Lecture 4: Offshoring and Task Trade

Economics 552

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Week 4

Trade in Tasks: A Simple Theory of Offshoring, Grossman and Rossi-Hansberg (2006)

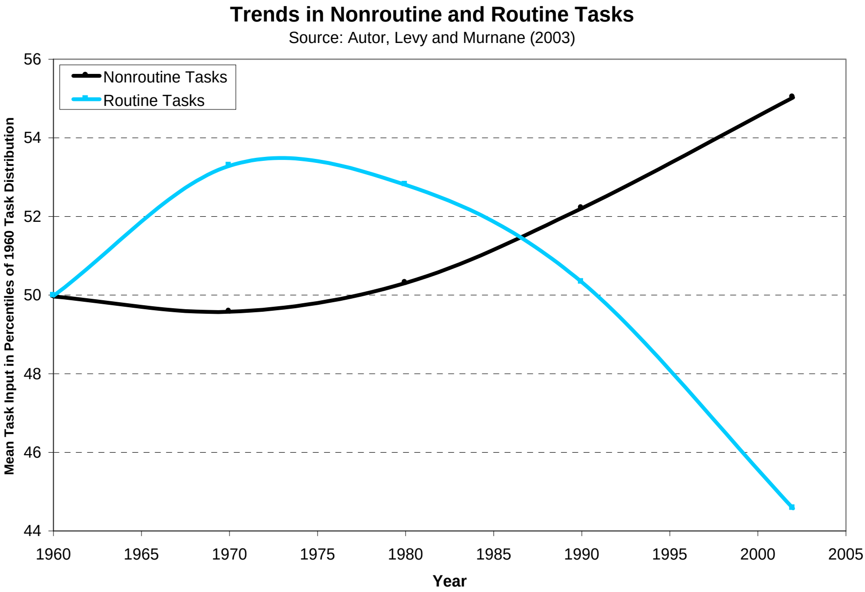
- Boom in "offshoring" of both manufacturing tasks and other business functions
  - Revolutionary advances in transportation and (especially) communications technology
  - Weaker link between specialization and geographic concentration
    - Firms can take advantage of factor cost disparities in different countries without sacrificing the gains from specialization
- Need for a new paradigm, one that puts task trade at center stage
- We develop a simple and tractable model of offshoring that features such trade in tasks

Some Evidence of Task Trade

- Hard evidence on the growing scale of task trade is hard to come by
  - Trade data are collected and reported as gross flows rather than as foreign value added (NRC, 2006)
  - Some of this trade leaves no paper trail
- But hints of the global disintegration of the production process abound:
  - Share of imported inputs in total inputs used by goods-producing sectors in the US rose from 7% in 1972 to 18% in 2000
  - Intra-firm trade accounted for 47% of U.S. total imports in 2005
  - In the US, imports of Business, Professional and Technical (BPT) services have increased by more than 66% in real terms from 1997 to 2004

But world is not (yet) flat

- Trade in tasks is still costly and varies widely across different tasks
  - "Routine" tasks vs. "Nonroutine" tasks (Autor, Levy and Murnane (ALM), 2003)
    - ALM document an increase in the number of "Nonroutine" tasks relative to "Routine" tasks in the US
  - Tasks that require "Codifiable" information and those that require "Tacit" information (Leamer and Storper, 2001)
  - Tasks that require physical contact and geographic proximity and those that generate outputs that can be delivered impersonally and from a distance (Blinder, 2006)
- There is a less than perfect relationship between the suitability of a task for offshoring and the level of skill required to perform the job



Trends in Nonroutine and Routine Tasks
Source: Autor, Levy and Murnane (2003)
Nonroutine Tasks
Routine Tasks
Mean Task Input in Percentiles of 1960 Task Distribution
56
54
52
50
48
46
44
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year

The Model

- Model allows trade in tasks, as well as trade in goods
- Production involves a continuum of L tasks, continuum of H tasks, etc., possibly with substitution
- Industries differ in factor intensity, as usual
- Normalize measure of tasks of each type to one, and model factor intensity differences as different required amounts of factors per task
  - Equivalently: different measures of tasks, with one unit of factor per task
- Cost of offshoring task i is given by $\beta t(i) \geq 1$
- Order tasks so $t'(i) \geq 0$ and assume $t(i)$ continuously differentiable
- For the moment only L-tasks can be offshored and same $t(i)$ schedule in each industry

Firm's Problem

- Consider production in sector j
- Assume firms, or industry, produces using a Constant Returns to Scale technology
- Firms maximize profits

$$\max_{Y_j, I_j} p_j Y_j - c_j Y_j$$

where

$$c_j = w a_{Lj}(\cdot)(1-I) + w^* a_{Lj}(\cdot) \int_0^I \beta t(i) di + s a_{Hj}(\cdot) + \dots$$

- Firm will offshore tasks $[0, I]$ where

$$w = \beta t(I) w^*,$$

and if the firm produces a positive amount

$$p_j = c_j$$

Marginal Costs

- Cost of producing good j using home technology are given by

$$
\begin{aligned}
c_j &= wa_{Lj}(\cdot)(1-I) + w^* a_{Lj}(\cdot)\int_0^I \beta t(i)di + sa_{Hj}(\cdot) + \dots \\
&= wa_{Lj}(\cdot)(1-I) + wa_{Lj}(\cdot)\frac{\int_0^I t(i)di}{t(I)} + sa_{Hj}(\cdot) + \dots \\
&= wa_{Lj}(\cdot)\,\Omega(I) + sa_{Hj}(\cdot) + \dots
\end{aligned}
$$

where

$$\Omega(I) = 1 - I + \frac{\int_0^I t(i)di}{t(I)} \qquad \text{and} \qquad \Omega'(I) = -\frac{\int_0^I t(i)di}{t^2(I)}t'(I) \leq 0$$

- So possibility of offshoring affects costs exactly as labor-augmenting technological change

The Three Effects of Offshoring

- To allow for all the potential effects of offshoring, we need a model with (at least) three factors and (at least) two goods
- Price less or equal than unit cost implies

$$
\begin{aligned}
1 &= w\Omega a_{Lx}\left(s/w\Omega,\cdot\right) + s a_{Hx}\left(s/w\Omega,\cdot\right) + \ldots \\
p &\leq w\Omega a_{Ly}\left(s/w\Omega,\cdot\right) + s a_{Hy}\left(s/w\Omega,\cdot\right) + \ldots
\end{aligned}
$$

- Factor market clearing implies

$$
a_{Lx}x(1-I) + a_{Ly}y(1-I) = L
$$
$$
\Leftrightarrow a_{Lx}x + a_{Ly}y = \frac{L}{1-I}
$$
$$
a_{Fx}x + a_{Fy}y = F \text{ for } F = H, \ldots
$$

- These $2+v$ equations determine $x, y, \Omega w, s$ as functions of p, I and $L, H, \ldots$

The Three Effects of Offshoring

- p and I are endogenous—determined in world equilibrium
- To close the model, we need to specify the foreign country's equilibrium conditions and the world market clearing conditions, which will allow us to determine I and p
- But instructive to treat I and p as exogenous for the moment
- Differentiating totally the $2 + v$-equation system on the previous slide we obtain

$$\hat{w} = -\hat{\Omega} + \mu_1 \hat{p} - \mu_2 \frac{dI}{1-I}$$

$$\hat{s} = -\mu_3 \hat{p} + \mu_4 \frac{dI}{1-I}$$

- Three effects: Productivity, Relative Price and Labor Supply

Small Heckscher-Ohlin Economy

- Consider a small economy (p and w^* fixed) with two factors, L and H and two goods. Then

$$\begin{aligned} \theta_{Lx}\left(\hat{w}+\hat{\Omega}\right)+\theta_{Hx}\hat{s} &= 0 \\ \theta_{Ly}\left(\hat{w}+\hat{\Omega}\right)+\theta_{Hy}\hat{s} &= \hat{p}=0 \end{aligned}$$

  which implies that

$$\hat{w}=-\hat{\Omega} \qquad \text{and} \qquad \hat{s}=0$$

- Since $w=\beta t(I)w^*$ and w^* is fixed, $\hat{w}=\hat{\beta}+\hat{t}(I)$, so

$$\frac{dI}{d\beta}=-\frac{(1-I)\,t(I)+\int_0^I t(i)di}{\beta t'(I)\,(1-I)}<0$$

  and so $\hat{\Omega}\leq 0$, which implies $\hat{w}\geq 0$

Why Does Unskilled Labor Benefit?

- Offshoring increases productivity of workers that remain employed at home
  - Lower β implies a lower cost of offshoring the marginal tasks and lower cost of offshoring all the infra-marginal tasks
  - Benefits from improved offshoring in proportion to the share of low-skilled labor
- Compare: Offshoring vs. Immigration
  - For marginal immigrant, $w = w^* \beta \tau(I)$
  - But domestic firms may pay w to all immigrants, unless they can price discriminate. Then rents may go to immigrants
- Why no Labor-Supply Effect?
  - This is a feature of HO model: equal number of produced tradable goods and factors

Characterization

- The effect of changes in β on wages is given by

$$\hat{w} = -\hat{\Omega} = -\hat{\beta}\frac{1}{(1-I)}\int_0^I \frac{t(i)}{t(I)}di$$

  - If $I = 0$, $\hat{w} = -\hat{\Omega} = 0$, and so there is no productivity effect
  - If $I > 0$, $\hat{w} = -\hat{\Omega} > 0$. Moreover, if $\eta(i) = t'(i)(1-i)/t(i)$ constant or $\eta(i) < 1$ for all i, the productivity effect increases with I everywhere
- What if easier to offshore in L-intensive industry relative to H-intensive industry?
  - This strengthens effect. If offshoring only possible in L-intensive industry y,

$$\hat{w} = -\hat{\Omega}\left(\frac{\theta_{Hx}\theta_{Ly}}{\theta_{Hx}\theta_{Ly} - \theta_{Lx}\theta_{Hy}}\right) > -\hat{\Omega} > 0 \qquad \text{and} \qquad \hat{s} = -\frac{\theta_{Lx}}{\theta_{Hx}}\hat{w} < 0$$

