr\left(\frac{\gamma_{ils}\tau_{lms}c_{ls}}{\nu_{ls}} \leq b\right) = 1 - \exp\left(-\left(\frac{\gamma_{ils}\tau_{lms}c_{ls}}{\phi_s \epsilon_{ls}}\right)^{-\theta} b^{\theta}\right). \quad (10)$$

Firm's behavior – Distribution of productivity

Distribution of unit supply cost (total in a firm)

- When we assume that
  - a set of production location Z is given,
  - a firm produces each goods v in the location where the firm can supply the goods at the lowest cost,

the unit cost b that firm $(i, s, Z, \phi, \epsilon)$ exports the goods to country m follows the following distribution:

$$B\left(b|i,s,Z,\phi,\epsilon\right) = 1 - \exp\left(-\sum_{l\in Z}\left(\frac{\gamma_{ils}\tau_{lms}c_{ls}}{\phi_s\epsilon_{ls}}\right)^{-\theta} b^{\theta}\right). \quad (11)$$

Firm's behavior – Optimization of export volume

Profit maximization problem

- A firm determines the export volume to country m to maximize the profit.

  - The profit of firm ω in industry s is given as follows when the firm produces goods v and exports to country m:

$$\pi_{ms}(\omega, v) = p_{ms}(\omega, v) q_{ms}(\omega, v) - b q_{ms}(\omega, v). \tag{12}$$

- From the first order condition:

$$p_{ms}(\omega, v) = \frac{\sigma_s b}{\sigma_s - 1}. \tag{13}$$

Firm's behavior – Optimization of export volume

Profit function of firm

- From Eq. (3) and (13), the profit function of Eq. (12) is rewritten as follows:

$$\pi_{ms}(\omega, v) = \sigma_s^{-\sigma_s}(\sigma_s - 1)^{\sigma_s - 1} P_{ms}^{\sigma_s} Q_{ms} b^{1-\sigma_s}. \tag{14}$$

- Using the distribution function of Eq. (11) and the profit function of Eq. (14), we can derive the aggregate profit of firm $(i, s, Z, \phi, \epsilon)$ exporting its all goods to country m:

$$\pi_m(i, s, Z, \phi, \epsilon) = \frac{\kappa_s}{\sigma_s} \left(\sum_{l \in Z} \left(\frac{\gamma_{ils} \tau_{lms} c_{ls}}{\phi_s \epsilon_{ls}} \right)^{-\theta} \right)^{\frac{\sigma_s - 1}{\theta}} P_{ms}^{\sigma_s} Q_{ms}. \tag{15}$$

  - $\kappa_s \equiv (\sigma_s/(\sigma_s - 1))^{1-\sigma_s} \Gamma((\theta + 1 - \sigma_s)/\theta)$
  - $\Gamma(t) \equiv \int_0^\infty x^{t-1} \exp(-x) dx$

Firm's behavior – Optimization of inputs

Production function

- A firm determines the inputs of labor and intermediate goods to minimize the production cost in achieving a certain level of output:

  - The production function of firm ω producing goods v in country l:

$$y_{ls}(\omega, v) \equiv L_{ls}(\omega, v)^{1-\delta_s} \left(\prod_{r=1}^{S} I_{lsr}(\omega, v)^{\alpha_{sr}} \right)^{\delta_s}. \tag{16}$$

    - $L_{ls}(\omega, v)$: firm ω's labor input to produce goods v.
    - $I_{lsr}(\omega, v)$: firm ω's input of intermediate goods from industry r to produce goods v.
    - α_{sr} and δ_s: parameters satisfying $\alpha_{sr}, \delta_s \in (0, 1)$ and $\sum_{r=1}^{S} \alpha_{sr} = 1$.

