Openness, Technology Capital, and Development

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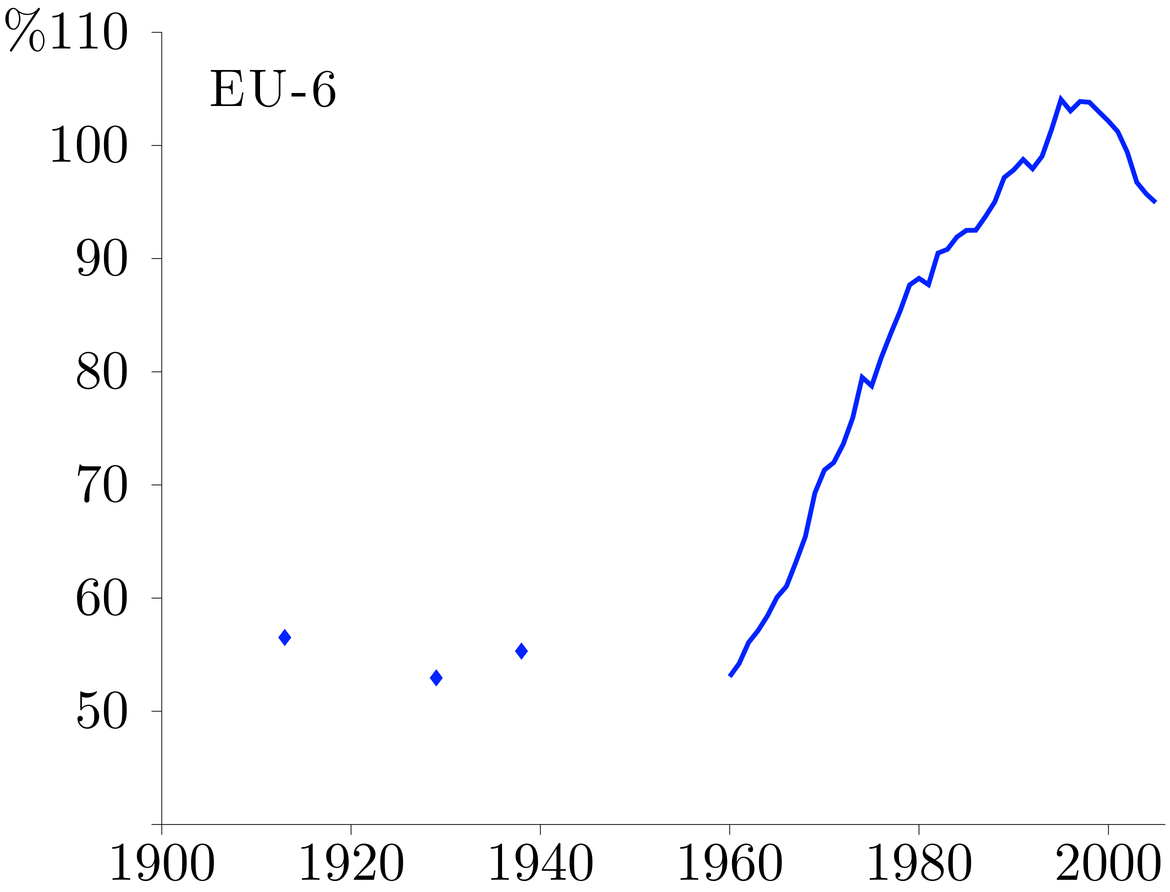
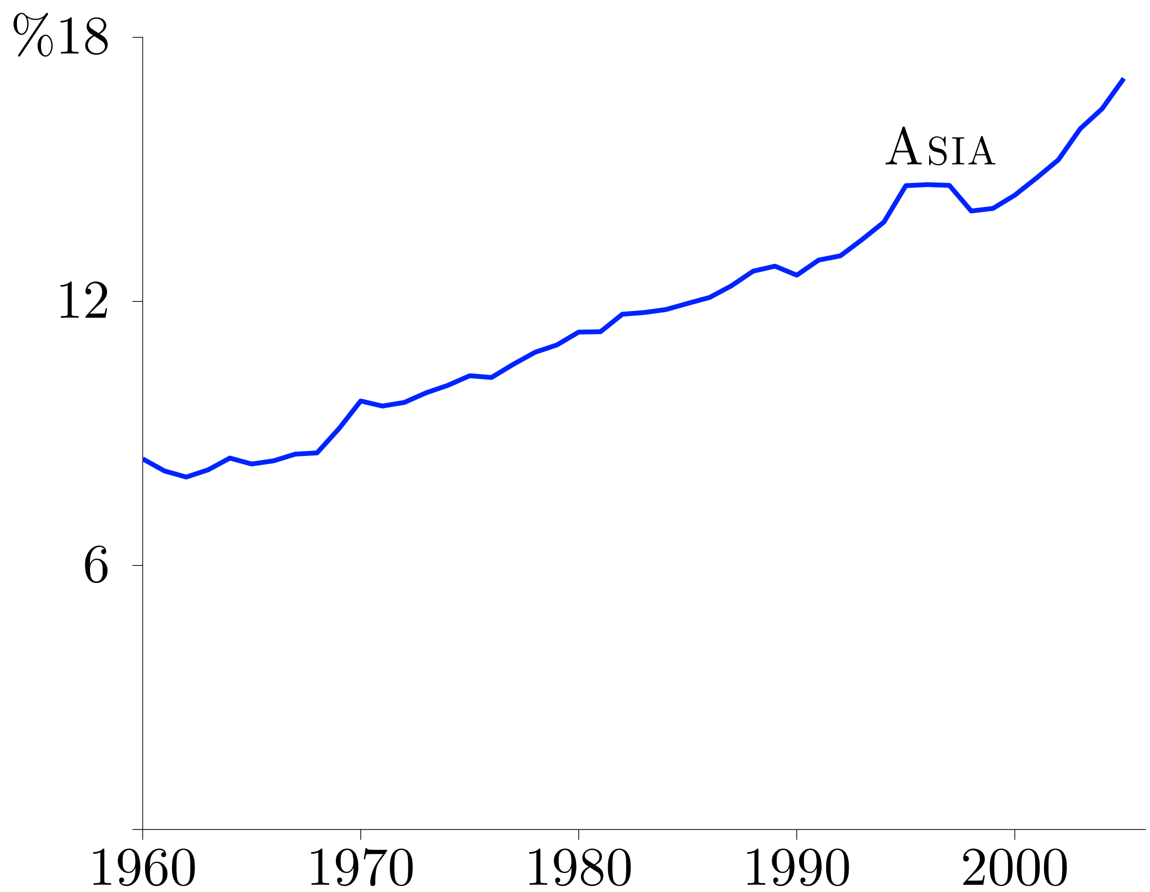
Why Did the EU-6 Catch Up?