Characterization

- In general

$$\hat{w} = \frac{\frac{\theta_{Hx}}{\theta_{Lx}}\left(-\hat{\Omega}_y\right) - \frac{\theta_{Hy}}{\theta_{Ly}}\left(-\hat{\Omega}_x\right)}{\frac{\theta_{Hx}}{\theta_{Lx}} - \frac{\theta_{Hy}}{\theta_{Ly}}}$$

$$\hat{s} = \frac{\theta_{Ly}\theta_{Lx}}{\theta_{Ly} - \theta_{Lx}}\left[\left(-\hat{\Omega}_x\right) - \left(-\hat{\Omega}_y\right)\right]$$

  where Ω_x is defined analogously to Ω_y.
- The factor-share ratios are such that $\theta_{Hx}/\theta_{Lx} > \theta_{Hy}/\theta_{Ly}$ so $\hat{w} > 0$ and $\hat{s} < 0$ if $-\hat{\Omega}_y > -\hat{\Omega}_x$.
- Take, for example, the case in which $t_x(i) = \alpha t_y(i)$ with common factor β.
  - Define $\eta_j(i) \equiv t_j'(i)(1-i)/t_j(i)$ for $i = x, y$
  - Then, if η_x and η_y are constants, or if $\eta_x(I_x) < 1$ and $\eta_y(I_y) < 1$, $\alpha < 1$ implies $I_x > I_y$ and $-\hat{\Omega}_y > -\hat{\Omega}_x$

Large Heckscher-Ohlin Economy

- Need a reason for differences in factor prices across countries
  - Assume foreign country has inferior technology so that offshoring flows in one direction (with $\beta t\left(i\right) \geq 1$ all i)
  - Let A^* measure Hicks-neutral technological inferiority in both industries, then with incomplete specialization

$$A^* a^*_{Lx} w^* + A^* a^*_{Hx} s^* = 1$$

$$A^* a^*_{Ly} w^* + A^* a^*_{Hy} s^* = p$$

- Incomplete specialization implies that in equilibrium there is adjusted Factor Price Equalization:

$$\begin{aligned} w\Omega &= w^* A^* \\ s &= s^* A^* \end{aligned}$$

Large Heckscher-Ohlin Economy

- This implies that both countries have similar a_{Fj}'s, so factor clearing conditions are given by

$$A^* a_{Lx} x^* + A^* a_{Ly} y^* + \beta \int_0^I t(i) di \left(a_{Lx} x + a_{Ly} y \right) = L^*$$

$$A^* a_{Hx} x^* + A^* a_{Hy} y^* = H^*$$

or

$$\begin{aligned} a_{Lx} x^* + a_{Ly} y^* &= \frac{L^*}{A^*} - \frac{\beta}{(1-I) A^*} \left[\int_0^I t(i) di \right] L \\ a_{Hx} x^* + a_{Hy} y^* &= \frac{H^*}{A^*} \end{aligned}$$

Large Heckscher-Ohlin Economy

- After some algebra we obtain

$$x + x^* = \frac{a_{Ly}\left(H + \frac{H^*}{A^*}\right) - a_{Hy}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right)}{\Delta_a}$$

$$y + y^* = \frac{a_{Hx}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right) - a_{Lx}\left(H + \frac{H^*}{A^*}\right)}{\Delta_a}$$

where

$$\Delta_a = a_{Hx}a_{Ly} - a_{Lx}a_{Hy} > 0$$

- So $\beta \downarrow \Rightarrow I \uparrow \Rightarrow \Omega \downarrow \Rightarrow \frac{x+x^*}{y+y^*} \downarrow \Rightarrow p \downarrow$ (with standard preferences)
  - Terms of Trade Gain for home country (c.f. Samuelson, 2004)

Large Heckscher-Ohlin Economy

- Hence, $p \downarrow$ implies Relative Price Effect favors H and harms L
- Overall:

$$\hat{w} = -\hat{\Omega} + \mu_1 \hat{p}$$

and

$$\hat{s} = -\mu_3 \hat{p}$$

  - H must gain, L may gain or lose
  - Possible Pareto gains for home country if productivity effect large enough
- Note complete analogy with labor-augmenting technological progress in home country

The Labor-Supply Effect

- Present as long as there are more factors than goods
  - Short term effect if factors are specific because of frictions on factor mobility across industries
- Simplest setting to illustrate the effect is small country specialized in producing one good with two factors
- Then, if price of good normalized to one, equilibrium is given by

$$
\begin{aligned}
\Omega w a_L + s a_H &= 1 \\
a_L x &= \frac{L}{1 - I} \\
a_H x &= H
\end{aligned}
$$

The Labor-Supply Effect

- Differentiate to obtain

$$\theta_L \left(\hat{w} + \hat{\Omega}\right) + (1 - \theta_L)\,\hat{s} = 0$$

and since

$$\frac{a_L}{a_H} H = \frac{L}{1 - I}$$

if σ is the elasticity of substitution between low and high-skilled labor

$$\sigma(\hat{s} - \hat{w} - \hat{\Omega}) = \frac{dI}{1 - I}$$

- So

$$\begin{aligned} \hat{w} &= -\hat{\Omega} - \frac{1 - \theta_L}{\sigma} \frac{dI}{1 - I} \\ \hat{s} &= \frac{1 - \theta_L}{\sigma} \frac{dI}{1 - I} > 0 \end{aligned}$$

The Labor-Supply Effect

- From the definition of $\Omega = 1 - I + \int_0^I t(i)/t(I)\,di$ we know that

$$\hat{\Omega} = -\eta\gamma \frac{dI}{1-I}$$

where

$$\eta(I) = \frac{t'(I)(1-I)}{t(I)},$$

$$\gamma(I) = \frac{\int_0^I t(i)di}{(1-I)t(I) + \int_0^I t(i)di} \in [0,1]$$

- Then

$$\hat{w} = \left(\eta\gamma - \frac{1-\theta_L}{\sigma}\right)\frac{dI}{1-I}$$

The Labor-Supply Effect

- Labor-supply effect is given by

$$\left(\frac{1-\theta_L}{\sigma}\right)\frac{dI}{1-I}$$

  - Large when σ small or labor share, θ_L, small

- At $I = 0$,

$$\hat{w} = \frac{1-\theta_L}{\sigma}\frac{dI}{1-I} < 0$$

- At $I > 0$, $\hat{w} > 0$ iff

$$\sigma\gamma\eta > 1-\theta_L$$

- Can also handle Specific-Factors model, which has all three effects

Offshoring Skill-Intensive Tasks

- Recent policy debate has focused on offshoring of white collar jobs
- May interpret this as offshoring of H-tasks
- Offshoring of H-tasks can be easily incorporated, for example, in small HO economy. Then

$$w = w^* \beta_L t_L(I_L) \qquad \text{and} \qquad s = s^* \beta_H t_H(I_H)$$

and

$$a_{Lx} w \Omega_L + a_{Hx} s \Omega_H = 1$$
$$a_{Ly} w \Omega_L + a_{Hy} s \Omega_H = p$$

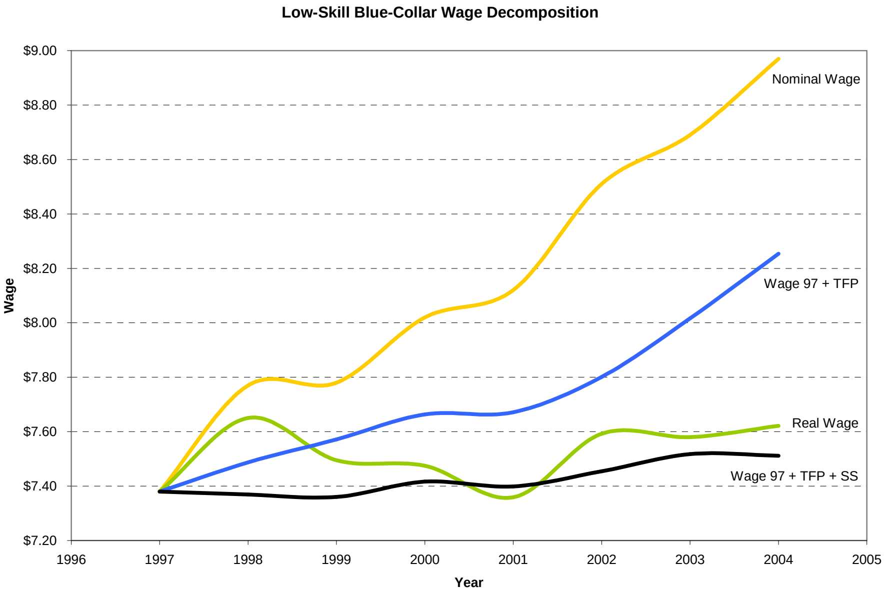
determine $I_L(\beta_L)$ and $I_H(\beta_H)$ and

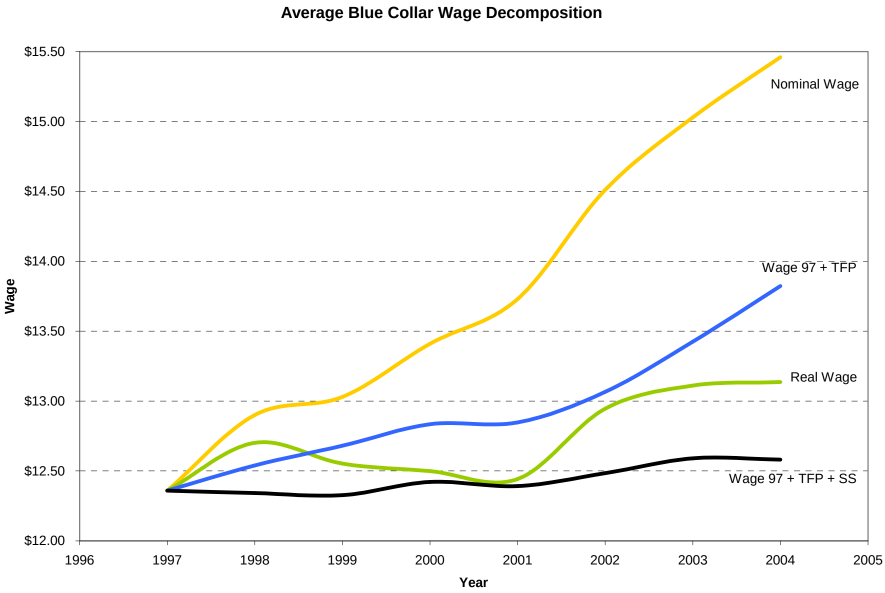
$$\hat{w} = -\hat{\Omega}_L \qquad \text{and} \qquad \hat{s} = -\hat{\Omega}_H$$