Firm's behavior – Optimization of inputs

Cost minimization problem

▷ The cost minimization problem of a firm is given by:

$$\min_{L_{ls}(\omega,v),I_{lsr}(\omega,v)} w_l L_{ls}(\omega,v) + \sum_{r=1}^{S} P_{lr} I_{lsr}(\omega,v)$$

$$s.t. \quad L_{ls}(\omega,v)^{1-\delta_s} \left(\prod_{r=1}^{S} I_{lsr}(\omega,v)^{\alpha_{sr}} \right)^{\delta_s} = y_{ls}(\omega,v). \qquad (17)$$

Firm's behavior – Optimization of inputs

Optimal inputs of labor and intermediate goods

- By solving this problem, we can obtain the optimal inputs of labor and intermediate goods:

$$L_{ls}(\omega, v) = \left(\frac{\delta_s w_l}{1-\delta_s} \prod_{r=1}^{S} \left(\frac{\alpha_{sr}}{P_{lr}} \right)^{\alpha_{sr}} \right)^{-\delta_s} y_{ls}(\omega, v). \tag{18}$$

$$I_{lsr}(\omega, v) = \frac{\alpha_{sr}}{P_{lr}} \left(\frac{\delta_s w_l}{1-\delta_s} \right)^{1-\delta_s} \left(\prod_{r=1}^{S} \left(\frac{\alpha_{sr}}{P_{lr}} \right)^{\alpha_{sr}} \right)^{-\delta_s} y_{ls}(\omega, v). \tag{19}$$

  - From Eq. (18) and (19), we can express the unit cost function as follows:

$$c_{ls} = \delta_s^{-\delta_s} (1-\delta_s)^{-(1-\delta_s)} w_l^{1-\delta_s} \left(\prod_{r=1}^{S} \left(\frac{\alpha_{sr}}{P_{lr}} \right)^{\alpha_{sr}} \right)^{-\delta_s}. \tag{20}$$

Firm's behavior – Location choice

Expected total profit

- ▷ At the time of entry, a firm knows its core productivity ϕ_s and fixed cost of establishing a production base η_{is}.
- When a firm chooses the combinations of locations of production bases Z, it bears the fixed cost $\sum_{l \in Z} \eta_{ils} w_l$.
- The expected total profit of the firm that chooses the combination of countries Z is given by:

$$E_\epsilon \left(\Pi(i, s, Z, \phi, \epsilon, \eta)\right) = \sum_{m=1}^{N} E_\epsilon \left(\pi_m(i, s, Z, \phi, \epsilon)\right) - \sum_{l \in Z} \eta_{ils} w_l. \quad (21)$$

Firm's behavior – Location choice

Location choice

- The firm chooses the combination of countries Z to maximize the expected total profit:

$$Z(i, s, \phi, \eta) \in \arg\max_{Z \in \mathcal{Z}_i} E_\epsilon \left(\Pi(i, s, Z, \phi, \epsilon, \eta)\right). \tag{22}$$

General equilibrium – Additional variables

We next derive the general equilibrium conditions.

Additional exogenous variables

- L_i: number of labor force in country i.
- M_{is}: **potential** number of country i' firms in industry s.

Distribution of random variables

- ϕ_s follows the distribution $G_s(\phi)$, which is continuous.
- η_{is} follows the distribution $F_{is}(\eta)$, which is different and independent across countries.

General equilibrium – Firm-level variables

Additional firm-level variables

▷ Firm-level price index

$$p_m(i,s,Z,\phi,\epsilon) = \kappa_s^{\frac{1}{1-\sigma_s}} \left(\sum_{l \in Z} \left(\frac{\gamma_{ils}\tau_{lms}c_{ls}}{\phi_s \epsilon_{ls}} \right)^{-\theta} \right)^{-\frac{1}{\theta}}. \tag{23}$$