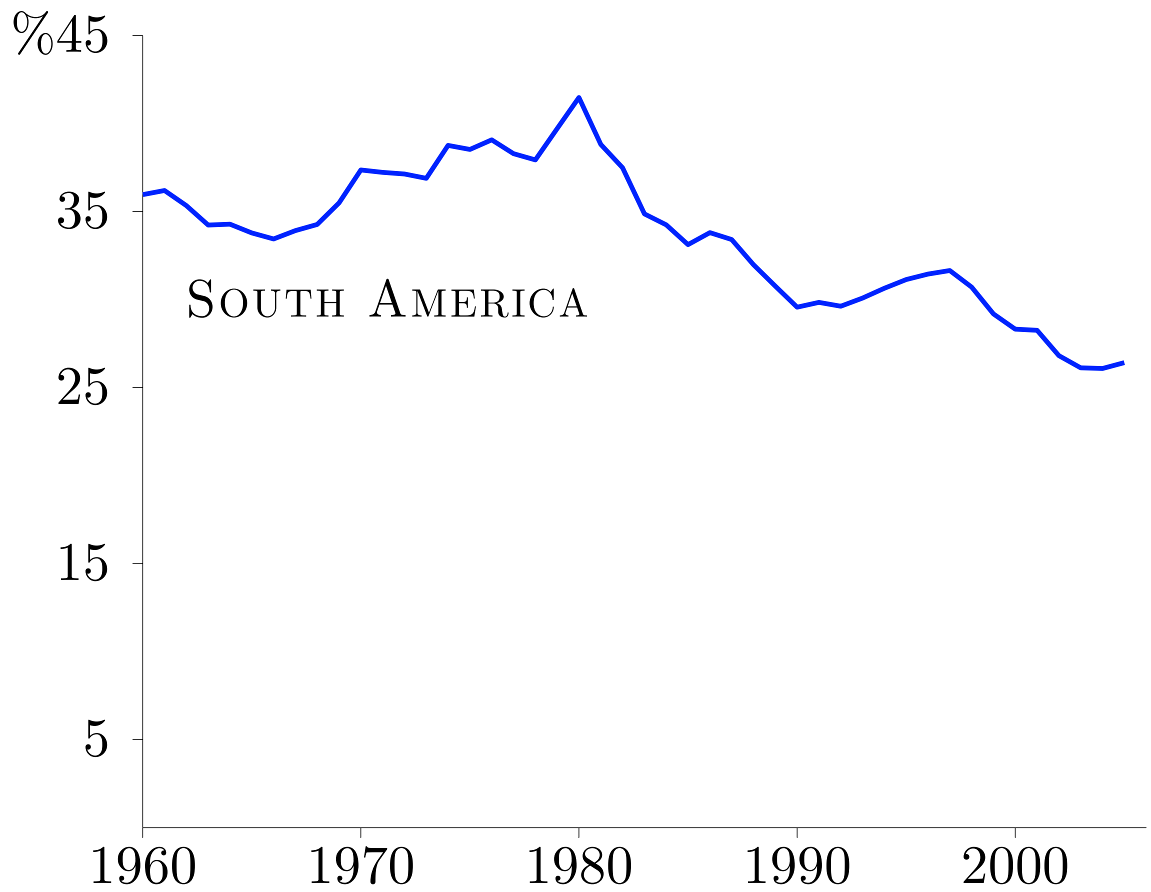
EU-6 Labor Productivity as % of US

Why is Asia Starting to Catch Up?



Asian Labor Productivity as % of US

While South America Is Losing Ground?



South American Labor Productivity as % of US

Questions

- Why did the EU-6 catch up?
- Why is Asia starting to catch up?
- Why is South America losing ground?

