Openness, Technology Capital, and Development

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http://minneapolisfed.org/research/economists/emcgrattan.html

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

Our Thesis

- Technology capital is critical to
  - Assessing gains from opening to FDI
  - Predicting current account flows/balances

New Model of FDI

- Countries are measures of locations
- Technology capital can be used in multiple locations
- Doesn't require monopoly rents to finance innovations

New Avenue for Gains From FDI

- Opening implies bigger aggregate production sets

- In our model, gains arise
  - Without increasing returns
  - Without traditional factor endowment differences
  - Even with symmetric countries

Main Findings

- Gains from opening to FDI are large
- Current account "puzzles" are not so puzzling

Theory

Closed-Economy Aggregate Output

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

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 $g(z) = Az^{1-\phi}$, increasing and strictly concave

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

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

$\Rightarrow$ organizational span of control limits

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

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

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

A Micro Foundation for Aggregate Function

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

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

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

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

A Micro Foundation for Aggregate Function

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

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

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

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

Production in Open Economy

- The degree of openness of country i is $\sigma_i \in [0,1]$

- Aggregate output in i is

$$\max_{z_d, z_f} \; M_i N_i A_i z_d^{1-\phi} + \sigma_i \sum_{j \neq i} M_j N_i A_i z_f^{1-\phi}$$

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

d, f indexes allocations to domestic and foreign operations

Production in Open Economy

- Aggregate output in i is

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

where

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

$$\omega_i = \sigma_i^{\frac{1}{\phi}}$$

- Alternative interpretation of openness: fraction of M_j let in

Production in Open Economy

- Aggregate output in i is

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

- Key result provided $\omega_i > 0$:

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

Production in Open Economy

- Aggregate output in i is

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

- Key result:

It is *as if* there were increasing returns,

when in fact there are none.

Production in Open Economy

- Aggregate output in i is

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

- Key result:

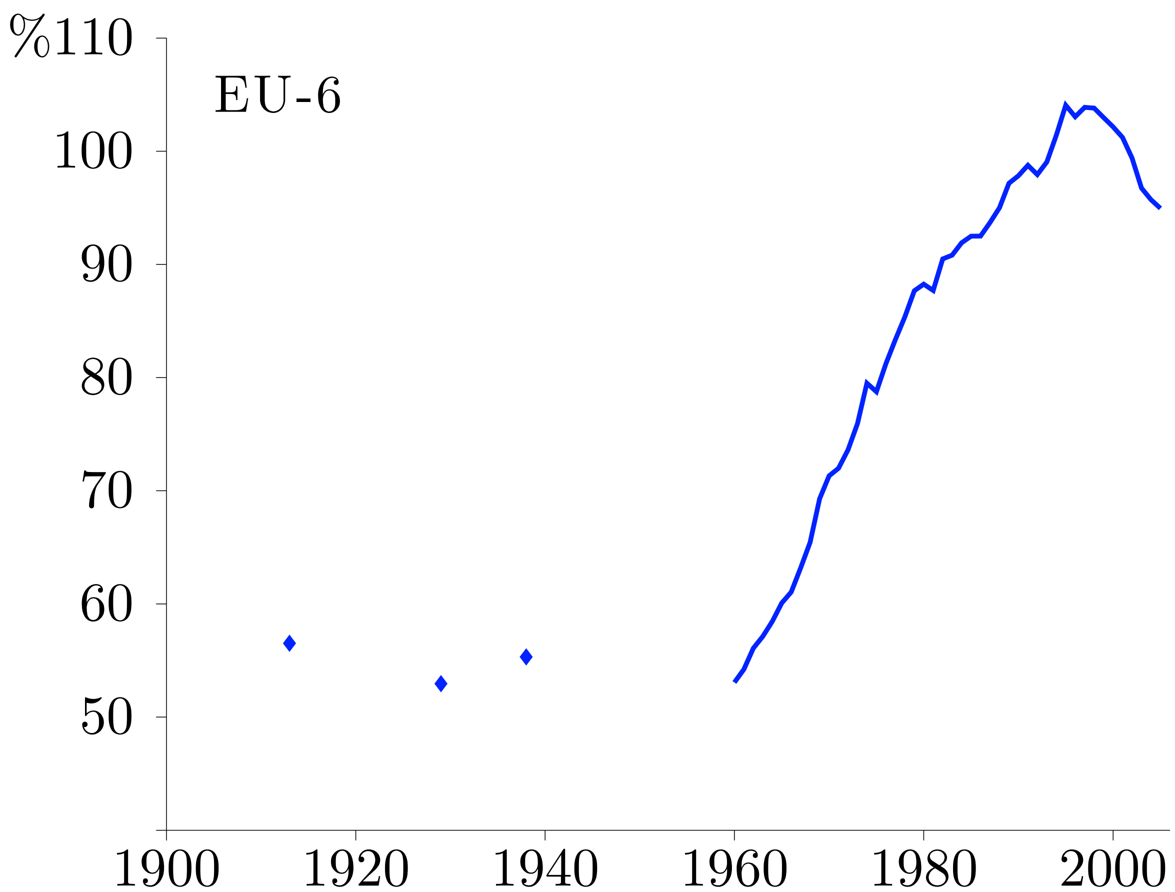
  We partially endogenize measured TFP since locations and technology capital affect measured TFP.