- Thus, $\beta_H \downarrow$ implies $s \uparrow$, w unchanged

Back-of-the-Envelope Calculation

- US wages for blue collar workers roughly flat over last 10 years
- Assume A has been rising in US at rate of TFP growth
- Look at TOT in manufactured goods vis-a-vis non-industrialized countries
  - TOT have been improving dramatically for US
- Take plausible values for Stolper-Samuelson coefficient, using labor shares in various import and export industries. These imply that low-skill wages should be falling, despite TFP improvement
  - Thus, positive residual
  - A bit heroic to associate this with net positive productivity plus labor supply effects of offshoring
- But, at least data leaves room for this interpretation


Low-Skill Blue-Collar Wage Decomposition
$9.00
$8.80
$8.60
$8.40
$8.20
$8.00
$7.80
$7.60
$7.40
$7.20
Wage
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Nominal Wage
Wage 97 + TFP
Real Wage
Wage 97 + TFP + SS

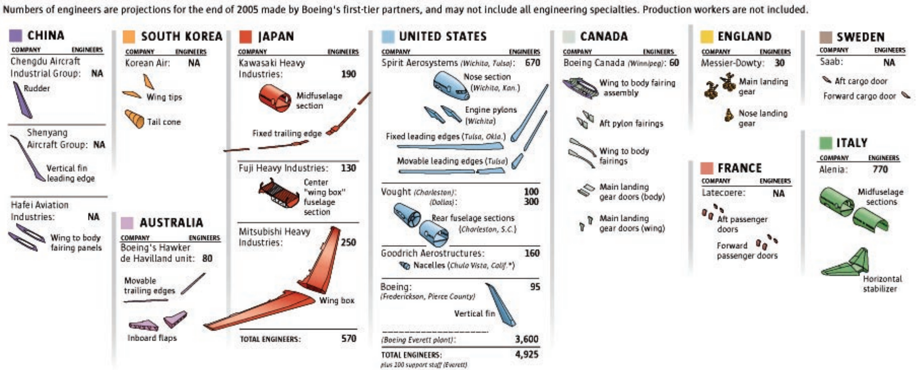

Average Blue Collar Wage Decomposition
Wage
$15.50
$15.00
$14.50
$14.00
$13.50
$13.00
$12.50
$12.00
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Nominal Wage
Wage 97 + TFP
Real Wage
Wage 97 + TFP + SS

Task Trade between Similar Countries, Grossman and Rossi-Hansberg (2010)

- Task trade between similar countries
  - Little studied
  - Appears to be large in magnitude
- Example: Boeing 787 Dreamliner
  - Offshore production accounts for 70% of parts
  - 43 suppliers in 135 sites
  - Most tasks performed in high-income countries
  - No clear pattern of technological advantage; experience and local knowledge play central role

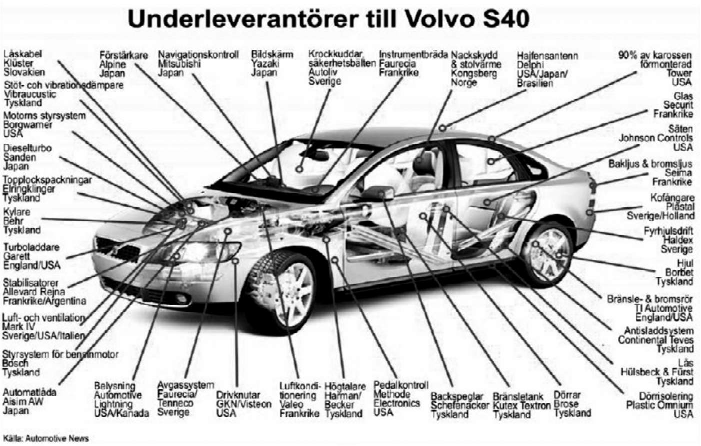
Boeing 787 Dreamliner

International Sourcing



Volvo S40

International Sourcing



Objectives of Paper

- Model offshoring between countries with similar technologies, similar factor endowments
  - Possible difference in country size
- Basis for Trade: Economies of Scale
  - At the task level
  - Local
  - External to the firm
    - ★ Coordination problem
    - ★ Role of outsourcing suppliers
- Heterogeneous offshoring costs as in our previous work
- Find relationship between relative wages, aggregate outputs and concentration of tasks

Model

- Two countries: East and West
- Two factors: $H/L = H^*/L^*$
- Differentiated final goods, CES with elasticity σ
- Fixed cost: f managers per product
  - Entry cost
  - Provides capacity to perform each task in some designated location
- Continuum of tasks, performed by production workers
- External economies at task level: $1/A(X_{ij})$ workers per task per unit local output
- Heterogeneous offshoring costs: $\beta t(i)/A(X_{ij})$ workers per task per unit offshore output
- Firms can serve as suppliers of a task for others
  - Possibility of large suppliers (of a task) plays role in coordination

Model (cont'd)

Siting and Sourcing of Tasks

- First stage: Entry
  - Firms hire f managers
- Second stage: Location and Pricing Stage
  - Firm chooses location for each task i
  - Firm quotes prices, with price discrimination by location of HQ
- Third stage: Production Stage
  - Firms decide make or buy: perform task in chosen location or procure from lowest cost supplier

Equilibrium Location of Tasks

Local Deviation

- Let us hypothesize that all firms locate task i in East
- If each expects others to locate similarly, Bertraqnd competition lead them to price at expected cost: $p_i^E = \frac{w}{A(nx+n^*x^*)}$ and $p_i^W = \frac{w\beta t(i)}{A(nx+n^*x^*)}$.
- Consider deviant that locates in West with intention of supplying itself and other Western firms. Deviant quotes prices $\tilde{p}_i^E = \infty$ and $\tilde{p}_i^W = p_i^W - \varepsilon$. Local deviation profitable if

$$\frac{w\beta t(i)}{A\left(nx + n^*x^*\right)} - \frac{w^*}{A\left(n^*x^*\right)} > 0$$

Necessary for equilibrium with task i in East: $i \leq I$ where

$$\beta t(I) = \frac{w^*}{w}\frac{A(nx + n^*x^*)}{A(n^*x^*)}$$

Equilibrium Location of Tasks

Global Deviation

- Consider deviant that locates in West with intention of supplying itself and other Western firms. Deviant quotes prices $\tilde{p}_i^E = p_i^E - \varepsilon$ and $\tilde{p}_i^W = p_i^W - \varepsilon$. Global deviation profitable if

$$\left[\frac{w}{A\left(nx + n^*x^*\right)} - \frac{\beta t(i) w^*}{A\left(nx + n^*x^*\right)}\right] nx + \left[\frac{\beta t(i) w}{A\left(nx + n^*x^*\right)} - \frac{w^*}{A\left(nx + n^*x^*\right)}\right] n^*x^* > 0,$$

- Define (if interior)

$$\beta t(J) = \frac{wnx - w^*n^*x^*}{w^*nx - wn^*x^*}$$

- Suppose for concreteness that $w \geq w^*$. Then deviation profitable for $i < J$.
- Necessary and sufficient for concentration in E: $i \leq I$ and $i \geq J$

Equilibrium Location of Tasks

Concentration in West

- Local deviation profitable if

$$\frac{w}{A(nx)} < \frac{\beta t(i)\, w^*}{A(nx + n^* x^*)}$$

- Necessary for concentration in West: $i \leq I^*$, where

$$\beta t(I^*) = \frac{w}{w^*} \frac{A(nx + n^* x^*)}{A(nx)}$$

- Global deviation profitable if $i > J$.
- So necessary and sufficient for concentration in W: $i \geq I^*$ and $i \leq J$

Equilibrium Location of Tasks

Dispersed Location

- Bertrand competition implies $p_i^E = w/A(nx)$ and $p_i^W = w^*/A(n^*x^*)$
- Local deviation to East is profitable if $i < I$
- Local deviation to West profitable if $i < I^*$
- Necessary and sufficient for dispersed location: $i \geq I$ and $i \geq I^*$

Equilibrium Location of Tasks (cont'd)

- Suppose $w > w^*$ and $J < I^* < I$
  - $i < J$ concentrated in West but not East
  - $i \in [J, I]$ concentrated in East but not West
  - $i \in [I, 1]$ dispersed
- Unique location for every task. Indifference between in-house and outsourcing

Equilibrium Location of Tasks (cont'd)

- Suppose $w > w^*$ and $I^* < J < I$
  - $i < I^*$ concentrated in West but not East
  - $i \in [J, I]$ concentrated in East but not West
  - $i \in [I, 1]$ dispersed
  - $i \in [I^*, J]$
    - ★ If concentrate in East, global deviation to West profitable
    - ★ If concentrate in West, local deviation to East profitable
    - ★ If dispersed, global deviation to East profitable ($i < I$)
    - ★ Eastern firms have clear incentive to locate in East. Western firms prefer to gain scale economies, but if all in East, a deviant can locate in West and profit.

Equilibrium Location of Tasks (cont'd)

- Suppose $w > w^*$ and $I^* < J < I$, $i \in [I^*, J]$
  - Let Eastern firms locate in East and price at cost assuming global scale:

$$p_i^E = \frac{w}{A\left(nx + n^* x^*\right)}, \qquad p_i^W = \frac{w\beta t(i)}{A\left(nx + n^* x^*\right)}$$

  - Let Western firms locate in West and price assuming local scale:

$$p_i^E = \infty, \qquad p_i^W = \frac{w^*}{A\left(n^* x^*\right)}$$

  - In production equilibrium, Western firms procure from East (outsourcing)
    - ★ Western firm has no incentive to deviate, because if it prices below $\frac{w}{A(nx+n^*x^*)}$ it would make losses on sales to Eastern firms and cannot profit on sales to Western firms, which have option to self-provide.
    - ★ Equilibrium has dispersed location, but concentrated production.