Answer: Open countries gain, closed countries lose

Our Notion of Openness

- Openness can mean many things
- We mean foreign multinationals' *technology capital* permitted
- We find big gains to openness

Technology Capital

- Is accumulated know-how from investments in
  - R&D
  - Brands
  - Organization know-how

which can be used in as many *locations* as firms choose

New Avenue for Gains

- Countries are measures of locations
- Technology capital can be used in multiple locations
- Implying gains to openness
  - Without increasing returns
  - Without factor endowment differences

Theory

Closed-Economy Aggregate Output

$$Y = A(NM)^{1-\phi} Z^{\phi}$$

M= units of *technology capital*

Z = composite of other factors, $K^{\alpha} L^{1-\alpha}$

N= number of production *locations*

A= the technology parameter

ϕ= the income share parameter

which is the result of maximizing plant-level output

A Micro Foundation for Aggregate Function

- $n \in \{1, \ldots, N\}$, $m \in \{1, \ldots, M\}$

$$F(N, M, Z) = \max_{z_{nm}} \sum_{n,m} g(z_{nm})$$

$$\text{subject to} \quad \sum_{n,m} z_{nm} \leq Z$$

We assume $g(z) = Az^{\phi}$, increasing and strictly concave

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$$\text{subject to} \quad \sum_{n,m} z_{nm} \leq Z$$

$\Rightarrow$ optimal to split Z evenly across location-technologies

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$$\Rightarrow F(N, M, Z) = NMg(Z/NM) = A(NM)^{1-\phi} Z^{\phi}$$

A Micro Foundation for Aggregate Function

- $n \in \{1, \dots, N\}$, $m \in \{1, \dots, M\}$

$$F(N, M, Z) = \max_{z_{nm}} \sum_{n,m} g(z_{nm})$$

$$\text{subject to} \quad \sum_{n,m} z_{nm} \leq Z$$

$$\Rightarrow F(N, \lambda M, \lambda Z) = \lambda F(N, M, Z)$$

Production in Open Economy

- The degree of openness of country i is σ_i

- Aggregate output in i is

$$\max_{z_d, z_f} \; M_i N_i A_i z_d^{\phi} + \sigma_i \sum_{j \neq i} M_j N_i A_i z_f^{\phi}$$

$$\text{subject to} \quad M_i N_i z_d + \sum_{j \neq i} M_j N_i z_f \leq Z_i$$

d, f indexes allocations to domestic and foreign operations

Production in Open Economy

- The degree of openness of country i is σ_i

- Aggregate output in i is

$$Y_i = A_i N_i^{1-\phi}(M_i + \omega_i \sum_{j \neq i} M_j)^{1-\phi} Z_i^{\phi}$$

where

$$Z_i = K_i^{\alpha} L_i^{1-\alpha}$$

$$\omega_i = \sigma_i^{\frac{1}{1-\phi}} = \text{fraction of foreign T-capital permitted}$$

Production in Open Economy

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- Aggregate output in i is

$$Y_i = A_i N_i^{1-\phi} (M_i + \omega_i \sum_{j \neq i} M_j)^{1-\phi} Z_i^{\phi}$$

- Key result:

  Each i has constant returns, but summing over i results in a *bigger* aggregate production set.

Production in Open Economy

- The degree of openness of country i is σ_i

- Aggregate output in i is

$$Y_i = A_i N_i^{1-\phi} (M_i + \omega_i \sum_{j \neq i} M_j)^{1-\phi} Z_i^{\phi}$$

- Key result:

It is *as if* there were increasing returns,

when in fact there are none.

Advantages to Our Technology

- Standard welfare analysis
- Standard national accounting
- Standard parameter selection

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- Standard welfare analysis

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- Standard parameter selection

Next, we describe the rest of the model

Introduce Population

- N_i = number of production locations in i
- $N_i \propto$ population in i
- Interpretation: expanding markets requires more consumers
- Implication: Canada is like Taiwan, not China

Country i Household's Problem

$$\max \quad \sum_t \beta^t U(C_{it}/N_{it}, L_{it}/N_{it})N_{it}$$

$$\text{s.t.} \qquad C_{it} + X_{ikt} + X_{imt} + NX_{it} = Y_{it}$$

Country i Household's Problem

$$\max \quad \sum_t \beta^t U(C_{it}/N_{it}, L_{it}/N_{it}) N_{it}$$

$$\text{s.t.} \quad C_{it} + X_{ikt} + X_{imt} + NX_{it} = Y_{it}$$

$$K_{i,t+1} = (1-\delta_k)K_{it} + X_{ikt}$$

$$M_{i,t+1} = (1-\delta_m)M_{it} + X_{imt}$$

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$$N_{it} = (1+\gamma_N)^t N_{i0}$$

Country i Household's Problem

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$$X_{imt}, X_{ikt} \geq 0$$

Country i Household's Problem

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$$X_{imt}, X_{ikt} \geq 0$$

$$K_{i0}; M_{i0}; \{A_{it}, \omega_{it}\}\ \forall i,t; \{M_{jt}\} \forall j \neq i, t; \{r_{it}^j\} \forall i,j,t \text{ given}$$

How do Countries Differ?

Differences Across Countries

- Degree of openness
- Size $= \mathcal{A}_i N_i$
  - N_i is proprotional to population
  - $\mathcal{A}_i$ is augmenting labor & location $(= A_i^{\frac{1}{1-\phi\alpha}})$

Results depend only on product $\mathcal{A}_i N_i$

Steady State Analysis

A Steady State Exists

- Assume labor is supplied inelastically (w.l.o.g.)
- Proposition. A non-zero steady state exists.