Assessing Gains to Openness

Gains to Opening to FDI

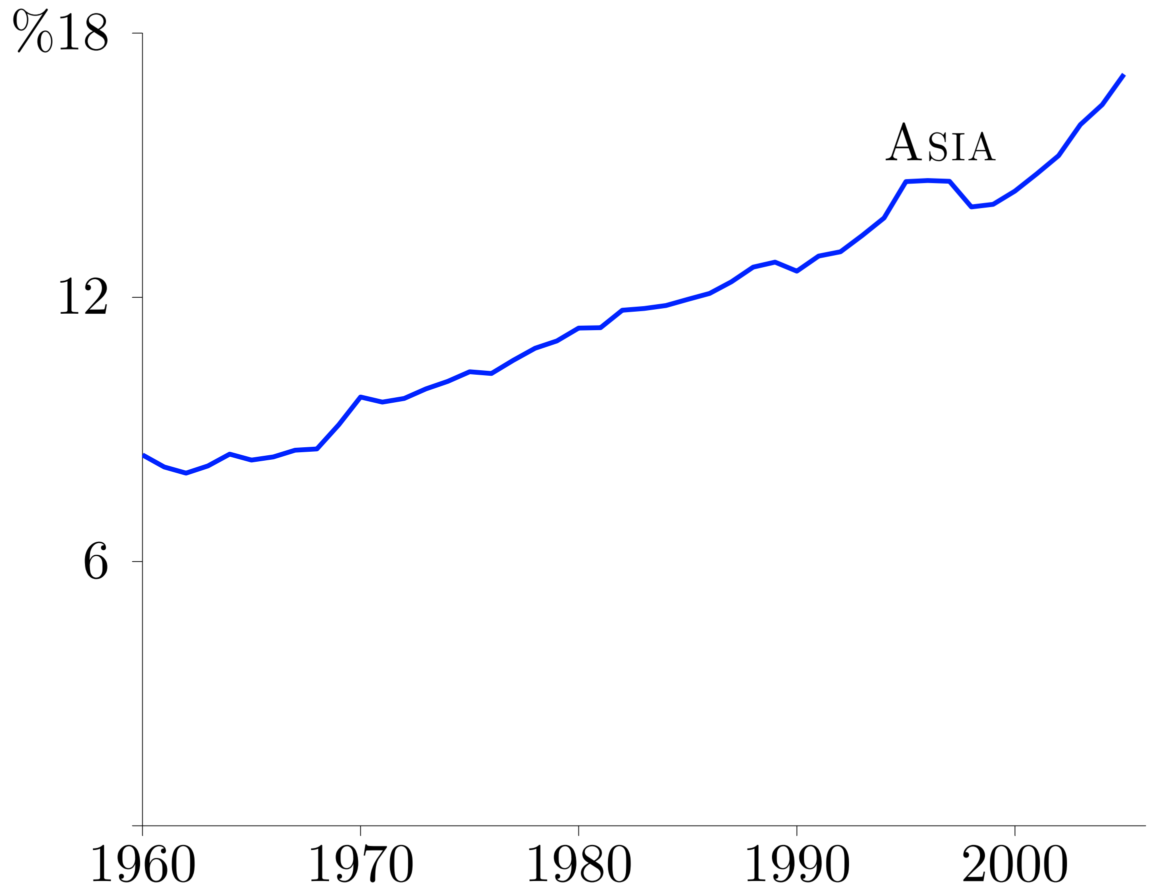
- Empirical evidence:
  - Mixed results in regressions of growth on FDI
  - But, huge successes of economic unions (eg, EU)

Why Did the EU-6 Catch Up?