Equilibrium Location of Tasks

- To sum up:
  - $i \leq \min[I, I^*]$ – task is concentrated in low-cost location
  - $\min[I, I^*] < i \leq \max[I, I^*]$ – task is concentrated in location that is not susceptible to deviation by firms in one country
  - $i > \max[I, I^*]$ – task is dispersed

General Equilibrium

Costs, Relative Demands, Zero-Profits

- Costs:

$$c = \frac{wM(\mathcal{E})}{A(nx + n^*x^*)} + \frac{w^*T(\mathcal{W})}{A(nx + n^*x^*)} + \frac{wM(\mathcal{B})}{A(nx)}$$

$$c^* = \frac{wT(\mathcal{E})}{A(nx + n^*x^*)} + \frac{w^*M(\mathcal{W})}{A(nx + n^*x^*)} + \frac{w^*M(\mathcal{B})}{A(n^*x^*)}$$

where $M(\mathcal{Z})$ is the Lebesgue measure of $\mathcal{Z}$ for $\mathcal{Z} = \{\mathcal{E}, \mathcal{W}, B\}$ and

$$T(\mathcal{Z}) = \int_{i \in \mathcal{Z}} \beta t(i) di$$

- Demands:

$$\frac{x}{x^*} = \left(\frac{c}{c^*}\right)^{-\sigma}$$

- Zero Profits:

$$sf = \frac{cx}{(\sigma - 1)}, \qquad s^*f = \frac{c^*x^*}{(\sigma - 1)}$$

General Equilibrium (cont'd)

Factor-Market Clearing

- Managers:

$$nf = H$$

$$n^* f = H^*$$

- Workers:

$$\frac{M(\mathcal{E})}{A(nx + n^* x^*)} nx + \frac{T(\mathcal{E})}{A(nx + n^* x^*)} n^* x^* + \frac{M(\mathcal{B})}{A(nx)} nx = L$$

$$\frac{T(\mathcal{W})}{A(nx + n^* x^*)} nx + \frac{M(\mathcal{W})}{A(nx + n^* x^*)} n^* x^* + \frac{M(\mathcal{B})}{A(nx)} n^* x^* = L^*$$

- Normalization:

$$w^* = 1$$

Equilibrium with High Offshoring Costs

- $A(X) = X^{\theta}$; $\theta = 0.8$
- $t(i) = 1 + i$; $\beta = 2$
- $H + H^{*} = L + L^{*} = 2$
- $\sigma = 2$, $f = 1$
- Vary L, $L^{*} = 2 - L$

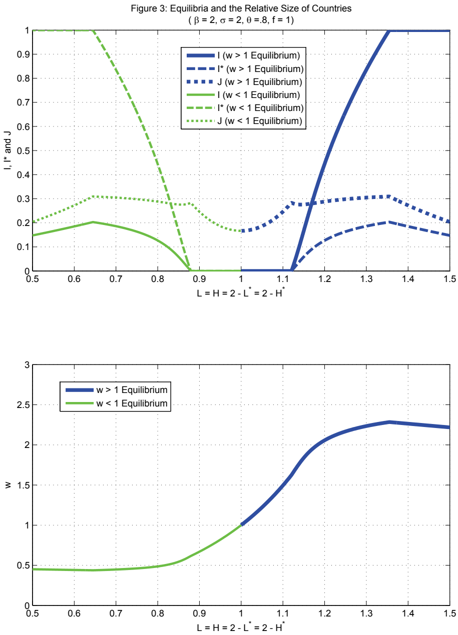


Figure 3: Equilibria and the Relative Size of Countries
(β = 2, σ = 2, θ =.8, f = 1)
I (w > 1 Equilibrium)
I* (w > 1 Equilibrium)
J (w > 1 Equilibrium)
I (w < 1 Equilibrium)
I* (w < 1 Equilibrium)
J (w < 1 Equilibrium)
I, I* and J
L = H = 2 - L* = 2 - H*
w > 1 Equilibrium
w < 1 Equilibrium
w
L = H = 2 - L* = 2 - H*

Equilibrium with Low Offshoring Costs

- $A(X) = X^{\theta}$; $\theta = 0.8$
- $t(i) = 1 + i$; $\beta = 1.1$
- $H + H^{*} = L + L^{*} = 2$
- $\sigma = 2$, $f = 1$
- Vary L, $L^{*} = 2 - L$

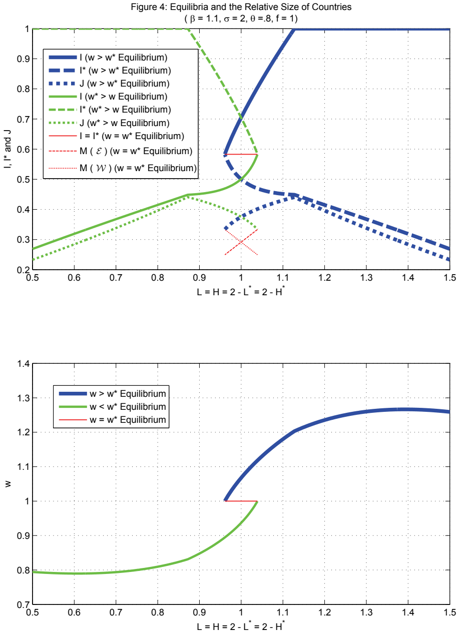
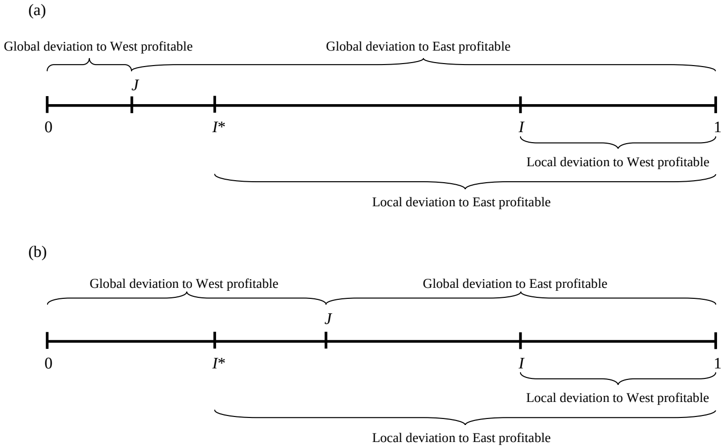
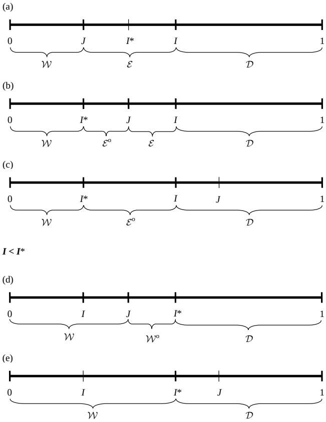


Figure 4: Equilibria and the Relative Size of Countries
(β = 1.1, σ = 2, θ =.8, f = 1)
I (w > w* Equilibrium)
I* (w > w* Equilibrium)
J (w > w* Equilibrium)
I (w* > w Equilibrium)
I* (w* > w Equilibrium)
J (w* > w Equilibrium)
I = I* (w = w* Equilibrium)
M (ℰ) (w = w* Equilibrium)
M (𝒲) (w = w* Equilibrium)
I, I* and J
L = H = 2 - L* = 2 - H*
w > w* Equilibrium
w < w* Equilibrium
w = w* Equilibrium
w
L = H = 2 - L* = 2 - H*

Task Allocation



Task Allocation



Lemma 1 If $w > 1$, then $J < I$ implies $I > I^*$

Task Allocation (cont'd)

Lemma 2 $w > 1$ if and only if $nx > n^* x^*$.

Proposition

The pattern of specialization is characterized by

(i) concentrated performance of tasks with the lowest offshoring costs in the country with low wages and low aggregate output,

(ii) concentrated performance of tasks with intermediate offshoring costs in the country with high wages and high aggregate output, and

(iii) dispersed performance of tasks with the highest offshoring costs in both countries.

The Pattern of Specialization

- Tasks that are costly to offshore are performed locally
- For other tasks
  - Country with smaller aggregate output has most to gain from moving tasks abroad
  - Country with larger aggregate output has most to lose from offshoring costs $\Rightarrow$ tasks that are most costly to offshore concentrate there
  - This bids up wage in this country ...
  - ... which creates an incentive for tasks with low offshoring costs to locate in country with smaller aggregate output.
- Pattern of specialization and productivity advantage for non-traded tasks validates relative wage

Comparative Statics

- Extent of Increasing Returns to Scale
- Extent of Product Differentiation
- Size of Offshoring Costs

Conclusion

- We developed a theory of task trade between similar countries
  - In equilibrium the country with higher wages and output performs the tasks —among those concentrated— that are more difficult to offshore
- Hard to test
  - Need to identify the characteristics of tasks performed in different countries
- Some effort to do it for the US (Autor et al., *QJE* 03) and Germany (Spitz-Oener, *JLE* 06) for a different classification of tasks
- Both the US and Germany specializing in tasks that are non-routine and either interactive or analytic
  - Germany is specializing also in non-routine manual tasks
- Consistent with our theory if non-routine manual tasks are relatively cheaper to offshore

Foreign Know-How, Firm Control, and the Income of Developing Countries, Burstein and Monge (2007)

What determines international diffusion of productive knowledge and income differences

- Emphasis of literature:
  - International trade in goods (and capital), patents, imitation.
- This paper:
  - Managerial know-how acquiring control of inputs in foreign country
- Managerial know-how
  - Shapes productivity of firms
    - Available technologies, production choices, market opportunities
  - Costly to reproduce, but internationally mobile
  - To evaluate gains of mobility, need to measure scarcity in each country
  - Separate it from other components of productivity fixed in country

Productivity

- "Country embedded productivity" z^i
  - Common to all firms operating in the country (e.g.: infrastructure, regulations, quality of labor force)
  - Internationally immobile
- "Firm embedded productivity" x
  - Know-how of individuals in control of the firm
  - Rival factor
  - Internationally mobile
- Y can result from different combinations of z and x.
- If x is rival factor that can be internationally reallocated:
  - Equal marginal product of x across countries.
  - Flows from countries where it is abundant to where it is scarce, as in Helpman (1984)
  - Higher fraction of inputs controlled by foreign managerial know-how indicates low x/z