  Sketch of Proof:

  - K_i / Y_i same across i

    $\Rightarrow Y_i = \psi \mathcal{A}_i N_i (M_i + \omega_i \sum_{j \neq i} M_j)^{\frac{1-\phi}{1-\alpha\phi}}$

  - Combined with $\sum_j \partial Y_j / \partial M_i \leq \rho + \delta_m, \; = \text{if } M_i > 0$

    $\Rightarrow$ System for which we apply Kakutani theorem

Algorithm to Compute Steady State

- System for $M = \{M_i\}_{i \in I}$:

$$\sum_{j \in I} \frac{\partial F_j}{\partial M_i} = \rho + \delta_m, \quad i \in J \subseteq I$$

$$M_i = 0 \quad \text{for } i \notin J$$

  - Step 1. Set $J = I$.
  - Step 2. Solve system. If $M \geq 0$, stop.
  - Step 3. Remove $i = \text{argmin}\{M_i\}$ from J. Go to 2.

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$

- Equilibrium conditions are:

$$\rho + \delta_m \geq \underbrace{(1-\phi)\frac{Y_1}{M_1 + \omega M_2}}_{\text{Return on } M_1 \text{ in } 1} + \underbrace{(1-\phi)\frac{\omega Y_2}{M_2 + \omega M_1}}_{\text{Return on } M_1 \text{ in } 2}$$

$$\rho + \delta_m \geq \underbrace{(1-\phi)\frac{Y_2}{M_2 + \omega M_1}}_{\text{Return on } M_2 \text{ in } 2} + \underbrace{(1-\phi)\frac{\omega Y_1}{M_1 + \omega M_2}}_{\text{Return on } M_2 \text{ in } 1}$$

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$
- Equilibrium conditions—if $M_1, M_2 > 0$—are:

$$M_1 \propto \frac{Y_1 - \omega Y_2}{1 - \omega}$$

$$M_2 \propto \frac{Y_2 - \omega Y_1}{1 - \omega}$$

$$M_i + \omega M_{-i} \propto (1 + \omega) Y_i$$

if ω is not too large so $M_2 > 0$

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$
- Substitute $M_i + \omega M_{-i}$ into production function

$$\frac{Y_i}{\mathcal{A}_i N_i} \propto (M_i + \omega M_{-i})^{\frac{1-\phi}{1-\alpha\phi}}$$

$$\propto [(1+\omega)\mathcal{A}_i N_i]^{\frac{1-\phi}{\phi(1-\alpha)}}$$

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Implying an advantage to size when ω small

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$

- Equilibrium conditions—if $M_2 = 0$—are:

$$\rho + \delta_m = \underbrace{(1-\phi)\frac{Y_1}{M_1 + \omega 0}}_{\text{Return on } M_1 \text{ in } 1} + \underbrace{(1-\phi)\frac{\omega Y_2}{0 + \omega M_1}}_{\text{Return on } M_1 \text{ in } 2}$$

$$\rho + \delta_m \geq \underbrace{(1-\phi)\frac{Y_2}{0 + \omega M_1}}_{\text{Return on } M_2 \text{ in } 2} + \underbrace{(1-\phi)\frac{\omega Y_1}{M_1 + \omega 0}}_{\text{Return on } M_2 \text{ in } 1}$$

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$

- Equilibrium conditions—if $M_2 = 0$—are:

$$\rho + \delta_m = \underbrace{(1-\phi)\frac{Y_1 + Y_2}{M_1}}_{\text{Total return on } M_1}$$

$$M_2 = 0$$

$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$
- Substitute M_1 into production function

$$\begin{aligned} Y_1 &\propto \mathcal{A}_1 N_1 M_1^{\frac{1-\phi}{1-\alpha\phi}} \\ &\propto \mathcal{A}_1 N_1 (Y_1 + Y_2)^{\frac{1-\phi}{1-\alpha\phi}} \end{aligned}$$

$$\begin{aligned} Y_2 &\propto \mathcal{A}_2 N_2 (\omega M_1)^{\frac{1-\phi}{1-\alpha\phi}} \\ &\propto \mathcal{A}_2 N_2 (\omega (Y_1 + Y_2))^{\frac{1-\phi}{1-\alpha\phi}} \end{aligned}$$