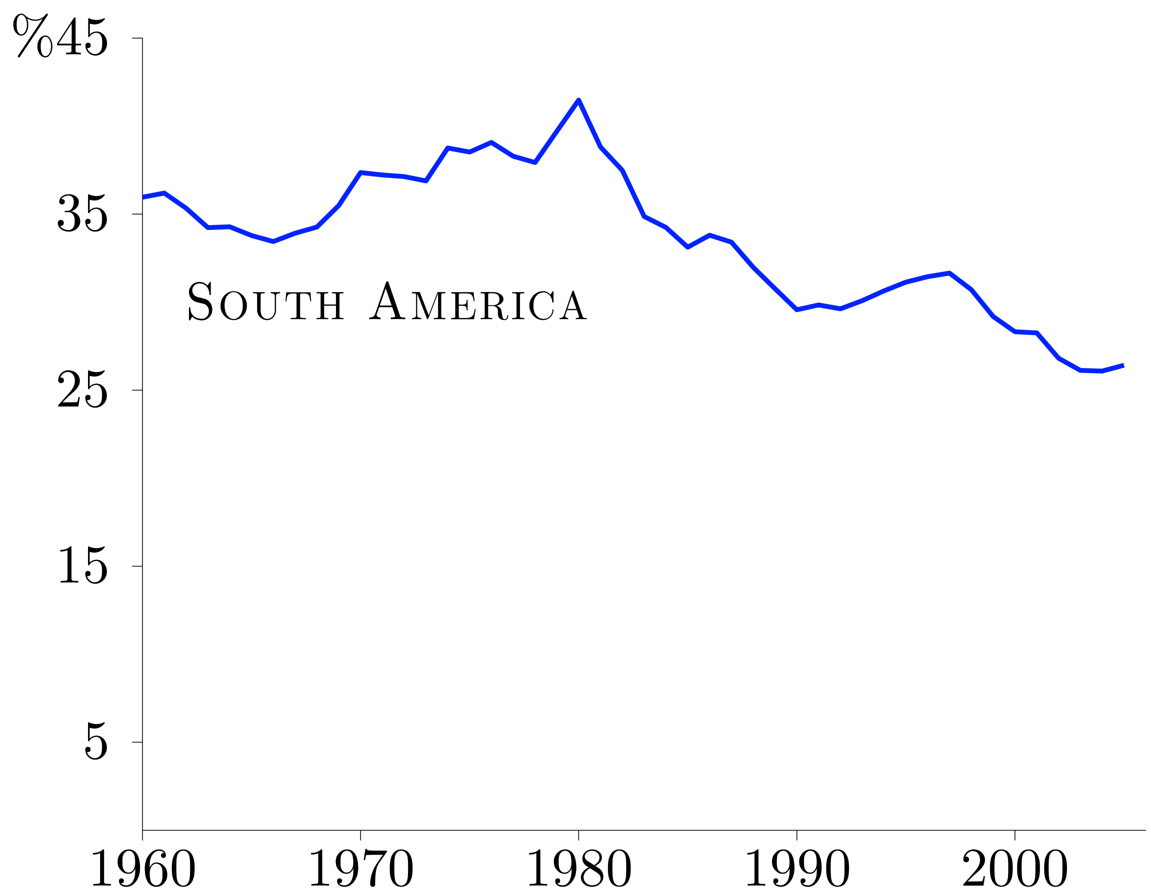
EU-6 Labor Productivity as % of US

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?

- And, specifically, what role does FDI play?

What Role does FDI Play?

- Answer depends on countries' openness policy and size

- Definition: Size = $\mathcal{A}_i N_i$

$\mathcal{A}_i$ is level of technology, $A_i^{\frac{1}{1-\alpha(1-\phi)}}$

N_i is number of production locations

What Role does FDI Play?

- Answer depends on countries' openness policy and size

- Definition: Size $= \mathcal{A}_i N_i$

$\mathcal{A}_i$ is level of technology, $A_i^{\frac{1}{1-\alpha(1-\phi)}}$

N_i is number of production locations

$\propto$ population in i

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N_i is number of production locations

$\Rightarrow$ expanding markets requires more consumers

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  $\mathcal{A}_i$ is level of technology, $A_i^{\frac{1}{1-\alpha(1-\phi)}}$

  N_i is number of production locations

  $\Rightarrow$ Canada is like Taiwan, not China

Steady State Analysis

A Steady State

- Common world interest rate determined by preferences

- Common K/Y ratio determined by interest rate

- Key result: Some M_i may be zero

Key Equilibrium Conditions

- K_i/Y_i same across i

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

- Combined with

$$\textstyle\sum_j \partial Y_j / \partial M_i \leq \rho + \delta_m, \quad = \text{if } M_i > 0$$

$\Rightarrow$ System for which we apply Kakutani theorem

Three Lessons from Steady State Analysis

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Let's consider an example that illustrates 3 lessons ...