Objectives

- Model of cross-country Y differences and international mobile managerial know-how
  - Multi-country Lucas (1978) model with rival managerial know-how (as in Antras, Garicano and Rossi-Hansberg 2006)
- Use model plus aggregate data to disentangle x and z in developing countries
  - Measure foreign control using data on FDI.
- Conduct policy counterfactuals on changes in barriers to foreign control.
  - Welfare gains 10% for average developing country in sample

The Model

- Two countries: Country 1 is “source”, Country 2 is “host”
- Firm employs one manager and several workers
- Foreign firm: manager from country i and workers from country j.
- Populations: L^i, fraction ω managers and $1-\omega$ workers
- Output of a firm producing in i is given by

$$z^i x^{1-v} n^v$$

- where z denotes “country embedded productivity” and x denotes “firm embedded productivity"
  - Assume (for now) that all managers in i have equal x^i

Autarky

- Each manager hires $n = (1-\omega)/\omega$ labor
- Country i's output is given by

$$
\begin{aligned}
Y^i &= \omega L^i z^i \left(x^i\right)^{1-\nu} n^{\nu} \\
&= \mu \left[z^i \left(x^i\right)^{1-v}\right] L^i, \quad \mu \equiv \omega^{1-v} (1-\omega)^v
\end{aligned}
$$

  - z^i and x^i indistinguishable
- World output is given by
- $Y^w = \mu \left\{ \left[z^1 \left(x^1\right)^{1-v}\right] L^1 + \left[z^2 \left(x^2\right)^{1-v}\right] L^2 \right\}$
  - Potential gains from reallocating managers from countries with high x^i/z^i to countries with low x^i/z^i

International Firm Mobility

- Fraction $m \geq 0$ of country 1 managers operates in country 2
- All managers from country 2 remain there
- Without loss of generality if equilibrium $m > 0$

Country 1

- $(1-m)\,\omega L^1$ managers
- Labor market clearing: $n_1 = (1-\omega) / [\omega(1-m)]$
- Output: $Y^1 = (1-m)^{1-v} \mu z^1 \left(x^1\right)^{1-v} L^1$

Country 2

- $m\omega L^1$ country 1 managers, ωL^2 country 2 managers.
- Equalization of marginal products of labor: $n_2^2 = \left(x^2/x^1\right) n_2^1$
- Labor market clearing: $m\omega L^1 n_2^1 + \omega L^2 n_2^2 = (1-\omega) L^2$
- Output:

$$
\begin{aligned}
Y^2 &= m\omega L^1 \left\{ z^2 \left(x^1\right)^{1-\nu} \left(n_2^1\right)^{\nu} \right\} + \omega L^2 \left\{ z^2 \left(x^2\right)^{1-\nu} \left(n_2^2\right)^{\nu} \right\} \\
&= \mu z^2 \left[mL^1 x^1 + L^2 x^2 \right]^{1-v} \left(L^2\right)^{v}
\end{aligned}
$$

Efficient allocation of managerial know-how

- Choose m such that $\partial Y^1/\partial m + \partial Y^2/\partial m = 0$
- Which implies

$$m^* = \frac{1 - \left(\frac{x^2}{x^1}\right)\left(\frac{z^1}{z^2}\right)^{1/\nu}}{1 + \left(\frac{L_1}{L_2}\right)\left(\frac{z^1}{z^2}\right)^{1/\nu}}$$

- so $m^* > 0$ iff $R \equiv \left(\frac{x^2}{x^1}\right)\left(\frac{z^1}{z^2}\right)^{1/\nu} < 1$ (a measure of the relative scarcity of x^2)
- World endowment of firm embedded productivity: $\omega\left[L^1 x^1 + L^2 x^2\right]$
  - Optimal allocations pin down net (but not gross) reallocation
- Aggregate outputs

$$Y^i = \mu\left(\frac{x^1 L^1 + x^2 L^2}{\left(z^1\right)^{1/\nu} L_1 + \left(z^2\right)^{1/\nu} L^2}\right)^{1-\nu}\left[L^i\left(z^i\right)^{1/\nu}\right]$$

- World output:

$$Y^w = \mu\left(x^1 L^1 + x^2 L^2\right)^{1-\nu}\left[L^1\left(z^1\right)^{1/\nu} + L^2\left(z^2\right)^{1/\nu}\right]^{\nu}$$

Share of foreign firms

- s is share of foreign controlled inputs in country 2:

$$s = \frac{\omega m L^1 n_1^2}{\omega m L^1 n_1^2 + \omega L^2 n_2^2} = \frac{m L^1 x^1}{m L^1 x^1 + L^2 x^2}$$

- Output of country 2 using s:

$$Y^2 = \mu z^2 \left(x^2\right)^{1-\nu} \left(\frac{1}{1-s}\right)^{1-\nu} L^2$$

- Consumption (GNP) and output (GDP):

$$C^2 = \left[1 - \left(1 - \nu\right) s\right] Y^2 \text{ and } C^1 = Y^1 + \left(1 - \nu\right) s Y^2$$

Competitive equilibrium

- Profits:

$$\pi_i^j = \max_{n_i^j} \left\{ z^j \left(x^i \right)^{1-\nu} \left(n_i^j \right)^{\nu} - n_i^j w^j \right\} = \kappa \left(z^j \right)^{\frac{1}{1-\nu}} x^i / \left(w^j \right)^{\frac{\nu}{1-\nu}}$$

- Wages:

$$\begin{aligned} w^1 &= \frac{\nu\mu}{1-\nu} z^1 \left(x^1 \right)^{1-\nu} (1-m)^{1-\nu} \\ w^2 &= \frac{\nu\mu}{1-\nu} z^2 \left[x^2 L^2 + m x^1 L^1 \right]^{1-\nu} \end{aligned}$$

- Share of managers operating abroad, $m^* : \pi_1^1 = \pi_1^2$

- Calculate x and z using observed $\{Y^i, L^i, s\}$
- Using aggregate output expressions:

$$\left(\frac{z^2}{z^1}\right) = \left(\frac{Y^2/L^2}{Y^1/L^1}\right)^v$$

- Equalization of marginal products of managerial know-how across countries:

$$\left(\frac{x^2}{x^1}\right) = \frac{(1-s)}{\left(\frac{Y^1}{L^1}\right) / \left(\frac{Y^2}{L^2}\right) + s\left(\frac{L^2}{L^1}\right)}$$

- Use them as key inputs in quantitative analysis: Y accounting

Extensions

1. Taxes on profits
2. Geographic and cultural barriers
3. Physical capital
4. Multilayered management and occupation choice

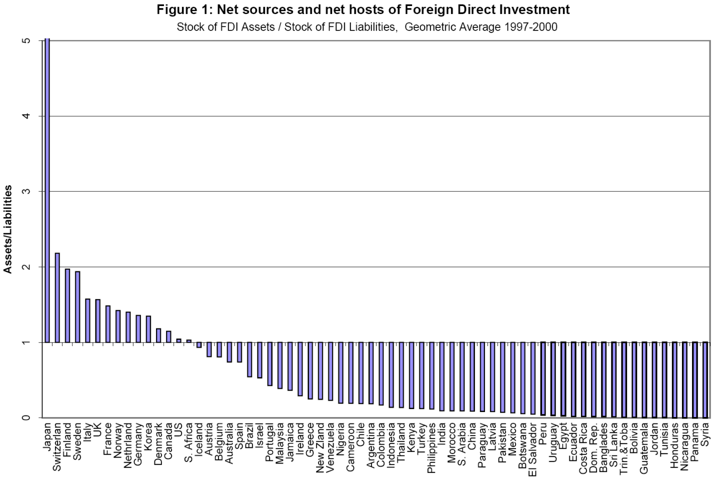
Quantitative Model

- I countries
- Country $i = 1$ net-source, $i = 2, 3, ...I$ net-hosts countries.
- World equilibrium determines $\left\{m^1, m^2, ..., m^I\right\}$, $\sum_{i=1}^{I} m^i = 1$
- $m^1 > 0$, $m^j > 0$ iff $\left(1 - \tau_F^j\right) \pi_1^j = \left(1 - \tau_D^1\right) \pi_1^1$
- World general equilibrium via π_1^1.

Data

- $i = 1$: consolidated net source countries
- $i = 2, ..., 38$:net host countries (most developing)
- $\{Y_t^i, L_t^i, K_t^i\}$: PWT 6.1.
- $\{s_t^i\} : s^i = \frac{\text{stock of inward FDI}}{\text{total capital stock}}$
- Also measure s^i using data on employment of US multinationals and FDI stocks.
- Measures of s^i imperfect, but constructed for multiple host countries.
- $\tau_F^i = \frac{\text{foreign income taxes}}{\text{net foreign income + foreign income taxes}}$

Data



Source: Lane and Milesi-Ferretti (2006). A country is a net-host of FDI if the ratio of assets to liabilites is less than one.