Implying no advantage to size for $\omega = 1$

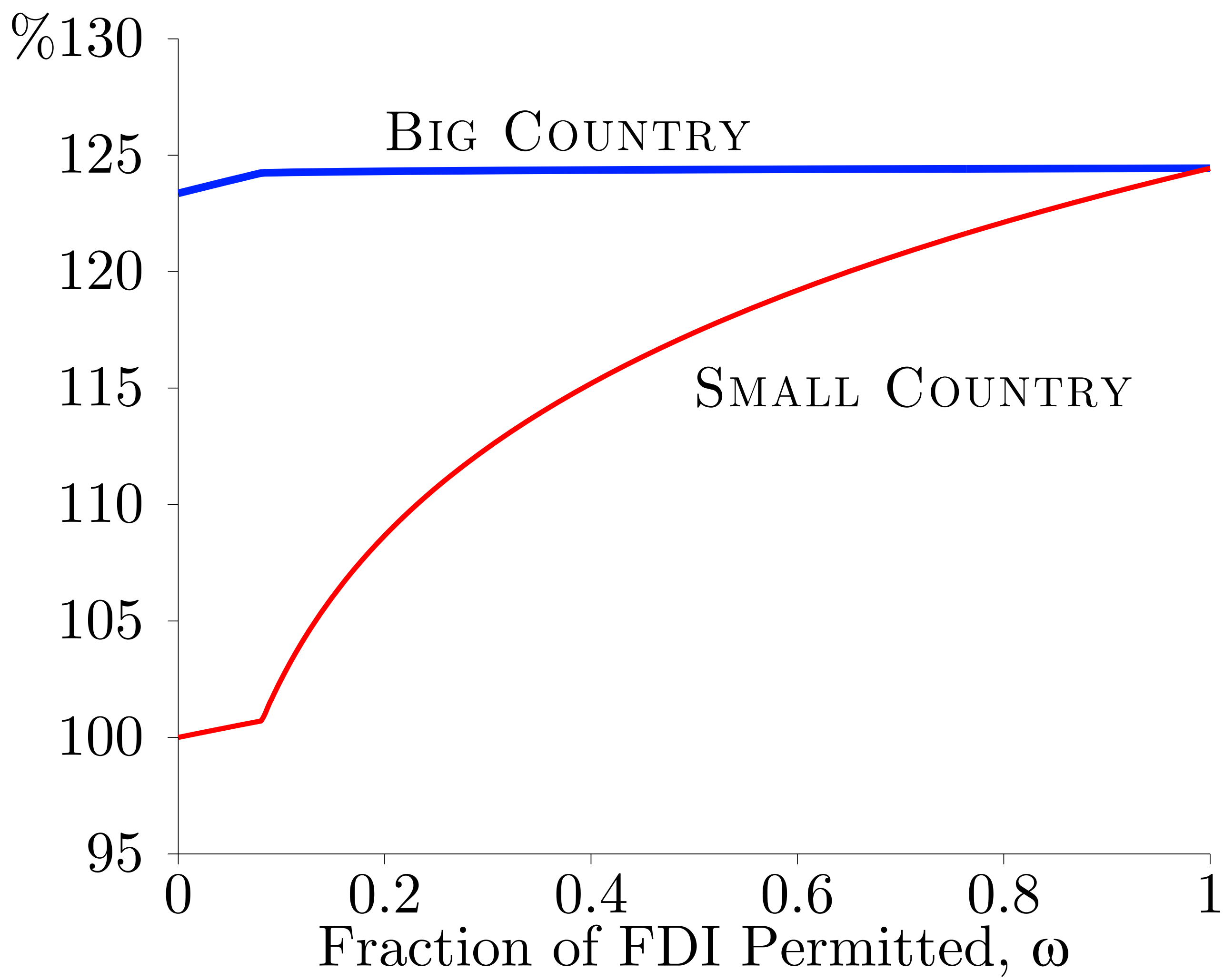
$I = 2$, Symmetric ω Case

- Country 1 is larger, $\mathcal{A}_1 N_1 \geq \mathcal{A}_2 N_2$
- Substitute M_1 into production function

$$Y_1 \propto \mathcal{A}_1 N_1 M_1^{\frac{1-\phi}{1-\alpha\phi}}$$
$$\propto \mathcal{A}_1 N_1 (Y_1 + Y_2)^{\frac{1-\phi}{1-\alpha\phi}}$$
$$Y_2 \propto \mathcal{A}_2 N_2 (\omega M_1)^{\frac{1-\phi}{1-\alpha\phi}}$$
$$\propto \mathcal{A}_2 N_2 (\omega (Y_1 + Y_2))^{\frac{1-\phi}{1-\alpha\phi}}$$