Example: $I = 2$, Symmetric ω

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

- Key equilibrium conditions imply a ω^* such that:

$$\text{Case 1: } M_1 > 0, M_2 > 0 \quad \text{if } \omega < \omega^*$$

$$\text{Case 2: } M_1 > 0, M_2 = 0 \quad \text{if } \omega > \omega^*$$

Lesson 1: Size Advantage ($\omega < \omega^*$)

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

- If $\omega < \omega^*$, then $M_1, M_2 > 0$ and

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

What matters is effective technology capital, $M_i + \omega M_{-i}$

Lesson 1: Size Advantage ($\omega < \omega^*$)

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

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

Which is proportional to size

Lesson 1: Size Advantage ($\omega < \omega^*$)

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

Implying an advantage to size when ω small

Lesson 1: Size Advantage ($\omega < \omega^*$)

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- If $\omega < \omega^*$, then $M_1, M_2 > 0$ and

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

$$\to \mathcal{A}_i \text{ as } \phi \to 0$$

As $\phi \to 0$, back to standard theory

Lesson 1: Size Advantage ($\omega > \omega^*$)

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

- If $\omega > \omega^*$, then $M_2 = 0$ and

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

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

When $\omega > \omega^*$, small country uses M_1

Lesson 1: Size Advantage ($\omega > \omega^*$)

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

- If $\omega > \omega^*$, then $M_2 = 0$ and

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

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

Implying a disappearing advantage as $\omega \to 1$

Lesson 1: Size Advantage ($\omega > \omega^*$)

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

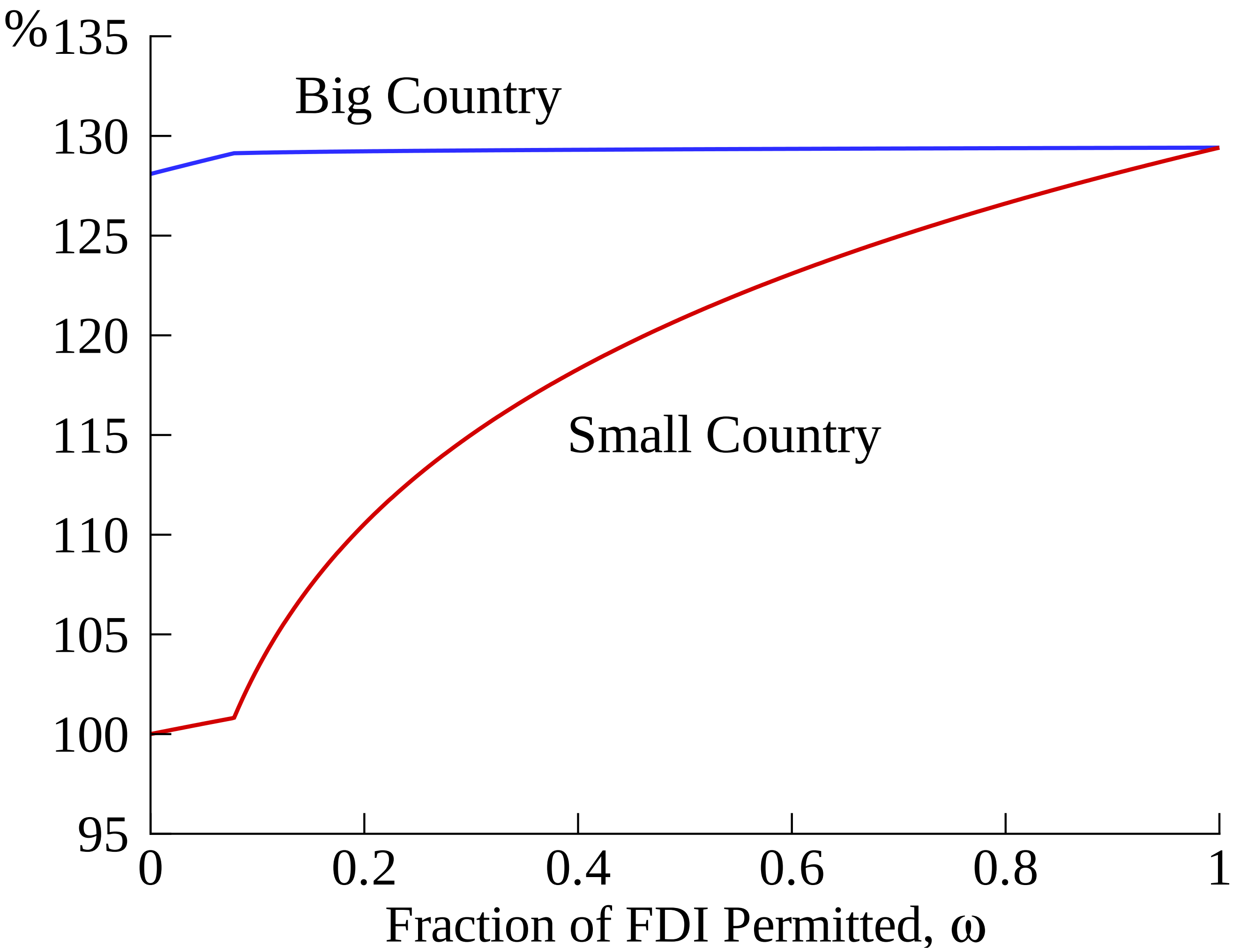
- If $\omega > \omega^*$, then $M_2 = 0$ and