▷ Firm-location-level inputs of labor and intermediate goods

$$L_l(i,s,Z,\phi,\epsilon) = \left(\frac{\delta_s w_l}{1-\delta_s} \prod_{r=1}^{S} \left(\frac{\alpha_{sr}}{P_{lr}} \right)^{\alpha_{sr}} \right)^{-\delta_s}$$

$$\times \sum_{m=1}^{N} \frac{\left(\gamma_{ils}\tau_{lms}c_{ls}/\epsilon_{ls}\right)^{-\theta}}{\sum_{l' \in Z} \left(\gamma_{il's}\tau_{l'ms}c_{l's}/\epsilon_{l's}\right)^{-\theta}} \; p_m(i,s,Z,\phi,\epsilon)^{-\sigma_s} P_{ms}^{\sigma_s} Q_{ms}. \tag{24}$$

$$I_{lr}(i,s,Z,\phi,\epsilon) = \frac{\alpha_{sr}}{P_{lr}} \left(\frac{\delta_s w_l}{1-\delta_s} \right)^{1-\delta_s} \left(\prod_{r=1}^{S} \left(\frac{\alpha_{sr}}{P_{lr}} \right)^{\alpha_{sr}} \right)^{-\delta_s}$$

$$\times \sum_{m=1}^{N} \frac{\left(\gamma_{ils}\tau_{lms}c_{ls}/\epsilon_{ls}\right)^{-\theta}}{\sum_{l' \in Z} \left(\gamma_{il's}\tau_{l'ms}c_{l's}/\epsilon_{l's}\right)^{-\theta}} \; p_m(i,s,Z,\phi,\epsilon)^{-\sigma_s} P_{ms}^{\sigma_s} Q_{ms}. \tag{25}$$

General equilibrium

General equilibrium conditions

1. **Industry-level price index**:

$$P_{ms} = \left(\sum_{i=1}^{N} \int_{\phi} \sum_{Z \in \mathcal{Z}_i} M_{is} \rho_Z(i,s,\phi) E_\epsilon \left(p_m(i,s,Z,\phi,\epsilon)^{1-\sigma_s} \right) dG_s(\phi) \right)^{\frac{1}{1-\sigma_s}}. \tag{26}$$

$\rho_Z(i,s,\phi)$ is the share of firms from country i in industry s having core productivity ϕ that chooses Z as the combination of production locations:

$$\rho_Z(i,s,\phi_s) = \int_{\eta} \mathbf{1}\left[Z(i,s,\phi,\eta) = Z \right] dF_{is}(\eta). \tag{27}$$

General equilibrium

2. Market clearing condition of compound goods:

$$Q_{lr} = \frac{\beta_{lr} Y_l}{P_{lr}} + \sum_{s=1}^{S} \sum_{i=1}^{N} \int_{\phi} \sum_{Z \in \Delta_{il}} M_{is} \rho_Z(i,s,\phi) E_\epsilon \left(I_{lr}(i,s,Z,\phi,\epsilon) \right) dG_s(\phi). \tag{28}$$

- $\Delta_l = \{Z \in \mathcal{Z} | l \in Z\}$: a set of Z that includes country l.
- Y_i is the total income:

$$Y_i = w_i L_i + \sum_{s=1}^{S} \int_{\phi} \int_{\eta} \sum_{Z \in \mathcal{Z}_i} M_{is} \mathbf{1}[Z(i,s,\phi,\eta) = Z] E_\epsilon \left(\Pi(i,s,Z,\phi,\epsilon,\eta) \right) dF_{is}(\eta) dG_s(\phi). \tag{29}$$

3. Labor market clearing condition:

$$\begin{aligned} L_l &= \sum_{s=1}^{S} \sum_{i=1}^{N} \int_{\phi} \sum_{Z \in \Delta_{il}} M_{is} \rho_Z(i,s,\phi) E_\epsilon \left(L_l(i,s,Z,\phi,\epsilon) \right) dG_s(\phi) \\ &+ \sum_{s=1}^{S} \sum_{i=1}^{N} \int_{\phi} \int_{\eta} \sum_{Z \in \Delta_{il}} M_{is} \mathbf{1}[Z(i,s,\phi,\eta) = Z] \eta_{il} dF_{is}(\eta) dG_s(\phi). \end{aligned} \tag{30}$$

Calibration and data

Calibration

Sample

8 countries and 6 manufacturing industries in 2016.