And productivity $\propto$ *total world output* to a power

Productivities vs. ω, $\mathcal{A}_1 N_1 = 10\mathcal{A}_2 N_2$



Big gains from Forming Unions

- I = number of equal-sized countries forming union

- Then, productivity gain for I in union is

$$y(I)/y(1) = I^{\frac{1-\phi}{\phi(1-\alpha)}}$$

- For example, if $\alpha = .3$, $\phi = .94$,

$$\text{gain} = 23\% \quad \text{if } I = 10$$

$$\text{gain} = 52\% \quad \text{if } I = 100$$

Big Gains from Unilaterally Opening

- I = number of equal-sized countries remaining closed

- Then, productivity gain of I+1st opening is

$$y_o/y_c = I^{\frac{1-\phi}{1-\phi\alpha}}$$

- For example, if $\alpha = .3$, $\phi = .94$,

  gain = 21% if $I = 10$

  gain = 47% if $I = 100$

Economies in Transition

In Transitions

- Allow for

  - Labor to be elastically supplied with

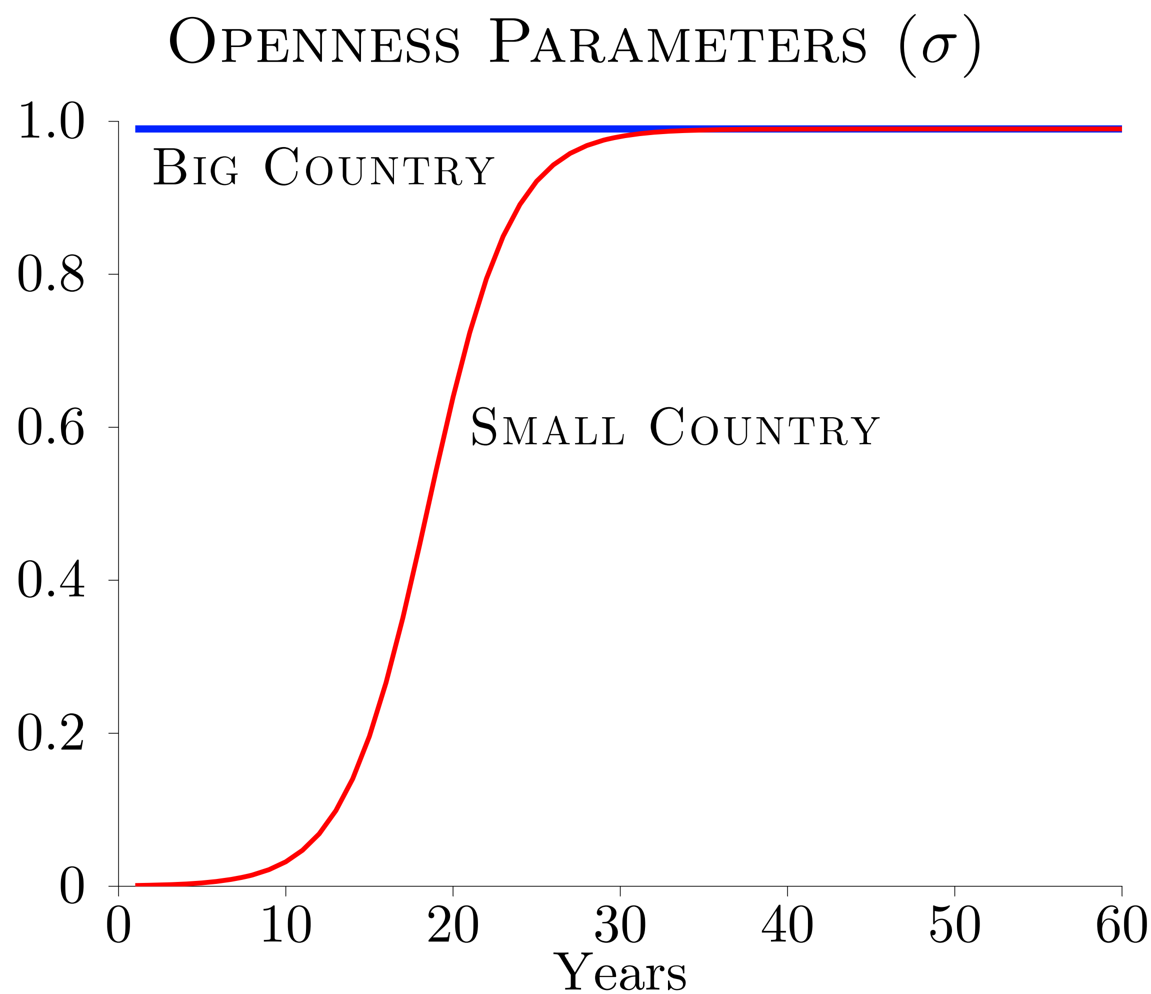
$$u(c, l) = \log c + \psi \log(1 - l)$$

  - Growth in population γ_N and technology $\gamma_{\mathcal{A}}$ so

$$\gamma_Y = [(1 + \gamma_{\mathcal{A}})(1 + \gamma_N)]^{(1-\phi\alpha)/(\phi-\phi\alpha)} - 1$$

- What happens to a country joining an open EU?

Small Country ($\mathcal{A}N = 1$) Opens to Big ($\mathcal{A}N = 10$)