Data

- $\nu = 0.85$
- $\alpha\nu = 0.3$
- Income accounting equation:

$$\left(\frac{Y^i/L^i}{Y^1/L^1}\right) = \left(\frac{\widetilde{z}^i}{\widetilde{z}^1}\right)^{\frac{1}{1-\alpha\nu}} \left(\frac{\widetilde{x}^i}{\widetilde{x}^1}\right)^{\frac{1-\nu}{1-\alpha\nu}} \left(\frac{K^i/Y^i}{K^1/Y^1}\right)^{\frac{\alpha\nu}{1-\alpha\nu}} \left(\frac{1}{\left(1-s^i\right)m^1}\right)^{\frac{1-\nu}{1-\alpha\nu}}$$

Data

Table 1: Aggregate data for sample of net host countries, 1997-2000

	1	2	3	4	5
	Aggregate Data				
Host country	Y^i/L^i	L^i	K^i/Y^i	s^i	τ^i_F
	Values as % of net source country			*Values in %*	
Argentina	53.6	3.8	78.4	10.7	43.4
Bolivia	13.7	0.8	45.9	38.3	28.2
Brazil	37.7	15.2	74.8	7.4	21.1
Chile	49.7	1.4	63.3	33.8	23.2
Colombia	23.8	4.7	53.7	11.6	47.3
Costa Rica	28.5	0.4	61.7	18.0	25.6
Dominican R	30.2	0.6	42.5	23.5	10.6
Ecuador	23.5	0.9	81.7	4.8	28.2
Guatemala	26.6	0.8	33.0	18.7	19.2
Honduras	13.4	0.5	60.1	15.1	34.4
Jamaica	15.0	0.3	96.1	18.5	13.9
Mexico	46.1	8.3	73.5	10.0	30.0
Nicaragua	10.8	0.4	70.5	26.1	33.5
Peru	20.6	2.7	92.9	10.7	28.2
Paraguay	22.6	0.6	55.5	11.7	29.0
El Salvador	27.3	0.5	32.1	15.8	33.5
Uruguay	43.7	0.4	54.9	7.7	29.0
Venezuela	37.7	2.1	74.2	14.5	18.9
China	11.2	184.8	55.8	19.2	24.3
Egypt	26.9	4.6	23.9	32.8	44.1
Indonesia	18.3	20.3	62.9	6.5	45.8
India	11.8	96.0	40.1	3.8	56.4
Israel	86.7	0.6	97.3	5.5	21.7
Jordan	33.0	0.3	58.4	10.7	44.1
Malaysia	53.8	2.0	78.1	23.5	26.0
Pakistan	13.9	9.3	41.6	7.7	56.4
Philippines	16.5	7.3	64.5	10.0	22.9
Syria	32.1	1.0	40.3	40.2	44.1
Thailand	25.0	7.9	112.6	7.4	19.5
Botswana	41.5	0.1	52.2	20.4	47.9
Morocco	23.2	2.2	51.3	14.6	47.9
Tunisia	38.1	0.8	53.5	37.7	47.9
Spain	84.9	3.9	108.5	7.9	25.5
Greece	67.6	1.1	110.3	4.0	41.6
Ireland	116.2	0.4	62.9	48.6	8.8
Iceland	86.3	0.0	97.5	2.2	20.9
Portugal	66.5	1.1	88.1	9.5	27.2
Turkey	30.6	7.1	69.0	2.8	52.2
Median	29.3	1.1	62.9	11.7	28.6
Average	37.1	10.4	66.1	16.1	32.2
Max	116.2	184.8	112.6	48.6	56.4
Min	10.8	0.0	23.9	2.2	8.8

Data

Table 2: Model inference of country- and firm-embedded productivities (benchmark parametrization, 1997-2000)

	1	2	3	4	5	6
Host country	$\tilde{z}^i/\tilde{z}^1$	$\tilde{x}^i/\tilde{x}^1$	z^i/z^1	x^i/x^1	R^i_{static}	R^i_{SS}
Argentina	78.8	35.6	84.1	39.2	0.70	0.60
Bolivia	42.1	8.0	49.1	10.7	0.64	0.42
Brazil	62.6	36.2	67.1	39.1	1.07	0.92
Chile	77.0	33.2	80.1	42.8	0.74	0.58
Colombia	57.2	14.6	65.8	16.1	0.63	0.44
Costa Rica	57.4	22.9	63.1	26.3	0.88	0.68
Dominican R	64.5	27.2	69.3	32.4	1.02	0.66
Ecuador	47.7	21.1	53.6	22.5	0.98	0.88
Guatemala	65.8	23.0	72.3	26.5	0.96	0.53
Honduras	38.9	9.8	46.1	11.1	0.79	0.59
Jamaica	34.6	13.8	39.6	15.9	1.04	1.04
Mexico	71.6	38.2	76.1	41.9	0.90	0.76
Nicaragua	32.9	7.0	39.5	8.5	0.70	0.57
Peru	42.7	17.4	48.5	19.1	0.92	0.89
Paraguay	52.6	18.7	59.3	20.6	0.90	0.65
El Salvador	69.4	20.1	77.3	22.8	0.79	0.42
Uruguay	75.7	37.6	80.8	40.7	0.94	0.68
Venezuela	62.5	34.4	66.6	38.6	1.02	0.88
China	35.3	9.0	42.0	10.4	0.89	0.65
Egypt	77.2	13.3	87.0	17.0	0.52	0.23
Indonesia	47.0	12.2	55.2	13.1	0.69	0.52
India	43.7	6.5	54.3	6.9	0.55	0.32
Israel	91.7	84.4	91.5	90.2	1.08	1.07
Jordan	66.1	21.7	73.6	23.8	0.68	0.50
Malaysia	75.9	40.1	78.9	47.7	0.82	0.72
Pakistan	47.1	7.4	57.8	7.9	0.53	0.31
Philippines	41.8	15.1	48.0	16.5	1.01	0.80
Syria	72.7	14.1	80.5	19.3	0.46	0.27
Thailand	44.0	24.5	48.8	26.4	1.09	1.18
Botswana	78.4	22.7	85.9	26.4	0.56	0.38
Morocco	57.2	13.6	66.0	15.3	0.60	0.41
Tunisia	74.2	16.3	81.5	21.7	0.44	0.30
Spain	88.3	76.7	88.7	83.0	0.99	1.04
Greece	80.5	49.9	84.2	52.9	0.78	0.80
Ireland	119.9	71.7	113.9	107.3	0.70	0.56
Iceland	91.2	87.9	91.2	92.3	1.13	1.13
Portugal	82.5	57.7	84.7	63.0	0.95	0.89
Turkey	61.7	18.7	70.2	19.7	0.62	0.49
Median	63.6	21.4	69.8	23.3	0.81	0.62
Average	63.4	28.5	69.0	32.5	0.81	0.65
Max	119.9	87.9	113.9	107.3	1.13	1.18
Min	32.9	6.5	39.5	6.9	0.44	0.23

Data

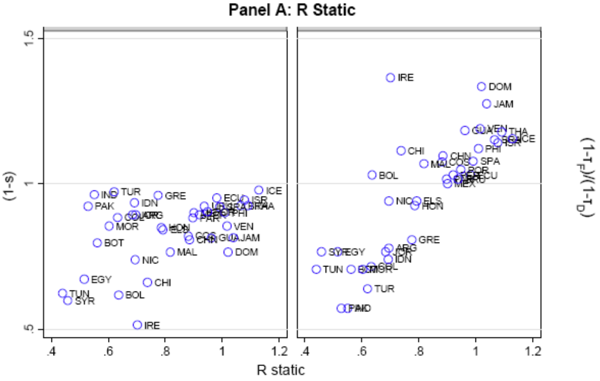
Table 3: Accounting for cross-country differences in output per worker

		1	2	3	4	5
			Decomposition (adds up to 100%)			
		$\log\left(\frac{Y^i/L^i}{Y^1/L^1}\right)$	$\frac{1}{1-\alpha v}\log\left(\frac{\tilde{z}^i}{\tilde{z}^1}\right)$	$\frac{1-v}{1-\alpha v}\log\left(\frac{\tilde{x}^i}{\tilde{x}^1}\right)$	$\frac{1-v}{1-\alpha v}\log\left(\frac{1}{(1-s^i)m^1}\right)$	$\frac{\alpha v}{1-\alpha v}\log\left(\frac{K^i/Y^i}{K^1/Y^1}\right)$
	Difference between Host and Source Countries, 1997-2000 (average host vs. source)					
1	Benchmark parametrization	-118.4%	60.5%	27.2%	-4.9%	17.2%
2	$v = 0.8$	-118.4%	55.2%	35.4%	-6.3%	15.7%
3	$v = 0.9$	-118.4%	66.1%	18.6%	-3.3%	18.6%
4	Reduced set of countries (FDI stocks)	-111.3%	63.2%	26.4%	-4.7%	15.0%
5	Reduced set of countries (employment shares)	-111.3%	63.2%	24.9%	-3.1%	15.0%
	Variation within Host Countries, 1997-2000 (variance-covariance decomposition)					
6	Benchmark parametrization	38.5%	67.1%	23.0%	0.3%	9.6%
7	$v = 0.8$	38.5%	60.8%	29.9%	0.4%	8.8%
8	$v = 0.9$	38.5%	73.6%	15.7%	0.2%	10.5%
9	Reduced set of countries (FDI stocks)	43.9%	67.0%	22.0%	1.2%	9.8%
10	Reduced set of countries (employment shares)	43.9%	67.0%	22.5%	0.8%	9.8%

Data

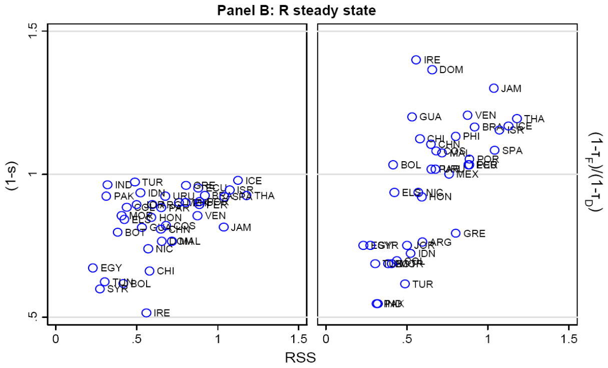
- $m^1 > 0$, $m^i > 0$, $m^{-i} = 0$ iff $R^i < 1$
- R^i measures scarcity of x^i, can be inferred from aggregate data
- $R^i_{\text{static}} \equiv \left(\frac{\tilde{z}^1}{\tilde{z}^i}\right)^{\frac{1}{v}} \left(\frac{\tilde{x}^i}{\tilde{x}^1}\right) \left(\frac{K^i/L^i}{K^1/L^1}\right)^{-\alpha} < 1$ if $(1 - s^i) \left(\frac{1-\tau^i_F}{1-\tau^1_D}\right)^{1/\nu} < 1$

Figure 2: Sources of variation of R in the data



Data

- $R^i_{SS} = \left(\frac{\tilde{z}^1}{\tilde{z}^i}\right)^{\frac{1}{\nu(1-\alpha)}} \left(\frac{\tilde{x}^i}{\tilde{x}^1}\right) < 1 \text{ if } (1-s^i)\left(\frac{1-\tau^i_F}{1-\tau^1_D}\right)^{\frac{1-\alpha\nu}{\nu(1-\alpha)}} \left(\frac{K^i/Y^i}{K^1/Y^1}\right)^{\frac{\alpha}{1-\alpha}} < 1$



Policy counterfactuals

Table 4: Output and consumption percentage gains for host countries of unilaterally moving from autarky to openness to foreign firms