Parameters

- δ_s: $1-$ share of payment for labor
  - We use the data on the value added share in total output of each industry from the IO table (OECDSTAN).
- α_{sr}: data on the input coefficients in the IO table (OECDSTAN)
- β_{ms}: data on the final demand share of each industry in the IO table (OECDSTAN)
- $\sigma_s = 6$ (Tintelnot, 2017)
- $\theta = 7$ (Tintelnot, 2017)

Exogenous variables

- L_i: data on the number of labor force (Penn World Table 10.0)
- M_{is}: data on the output in each country and industry (OECDSTAN)

Calibration – Trade costs

Calibration of trade costs

- We estimate trade costs τ by approximating the export share calculated from the model to that in the data.
- We consider the model that excludes the setting of multinational production (pure trade model).
  - ▷ The export sales of a firm is given by:

$$r_{lm}^{pure}(l,s,l,\phi,\epsilon) = \kappa_s \left(\tau_{lms} c_{ls}/\phi_s \epsilon_{ls}\right)^{1-\sigma_s} P_{ms}^{\sigma_s} Q_{ms}. \tag{31}$$

  - ▷ The total exports from country l to country m of industry s can be expressed as follows:

$$X_{lms}^{pure} = \int_{\phi} M_{ls} E_{\epsilon}\left(r_{lm}^{pure}(l,s,l,\phi,\epsilon)\right) dG_s(\phi). \tag{32}$$

Calibration – Trade costs

Calibration of trade costs (cont'd)

- The export share is represented as follows:

$$\xi_{lms}^{pure} = \frac{X_{lms}^{pure}}{\sum_{m=1}^{N} X_{lms}^{pure}} = \frac{\tau_{lms}^{1-\sigma} P_{ms}^{\sigma_s} Q_{ms}}{\sum_{m=1}^{N} \tau_{lms}^{1-\sigma_s} P_{ms}^{\sigma_s} Q_{ms}}. \tag{33}$$

- We define the following vector:

$$d^{pure}(\tau) = \left(\xi^{pure}(\tau) - \hat{\xi} \right), \tag{34}$$

where $\hat{\xi}$ is the export share that is calculated from the data.

- We estimate τ by minimizing $d^{pure}(\tau)' d^{pure}(\tau)$ with respect to τ.

Calibration – Distribution parameters

Calibration of distribution parameters

We borrow the value of distribution parameters from Tintelnot (2017).

- $\gamma_{ils} = 1.211 \times dist_{il}^{0.004} \times 0.984^{contig_{il}} \times 0.944^{lang_{il}}$
- The local productivity shifter ϵ follows the log-normal distribution $\log \mathcal{N}(0, \sigma_\epsilon)$.
  - $\sigma_\epsilon = 0.108$
- The core productivity ϕ_s follows the Pareto distribution with the scale parameter estimated as $\mu_\phi = 0.783$ and shape parameter estimated as $\sigma_\phi = 6.436$.
  - $\mu_{\phi_s} = 0.783$
  - $\sigma_{\phi_s} = 6.436$
- The fixed cost η_{ils} follows the log-normal distribution $\log \mathcal{N}(\mu_{\eta_{il}}, \sigma_\eta)$.
  - $\mu_{\eta_{ils}} = 2.608 \times dist_{il}^{0.000} \times 0.851^{contig_{il}} \times 1.429^{lang_{il}}$
  - $\sigma_{\eta_{ils}} = 0.262$

Quantitative analysis

Methodology

Counterfactual senario

We calculate the change in multinational production in Ireland when the economy moves from the baseline equilibrium to the counterfactual equilibrium with import costs in Ireland $\tau_{l,IRL,s}$ being 1.

Methodology

How to measure "multinational production"

1. Probability of a foreign firm establishing a production base in Ireland.
2. Output of foreign firms at their production bases in Ireland.