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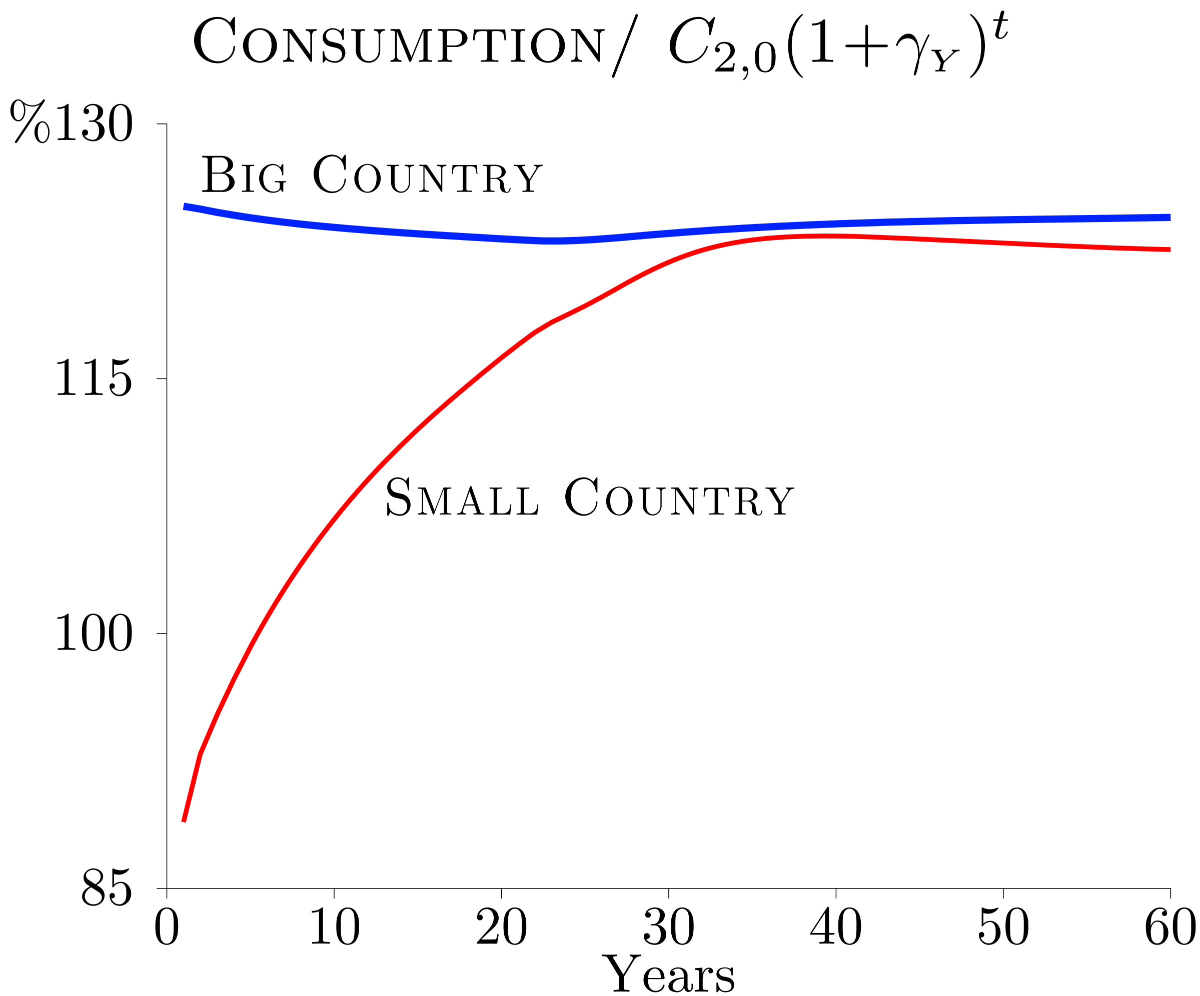

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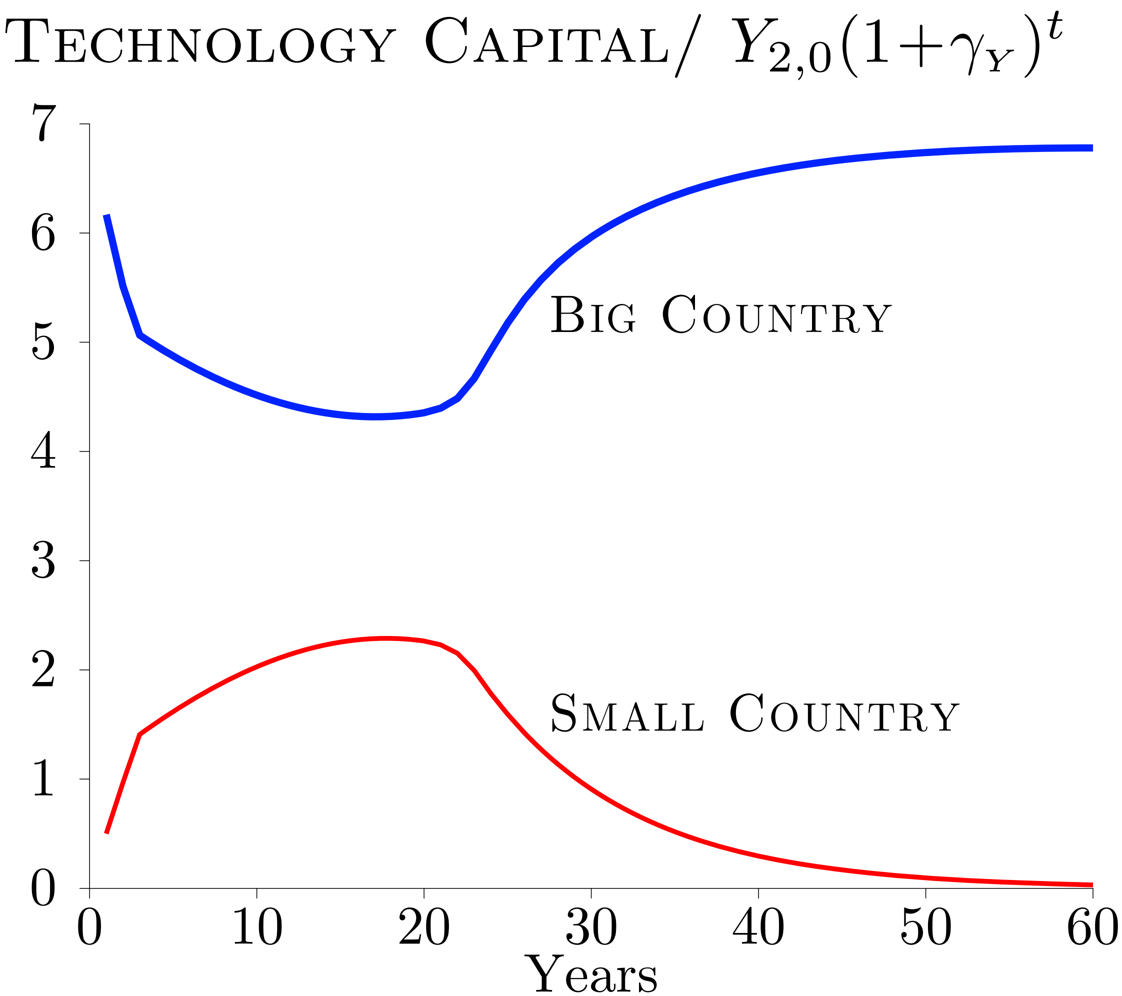