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

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

As $\phi \to 0$, back to standard theory

PRODUCTIVITIES VS. ω, $\mathcal{A}_1 N_1 = 10\mathcal{A}_2 N_2$



Lesson 2: Gain from Forming Unions

- I = number of equal-sized countries forming union

- Then, factor gain in productivity y for union is

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

- A union of small countries is like a large country

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- How large are the potential gains?

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

- If $\alpha = .3$, $\phi = .07$, then

$$\text{Gain} = 28\% \quad \text{if } I = 10$$

$$\text{Gain} = 64\% \quad \text{if } I = 100$$

Lesson 3: Gain from Unilaterally Opening

- I = number of equal-sized countries remaining closed

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

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

- Countries gain when unilaterally opening

Lesson 3: Gain from Unilaterally Opening

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Lesson 3: Gain from Unilaterally Opening

- I = number of equal-sized countries remaining closed
- Then, factor gain in productivity of $I+1$st opening is

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

- If $\alpha = .3$, $\phi = .07$, then

  Gain = 25% if $I = 10$

  Gain = 56% if $I = 100$

Bottom Line

- Gains to opening are large if ϕ not small
- To determine how large, need to know ϕ

Using US Accounts to Estimate ϕ

- If ϕ sizable, gains to opening are large

- In "Technology Capital and the US Current Account"

  - Chose ϕ, size, openness to match US

    - International accounts

    - National accounts

  - Needed $\phi = .07$ for consistency with accounts

Technology Capital and the US Current Account

- Households choose:

  Consumption, hours, domestic & foreign equity and debt

- Multinationals choose:

  Locations, labor, and tangible and intangible capitals

- No asset or goods market frictions

$\Rightarrow$ Generate domestic and current accounts for the model

- Households choose:

  Consumption, hours, domestic & foreign equity and debt

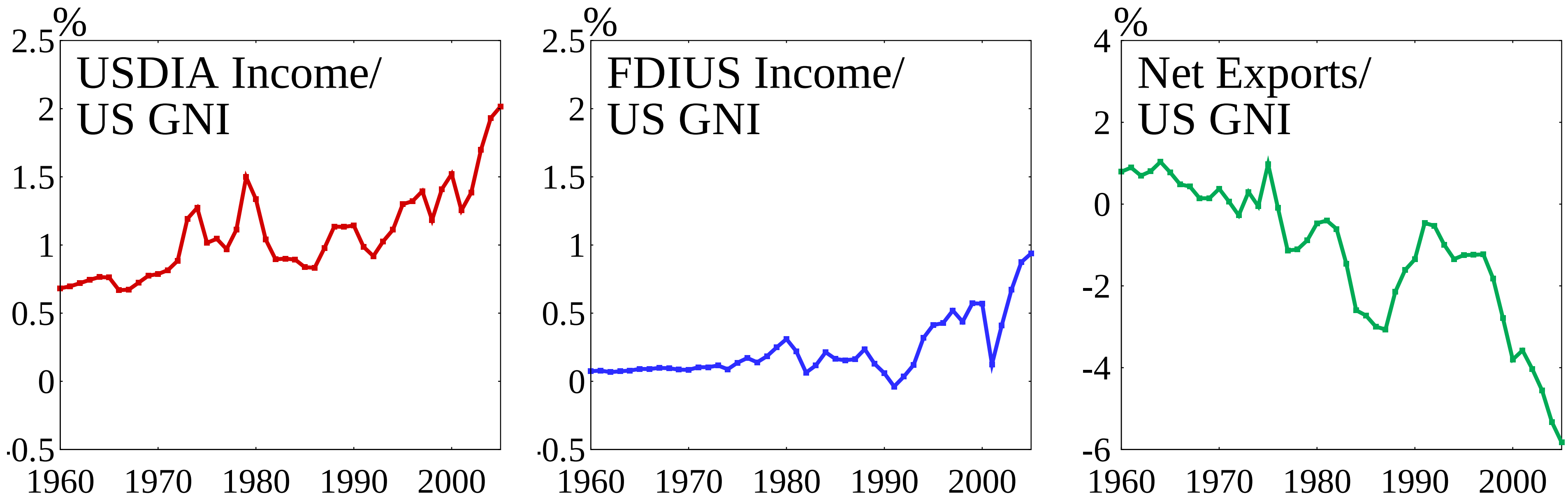
- Multinationals choose:

  Locations, labor, and tangible and intangible capitals

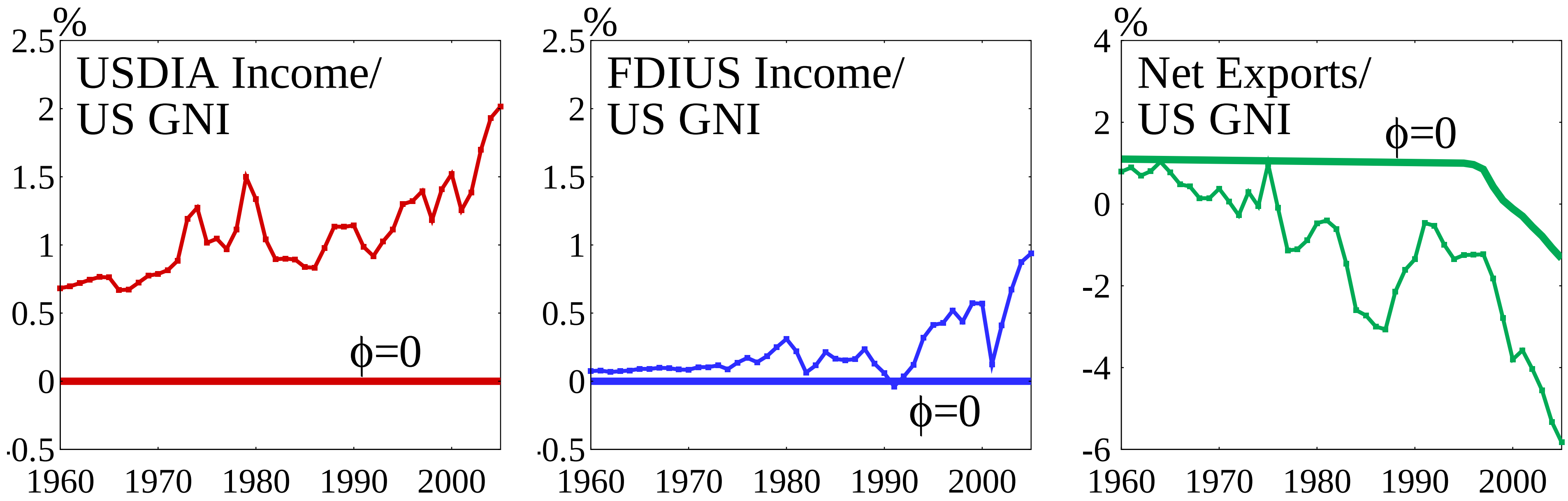
- No asset or goods market frictions

⇒ Can directly compare model and US accounts

FDI Incomes and Trade Balance

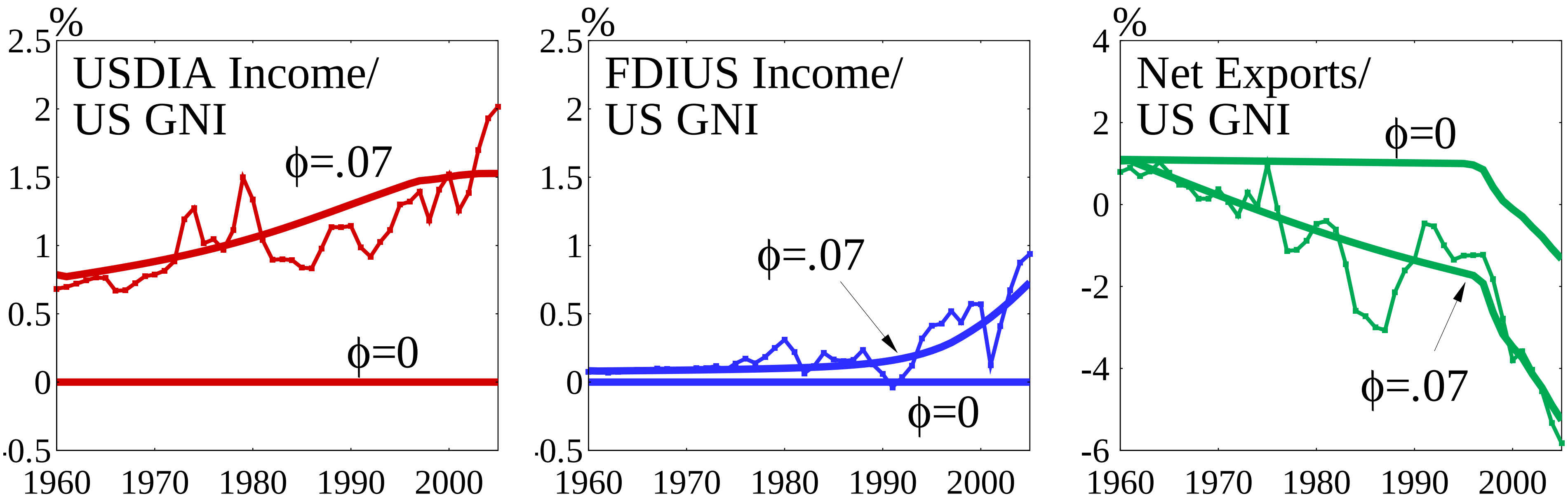


FDI Incomes and Trade Balance, $\phi = 0$



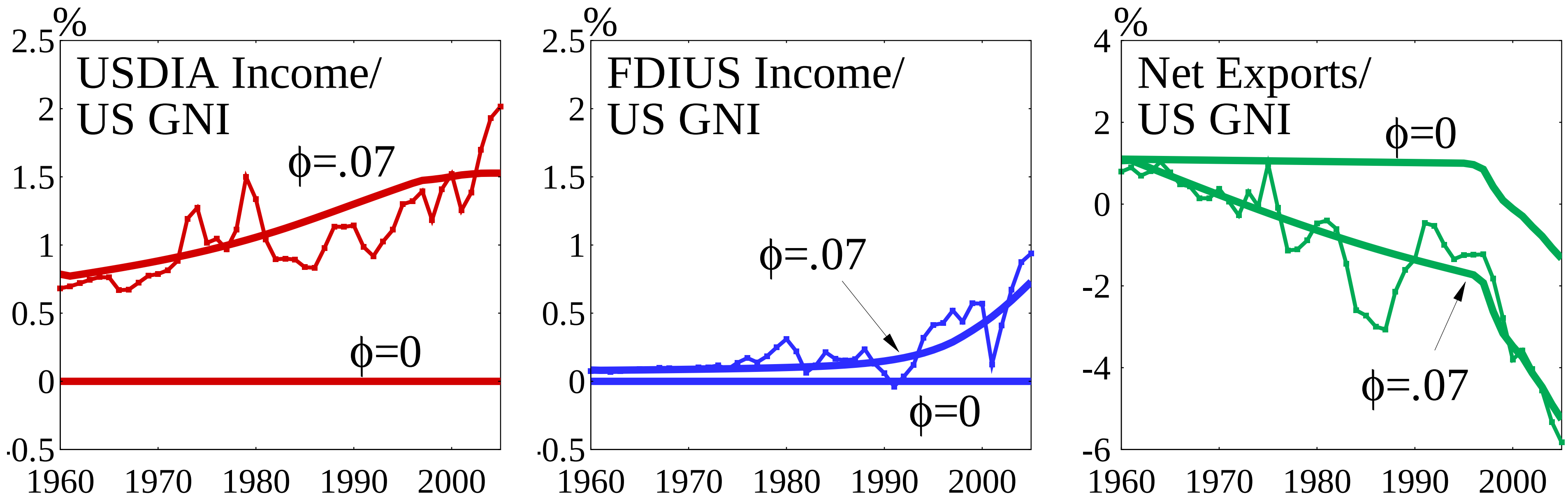
No technology capital case

FDI Incomes and Trade Balance, $\phi = .07$



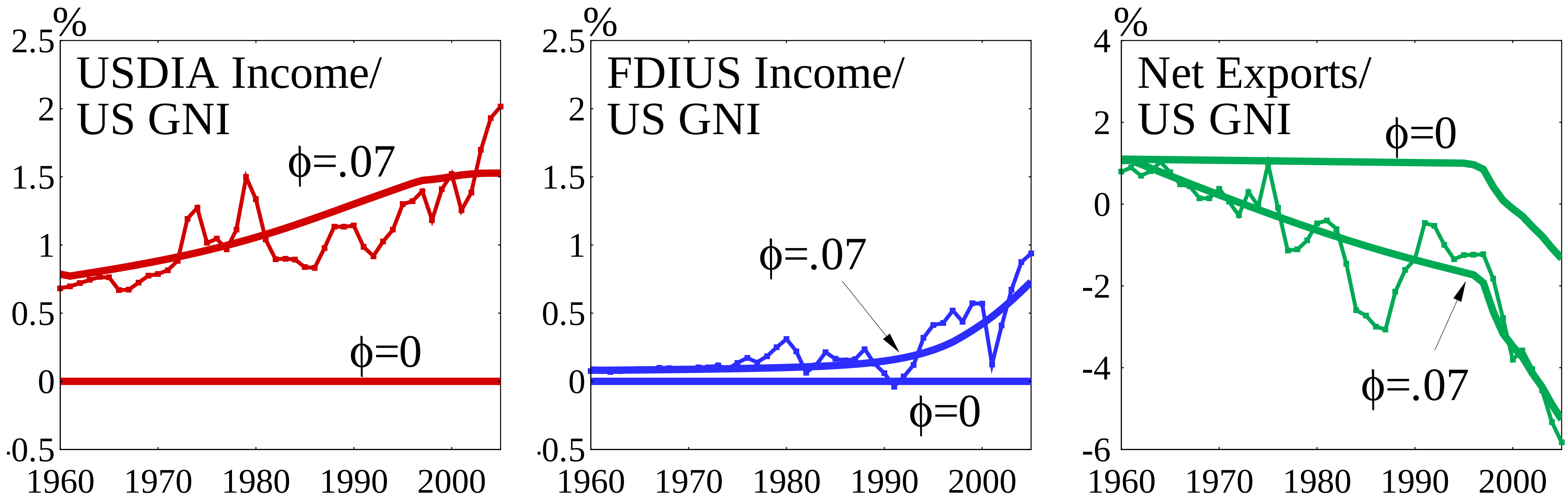
Increase ϕ to fit trends in data

FDI Incomes and Trade Balance, $\phi = .07$



International data consistent with $\phi = .07$

FDI Incomes and Trade Balance, $\phi = .07$



Bottom line: gains from opening to FDI are large