How to measure horizontal and vertical FDI

We analyze the impacts on horizontal and vertical FDI by comparing following two models:

- ▷ Full model: model explained in the previous section (considers **both** types of FDI).
- ▷ No-IO model: model that excludes the setting of input-output linkages (only considers **horizontal FDI**)

Methodology

Hypothesis

- Multinational production in Ireland will **decrease** in the **No-IO model** when import costs in Ireland decrease.
- The scale of decrease in multinational production will be **smaller** (or multinational production will even **increase**) in the **full model** because the positive effect on vertical FDI may offset the negative impact on horizontal FDI.

Methodology

Industry classification

A. Total petroleum, chemical, rubber and plastic products (ISIC4: C19-22)
B. Basic metals and fabricated metal products (ISIC4: C24-25)
C. Computer, electronic and optical products (ISIC4: C26)
D. Electrical equipment (ISIC4: C27)
E. Machinery and equipment n.e.c. (ISIC4: C28)
F. Transport equipment (ISIC4: C29-30)

Table 1: Changes in the probability to choose Ireland for the production location (%).

Home country	Chemical product	Metal product	Electronic product	Electrical equipment	Machinery	Transport equipment
Full model						
Austria	-28.9729	-34.8225	-35.5755	-33.6218	-35.8425	-36.0094
Belgium	-36.5200	-40.2645	-40.6853	-38.7508	-40.9503	-41.0881
Switzerland	-29.7847	-35.7498	-35.5608	-33.2851	-36.0238	-36.1437
Germany	-24.4920	-28.9033	-29.2592	-27.7830	-29.4505	-29.5568
France	-28.9051	-32.6112	-33.1782	-31.9294	-33.3038	-33.3742
United Kingdom	-39.6562	-44.4803	-46.4545	-43.2729	-46.5684	-46.9596
Italy	-23.1175	-28.9711	-29.4018	-27.5828	-29.8261	-29.9674
No-IO model						
Austria	-68.0711	-66.1611	-56.6857	-39.6394	-65.7097	-64.8338
Belgium	-70.6284	-67.6142	-55.6228	-34.8411	-67.0617	-65.7319
Switzerland	-69.4278	-66.8063	-54.2333	-32.6866	-66.3501	-62.9373
Germany	-54.9248	-51.2854	-38.1958	-15.1591	-50.6486	-48.4673
France	-62.3231	-57.9940	-50.4250	-32.2503	-57.5320	-55.9546
United Kingdom	-77.2794	-77.3259	-69.7093	-58.0427	-76.9989	-75.6905
Italy	-59.8338	-56.9270	-40.5418	-24.6321	-56.4425	-54.2451

Note: This table shows the changes in the probability of a foreign firm establishing a production base in Ireland when the economy moves from the baseline equilibrium to the counterfactual equilibrium with import costs in Ireland $\tau_{l,IRL,s}$ being 1. The block named "Full model" shows the results obtained from the model explained in the previous section while the block named "No-IO model" shows the result obtained from the model that excludes the setting of input-output linkages from the full model.

Table 2: Changes in the output of foreign firms in Ireland (%).

Home country	Chemical product	Metal product	Electronic product	Electrical equipment	Machinery	Transport equipment
Full model						
Austria	185.8714	110.3171	-0.1566	8.7872	-3.2344	-12.3888
Belgium	155.1982	93.7191	-6.3783	0.8948	-7.6572	-14.9461
Switzerland	187.8808	102.8851	2.8371	9.4797	3.7711	-12.9977
Germany	206.5231	133.9584	13.8785	22.7394	14.1001	6.4495
France	185.4435	117.6358	5.0617	14.3636	4.8546	-0.9362
United Kingdom	158.8373	75.3770	-14.3455	-7.4486	-16.8961	-22.5936
Italy	215.4915	135.9654	10.8966	21.1219	11.4672	-5.3078
No-IO model						
Austria	-70.9619	-74.6013	-32.2521	-4.1402	-50.9541	-50.0211
Belgium	-73.8359	-74.3876	-29.7975	2.4536	-51.2270	-49.3558
Switzerland	-72.4621	-75.6928	-28.0498	5.5322	-49.3534	-46.5182
Germany	-59.2278	-58.9451	-1.6252	35.7643	-26.5429	-23.0414
France	-67.1286	-67.6255	-21.9237	9.6159	-37.5249	-33.4477
United Kingdom	-79.2912	-80.1154	-51.3913	-31.1525	-65.2610	-63.1823
Italy	-63.8434	-65.6362	-7.4073	20.8220	-36.1375	-34.7184