Small Country Opens to Big – Recap

- Large and rapid gains in consumption

- Specialization in technology capital investment
  - Initially takes advantage of new markets
  - Eventually exploits big country's stock

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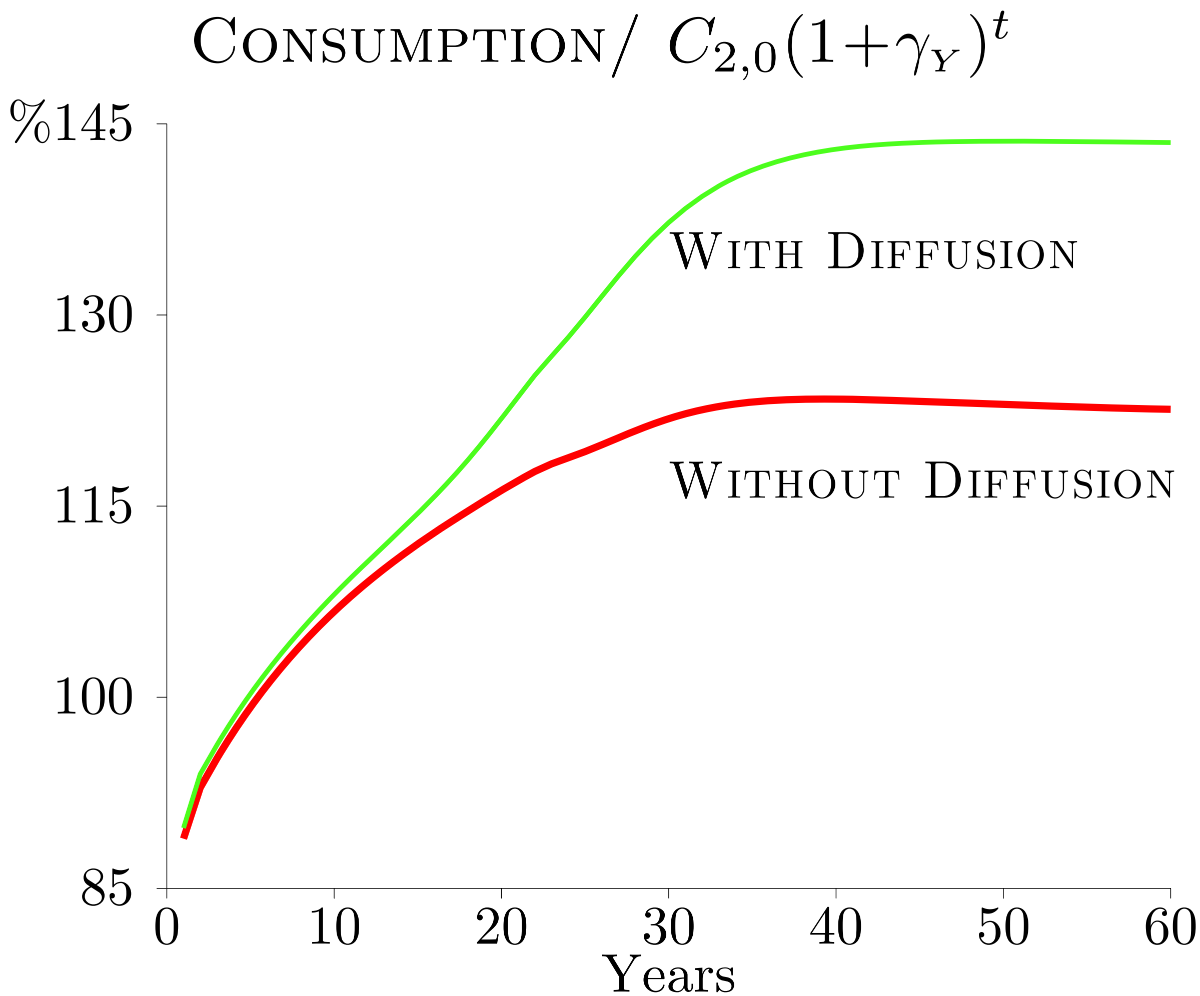
- What if there is diffusion of knowlege?

Gains from Opening with Diffusion

- Compare small country's consumption in 2 cases:
  - Without diffusion ($A_{2t} = A_{1t}$)
  - With diffusion ($A_{2t} = A_{1t}(.9 + .1\sigma_{2,t})$)

Gains from Opening with Diffusion



Summary

- Paper extends neoclassical growth model by adding
  - Locations
  - Technology capital
- Use new theory to assess the gains from openness
- Elsewhere, use theory to study U.S. net asset position