Host Country	1	2	3	4	5	6
	Initial K and Fixed OC		SS K and Fixed OC		SS K and Endog. OC	
	Y	C	Y	C	Y	C
Argentina	6.8	1.3	13.4	5.0	26.8	9.4
Bolivia	8.3	1.7	22.7	10.1	34.4	13.0
Brazil	0.3	0.0	3.4	0.9	3.6	0.9
Chile	5.9	1.0	14.3	5.5	17.5	5.5
Colombia	8.4	1.8	21.2	9.2	41.2	17.6
Costa Rica	3.2	0.3	10.5	3.7	16.4	5.1
Dominican R	0.9	0.0	11.4	4.1	16.1	4.9
Ecuador	1.5	0.1	4.6	1.3	7.1	1.9
Guatemala	1.8	0.1	16.4	6.6	30.5	11.1
Honduras	4.9	0.7	13.9	5.3	25.9	9.0
Jamaica	0.7	0.0	1.0	0.2	0.0	0.0
Mexico	2.7	0.2	7.6	2.4	12.9	3.8
Nicaragua	6.9	1.3	14.7	5.7	22.7	7.6
Peru	2.5	0.2	4.4	1.3	4.6	1.2
Paraguay	2.9	0.2	11.5	4.1	21.7	7.2
El Salvador	4.8	0.6	22.3	9.8	41.5	17.8
Uruguay	2.2	0.1	10.6	3.7	21.0	6.9
Venezuela	1.0	0.0	4.7	1.3	3.7	0.9
China	2.6	0.2	9.5	3.2	15.2	4.6
Egypt	11.7	3.1	38.6	20.3	55.8	29.4
Indonesia	6.8	1.2	16.2	6.5	35.6	13.6
India	9.8	2.3	26.3	12.2	50.0	24.7
Israel	0.1	0.0	0.2	0.1	0.0	0.0
Jordan	7.1	1.3	18.1	7.4	37.7	14.7
Malaysia	4.3	0.5	9.2	3.1	10.8	3.1
Pakistan	11.3	3.0	30.1	14.6	52.5	26.8
Philippines	1.1	0.0	6.6	2.1	10.4	2.9
Syria	13.8	4.2	34.3	17.3	48.1	23.2
Thailand	0.0	0.0	0.0	0.0	0.0	0.0
Botswana	10.4	2.6	25.0	11.4	43.5	19.4
Morocco	9.2	2.1	23.2	10.4	42.9	19.0
Tunisia	14.5	4.7	31.3	15.4	45.6	21.2
Spain	1.3	0.1	0.8	0.2	0.0	0.0
Greece	5.1	0.8	6.6	2.1	12.6	3.7
Ireland	6.7	1.2	15.2	5.9	9.9	2.8
Iceland	0.0	0.0	0.0	0.0	0.0	0.0
Portugal	2.0	0.1	4.4	1.2	4.9	1.3
Turkey	8.6	1.9	18.3	7.5	39.5	16.2
Median	4.6	0.6	12.5	4.6	19.3	6.2
Average	5.1	1.0	13.7	5.8	22.7	9.2
Max	14.5	4.7	38.6	20.3	55.8	29.4
Min	0.0	0.0	0.0	0.0	0.0	0.0

Policy counterfactuals

Table 5: Output and consumption percentage gains for host countries of globally moving from autarky to openness to foreign firms

	1	2	3	4	5	6
Host Country	**Initial K and Fixed OC**		**SS K and Fixed OC**		**SS K and Endog. OC**	
	Y	**C**	**Y**	**C**	**Y**	**C**
Argentina	5.0	0.7	7.4	2.4	16.1	5.0
Bolivia	6.4	1.1	16.0	6.3	23.0	7.7
Brazil	0.0	0.0	0.0	0.0	0.0	0.0
Chile	4.1	0.5	8.1	2.6	6.8	1.8
Colombia	6.5	1.1	14.8	5.7	34.1	12.8
Costa Rica	1.3	0.1	4.4	1.3	5.6	1.5
Dominican R	0.0	0.0	5.3	1.6	5.3	1.4
Ecuador	0.0	0.0	0.0	0.0	0.0	0.0
Guatemala	0.0	0.0	10.1	3.5	19.3	6.2
Honduras	3.1	0.3	7.6	2.4	14.8	4.5
Jamaica	0.0	0.0	0.0	0.0	0.0	0.0
Mexico	1.0	0.0	2.0	0.5	2.7	0.7
Nicaragua	5.0	0.7	8.4	2.8	11.7	3.4
Peru	0.7	0.0	0.0	0.0	0.0	0.0
Paraguay	1.1	0.0	5.4	1.6	10.7	3.0
El Salvador	3.0	0.2	15.6	6.1	34.2	12.9
Uruguay	0.4	0.0	4.5	1.3	10.1	2.8
Venezuela	0.0	0.0	0.0	0.0	0.0	0.0
China	1.3	0.0	5.5	1.6	7.8	2.1
Egypt	9.8	2.3	31.6	15.6	49.9	24.6
Indonesia	5.1	0.7	10.4	3.6	25.4	8.7
India	8.7	1.9	22.8	10.1	46.9	22.2
Israel	0.0	0.0	0.0	0.0	0.0	0.0
Jordan	5.3	0.8	11.6	4.2	26.5	9.3
Malaysia	2.5	0.2	3.2	0.9	0.2	0.0
Pakistan	9.4	2.2	23.3	10.4	46.7	22.1
Philippines	0.0	0.0	0.8	0.2	0.0	0.0
Syria	11.8	3.2	27.0	12.6	42.2	18.4
Thailand	0.0	0.0	0.0	0.0	0.0	0.0
Botswana	8.4	1.8	18.1	7.5	37.7	14.8
Morocco	7.3	1.4	16.6	6.6	37.3	14.4
Tunisia	12.5	3.6	24.1	10.9	39.8	16.5
Spain	0.0	0.0	0.0	0.0	0.0	0.0
Greece	3.3	0.3	0.8	0.2	1.9	0.5
Ireland	4.9	0.7	8.9	3.0	0.0	0.0
Iceland	0.0	0.0	0.0	0.0	0.0	0.0
Portugal	0.2	0.0	0.0	0.0	0.0	0.0
Turkey	6.8	1.3	12.1	4.4	31.0	11.4
Median	2.7	0.2	6.5	2.0	8.9	2.5
Average	3.6	0.7	8.6	3.4	15.5	6.0
Max	12.5	3.6	31.6	15.6	49.9	24.6
Min	0.0	0.0	0.0	0.0	0.0	0.0

Trade, Multinational Production, and the Gains from Openness (Ramondo and Rodriguez-Clare, 2010)

- Quantitative framework for trade and MP in a multi-country, general equilibrium, Eaton-Kortum model
  - Trade and MP are alternative ways to serve a market $\longrightarrow$ substitutes
  - But foreign affiliates import intermediates from home $\longrightarrow$ complementarity
  - Also: "bridge" MP
  - ★ A does MP in B and exports to C $\longrightarrow$ complementarity
- The model is calibrated to match bilateral trade and MP data for OECD (19)
  - Growth pins down "comparative advantage" parameter (θ)
  - Quantification of gains from openness, trade, and MP

The Model

- I countries of size L_i
- Continuum of tradable goods, $v \in [0,1]$, CES aggregator
- Unit cost of good v in country i is $c_i / z_i(v)$
  - $z_i(v)$ is independently drawn (across i and v)

$$F_i(z) = \exp\left[-T_i z^{-\theta}\right]$$

- Iceberg trade costs $d_{ni} \geq 1$
  - unit cost in n of good v produced in i is $d_{ni} c_i / z_i(v)$
- Lowest cost producer of good v in country n

$$p_j(v) = \min_i \left[d_{ni} \frac{c_i}{z_i(v)}\right]$$

Multinational Production

- A good is produced in country l with technologies from i, and sold in country n
  - i: country of origin
  - l: country of production
  - n: country of destination
- A country i can produce good v in country l at cost

$$\frac{c_{li}}{z_{li}(v)}$$

  where c_{li} is unit cost of multinational input bundle for MP
- Unit cost for n of v produced in l with technology from i is

$$d_{nl}\frac{c_{li}}{z_{li}(v)}$$

- Bridge MP (BMP): i does MP in l to sell to n
- Trade and MP are substitute ways to serve a market, but BMP introduces a source of complementarity

MP Productivity

- The vector $\mathbf{z}_i = (z_{1i}, z_{2i}, ..., z_{Ii})$ is drawn independently across goods v from a *Multivariate Fréchet* distribution,

$$F_i(\mathbf{z}_i) = \exp\left[-\left(\sum_{l=1}^{I}\left(T_{li} z_{li}^{-\theta}\right)^{\frac{1}{1-\rho}}\right)^{1-\rho}\right]$$

- $\rho \in [0, 1)$:
    - correlation $\rightarrow 1$ as $\rho \rightarrow 1$
    - correlation $= 0$ as $\rho = 0$
- The vector $\mathbf{z}_i$ is drawn independently across i

Complementarities through Imported Inputs

- Unit cost of the multinational input bundle for MP by i in l

$$c_{li} = \left[(1-a) \left(c_l h_{li} \right)^{1-\xi} + a \left(c_i d_{li} \right)^{1-\xi} \right]^{\frac{1}{1-\xi}}$$

- h_{li} is an "iceberg" cost of MP by i in l ($h_{li} \geq 1$, $h_{ii} = 1$)
- Key parameters: a, ξ
  - if $a = 0$, $c_{li} = c_l h_{li}$
  - $\xi \to 1$, inputs are complements; $\xi \to \infty$, inputs are substitutes
- Home input bundle for MP by i in l
  - imports from i to l associated with MP by i in l
  - source of *complementarity* between trade and MP

Costs

- Tradable intermediate goods $v \in [0,1]$, CES aggregator with price index P_{gn}
  - MP by i in n has unit cost c_{ni} (imports of the Home input bundle for MP)
- Non-tradable final goods $u \in [0,1]$, CES aggregator with price index P_{fn}
  - MP by i in n has unit cost $c_n h_{ni}$ (no imports of the Home input bundle for MP)
- Input-Output loop:

$$
\begin{aligned}
c_{gn} &= B w_n^{\beta} P_{gn}^{1-\beta} \\
c_{fn} &= A w_n^{\alpha} P_{gn}^{1-\alpha}
\end{aligned}
$$

Gains and Definitions

- Gains = change in real wage w/P_f from
  - only MP to trade and MP, GT
  - only trade to trade and MP, GMP
- The gains of moving from isolation to:
  - trade in a model with only trade are GT^*
  - MP in a model with MP are GMP^*
- Complementarity and Substitution
  - $GT > GT^*$: trade is MP-complement
  - $GT < GT^*$: trade is MP-substitute
  - $GT = GT^*$: trade is MP-independent
  - analogous definitions for MP ...