Note: This table shows the changes in the output of production bases of foreign firms in Ireland when the economy moves from the baseline equilibrium to the counterfactual equilibrium with import costs in Ireland $\tau_{l,IRL,s}$ being 1. The block named "Full model" shows the results obtained from the model explained in the previous section while the block named "No-IO model" shows the result obtained from the model that excludes the setting of input-output linkages from the full model.

Results

Summary of results

- The **probability** of establishing a production base in Ireland **decrease**, but the extent of the decline is **smaller** when we consider input-output linkages.
  - This suggests that lower import costs in a specific country will increase the relocation of production bases through vertical FDI to that country, although this will not offset the decrease in the relocation through horizontal FDI.
  - This result is consistent with the result of previous empirical studies (Markusen and Maskus, 2002; Ramondo et al., 2013).
- The **output** of foreign firms in Ireland **increases** for many countries and industries when we consider input-output linkages while their output decreases when we exclude the setting of input-output linkages.

Results

Implication of results

- When import costs in Ireland decrease, fewer foreign firms will locate their production bases in Ireland (**negative extensive margin**),
- while the output of the foreign firms that remain in Ireland will conversely increase because it will be easier to procure intermediate goods from abroad (**positive intensive margin**).

Conclusion

Summary of this study

Purpose of this study

- ▷ This study constructs a quantitative trade general equilibrium model with multinational production and input-output linkages,

  which can capture both horizontal and vertical FDI.
- ▷ This study simulates how the decrease in import costs in a host country changes the multinational production in the host country.

Main finding

When import costs in Ireland **decrease**, foreign firms will be less likely to locate their production bases in Ireland, while the output of the foreign firms that remain in Ireland will conversely **increase**.

Ongoing tasks

Estimation of distribution parameters

- I'm working on the estimation the distribution parameters of random variables (such as productivity and fixed cost).
- I'm now using firm-level data on multinational and domestic sales of Japanese firms from following sources:
  - Basic Survey on Overseas Business Activities (海外事業活動基本調査)
  - Basic Survey of Japanese Business Structure and Activities (企業活動基本調査)

Additional analysis

- The effects of NAFTA
- The impact of Brexit

Reference

- Alviarez, Vanessa. 2019. "Multinational production and comparative advantage." *Journal of International Economics.* 119: 1-54.
- Caliendo, Lorenzo, and Fernando Parro. 2015. "Estimates of the trade and welfare effects of NAFTA." *Review of Economic Studies.* 82(1): 1-44.
- Markusen, James R. and Maskus, Keith E. 2002. "Discriminating among alternative theories of the multinational enterprise." *Review of International Economics.* 10(4): 694707.
- Markusen, James R., and Venables, Anthony J. 1998. "Multinational firms and the new trade theory." *Journal of International Economics.* 46: 183-203.
- Ramondo, Natalia, Rappoport, Veronica, and Ruhl., Kim J. 2013. "Horizontal versus vertical foreign direct investment: evidence from US multinationals." Working Paper. London: London School of Economics.
- Tintelnot, Felix. 2017. "Global production with export platforms." *Quarterly Journal of Economics.* 132(1): 157-209.
- Yeaple, Stephen R. 2003. "The complex integration strategies of multinationals and cross country dependencies in the structure of foreign direct investment." *Journal of International Economics.* 60: 293-314.