Special Cases

- A Special Case: For $a = \rho = 0$, the model generates no interaction between trade and MP. Thus,
  - $GT = GT^*$; $GMP = GMP^*$; $GO = GT^* \times GMP^*$
  - GT^* and GMP^* can be computed as functions of trade and MP shares, respectively
- Symmetry: L; T; $d > 1$, $h > 1$, for all $l \neq n$. Define $\eta \equiv (1-\alpha)/\beta$
  - Wages, costs, and prices are equal across countries: w, c_g, c_f, P_g, P_f
  - Unit cost of the multinational input bundle for MP $= mc_g$

$$m = \left[(1-a)h^{1-\xi} + ad^{1-\xi}\right]^{\frac{1}{1-\xi}}$$

  - If $d \to \infty$ (no trade) then

$$\widetilde{m} = (1-a)^{\frac{1}{1-\xi}}\, h$$

Symmetry: Real Wages

w/P_f

- Isolation:

$$T^{\frac{1+\eta}{\theta}}$$

- Trade:

$$\left[1+(I-1)d^{-\theta}\right]^{\frac{\eta}{\theta}} T^{\frac{1+\eta}{\theta}}$$

- MP:

$$\left[1+(I-1)h^{-\theta}\right]^{\frac{1}{\theta}} \cdot \left[1+(I-1)\widetilde{m}^{-\theta}\right]^{\frac{\eta}{\theta}} T^{\frac{1+\eta}{\theta}}$$

- Trade and MP:

$$\left[1+(I-1)h^{-\theta}\right]^{\frac{1}{\theta}} \cdot \left[\Delta_0+(I-1)\Delta_1\right]^{\frac{\eta}{\theta}} T^{\frac{1+\eta}{\theta}}$$

Symmetry: Gains

- Gains

$$GO = \left[1 + (I-1)h^{-\theta}\right]^{\frac{1}{\theta}} \cdot \left[\Delta_0 + (I-1)\Delta_1\right]^{\frac{\eta}{\theta}}$$

where

$$\begin{aligned}\Delta_0 &\equiv \left(1 + (I-1)(md)^{-\frac{\theta}{1-\rho}}\right)^{1-\rho} \\ \Delta_1 &\equiv \left(d^{-\frac{\theta}{1-\rho}} + m^{-\frac{\theta}{1-\rho}} + (I-2)(md)^{-\frac{\theta}{1-\rho}}\right)^{1-\rho}\end{aligned}$$

- Gains from Trade given MP

$$GT = \left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)\widetilde{m}^{-\theta}}\right]^{\frac{\eta}{\theta}}$$

- Gains from MP given Trade

$$GMP = \left[1 + (I-1)h^{-\theta}\right]^{\frac{1}{\theta}} \cdot \left[\frac{\Delta_0 + (I-1)\Delta_1}{1 + (I-1)d^{-\theta}}\right]^{\frac{\eta}{\theta}}$$

Symmetry: Substitution and Complementarity

- For $\rho = 0$ (no correlation),
  - trade is MP-complement, $GT \geq GT^*$ (independent for $a = 0$)
  - MP is trade-independent, $GMP = GMP^*$
  - BMP is not enough to generate complementarity
- For $0 < \rho < 1$ (some correlation),
  - for $a = 0$, trade is MP-substitute, $GT < GT^*$
  - MP is trade-substitute, $GMP < GMP^*$
- If $\xi \to 1$, trade is MP-complement, $GT > GT^*$
- If $\xi \to \infty$, trade is MP-substitute, $GT < GT^*$

Data

- Countries: OECD 19
- Bilateral trade in intermediates in the model = manufacturing trade from i to n (STAN, avg. 90s)
- Bilateral MP in the model = gross value of production of affiliates from i in l (UNCTAD, avg. 90s)
- Imports of Home input bundle for intermediates by MP in l from i in the model = intra-firm imports from i to l (BEA data from/to US, avg. 90s)
- Bilateral MP by i in l in intermediates in the model = gross value of production of affiliates from i in l in manufacturing (BEA data from/to US, avg. 90s)
- Income per capita in the model = PPP-adjusted real GDP per worker (PWT, avg. 90s)

Calibration: Cost Parameters

$$
\begin{aligned}
d_{ni} &= 1 + (\delta^d + \delta^d_{dist} dist_{ni}) \times (\delta^d_{border})^{b_{ni}} \times (\delta^d_{language})^{l_{ni}} \\
h_{gni} &= 1 + (\delta^h + \delta^h_{dist} dist_{ni}) \times (\delta^h_{border})^{b_{ni}} \times (\delta^h_{language})^{l_{ni}} \\
h_{fni} &= \mu \cdot h_{gni}
\end{aligned}
$$

$dist_{ni}$ is distance between i and n; b_{ni} (l_{ni}) is one if i and n share border (language)

Calibration: Growth Implications

- They think of the Multivariate Fréchet in the static model as the result of the steady state equilibrium of a dynamic model where productivity $Z_s \equiv (\mathbf{z}_{s1}, ..., \mathbf{z}_{sI})$, for $s = f, g$, evolves according to an exogenous research process
  - they have a quasi-endogenous growth similar to Jones (95), Kortum (97), and Eaton and Kortum (01) where growth is driven by aggregate economies of scale (larger population implies a higher stock of non-rival ideas)
- $T_{li} = \lambda_i$. We assume
  - $g_{\lambda_i} = g_\lambda$ so that $g_T = g_\lambda$
- The (common) growth rate of real wages is

$$g = \frac{1+\eta}{\theta} \cdot g_\lambda$$

Calibration: Remaining Parameters

- The labor shares parameters are from AL (07)
  - for final sector: $\alpha = 0.75$; for intermediate sector: $\beta = 0.5$
  - then, $\eta \equiv (1 - \alpha)/\beta = 0.5$
- The elasticity of substitution between Home and Host inputs in MP is from Becker and Muendler (09), $\xi = 1.5$
- The parameter $\theta = 7.2$ (similar to EK 02, AL 07, SW 09)
  - $g_y = \frac{1}{1-\alpha_k} g = \frac{1}{1-\alpha_k} \frac{1+\eta}{\theta} g_\lambda$
  - $g_y = 0.015$ is growth rate of real output per worker in the OECD over the last four decades (K-RC, 05)
  - $g_\lambda = 0.048$ is growth rate of R&D employment over the last decades in the top five R&D countries (Jones, 02)
- We assume $\lambda_n \sim L_n$
- We fix $\rho = 0.5$ (robustness on this)

Calibration: Procedure

- The algorithm: for each set of cost parameters

$$\Upsilon = \left\{ \delta^s, \delta^s_{dist}, \delta^s_{border}, \delta^s_{lang} \right\}^{s=h,d}$$

choose $\{L_i\}_{i=1}^{I}$, a, and μ to match real income per worker, average bilateral intra-firm trade shares (for US), and average bilateral MP share in intermediates (for US), and then choose Υ to minimize

$$\frac{\sum_{n,i;n\neq i}\left(\widetilde{X}_{ni}^{data} - \widetilde{X}_{ni}^{model}\right)^2}{\sum_{n,i;n\neq i}\left(\widetilde{X}_{ni}^{data}\right)^2} + \frac{\sum_{n,i;n\neq i}\left(\widetilde{Y}_{ni}^{data} - \widetilde{Y}_{ni}^{model}\right)^2}{\sum_{n,i;n\neq i}\left(\widetilde{Y}_{ni}^{data}\right)^2}$$

Results: Cost Parameters

Costs:	Trade (d_{ni})	MP (h_{gni})
δ_{dist}	0.05	0.03
δ_{border}	0.74	0.80
$\delta_{language}$	0.68	0.65
δ	0.50	0.66
Average Costs	1.77	1.81
	(0.2)	(0.16)

Results: Goodness of Fit

Model's R^2	
bilateral trade shares	0.77
bilateral MP shares	0.64

Correlations model-data	
bilateral trade shares	0.84
bilateral MP shares	0.74
total exports shares	0.79
total imports shares	0.83
total outward MP shares	0.28
total inward MP shares	0.29

Results: Summary Statistics

	Data	$\rho = 0.5$	$\rho = 0$
Avg. trade share from i to l	0.019	0.018	0.018
Avg. MP share by i in l	0.022	0.020	0.019
corr. trade and MP shares from i to l	0.70	0.83	0.85
Avg. "BMP" by US in l (as share of MP by US in l)	0.30	0.03	0.14
Avg. "BMP" by i in US (as share of MP by i in US)	0.05	0.004	0.03

Gains from Openness, Trade, and MP

Gains = change in real wages

OECD (19)	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*
Average	1.09	1.05	1.03	1.04	1.08
STD	0.06	0.03	0.02	0.03	0.05
Minimum (Japan)	1.005	1.003	1.002	1.001	1.005
Maximum (Belgium)	1.19	1.11	1.07	1.09	1.18

$GO_n >> GT_n^*$ and $GO_n > GMP_n^*$
Trade is MP-complement: $GT_n > GT_n^*$
MP is trade-substitute: $GMP_n < GMP_n^*$

Gains from Openness, Trade, and MP, by Sector

	GO_n	GT_n	GT_n^*	GMP_n	GMP_n^*
All sectors	1.09	1.05	1.03	1.04	1.08
Intermediate good sector	1.06	1.05	1.03	1.01	1.05
Final good sector	1.03	-	-	1.03	1.03

Conclusion

- $GT_n > GT_n^*$ because trade facilitates MP
- $GMP_n < GMP_n^*$ because MP is a substitute for trade
- $GO_n >> GT_n^*$ due to MP and complementarity forces from trade