Intuition for Large Decline in Net Exports

- Let u=US, r=ROW

- Net exports relative to size for US and ROW:

$$\frac{NX_u}{\mathcal{A}_u N_u} = \frac{Y_u - X_{m,u} - X_{k,u} - C_u}{\mathcal{A}_u N_u} \tag{1}$$

$$\frac{-NX_u}{\mathcal{A}_r N_r} = \frac{Y_r - X_{m,r} - X_{k,r} - C_r}{\mathcal{A}_r N_r} \tag{2}$$

where X_m, X_k are investments in M and K

- Subtract (2) from (1)

Intuition for Large Decline in Net Exports

- If change in size due to change in population, then

$$\left(\frac{1}{\mathcal{A}_u N_u}+\frac{1}{\mathcal{A}_r N_r}\right) NX_u = \underbrace{\left(\frac{X_{k,u}}{\mathcal{A}_u N_u}-\frac{X_{k,r}}{\mathcal{A}_r N_r}\right)}_{\text{Equates } K/Y'\text{s}}+\underbrace{\left(\frac{C_u}{\mathcal{A}_u N_u}-\frac{C_r}{\mathcal{A}_r N_r}\right)}_{=0}$$

$$+\underbrace{\left(\frac{X_{m,u}}{\mathcal{A}_u N_u}-\frac{X_{m,r}}{\mathcal{A}_r N_r}\right)}_{\substack{=0 \text{ if } \phi=0 \\ \text{amplifies } X_k \text{ term if } \phi>0}}+\underbrace{\left(\frac{Y_u}{\mathcal{A}_u N_u}-\frac{Y_r}{\mathcal{A}_r N_r}\right)}_{\substack{=0 \text{ if } \phi=0 \\ \text{varies with size if } \phi>0}}$$

- Implies large decline in NX_u and reversal

Current Account Puzzles Not so Puzzling

- With technology capital included, predict
  - Large decline in net exports share
  - Large rise in consumption share
  - Large gap between USDIA and FDIUS returns

What Implications for Growth Regressions?

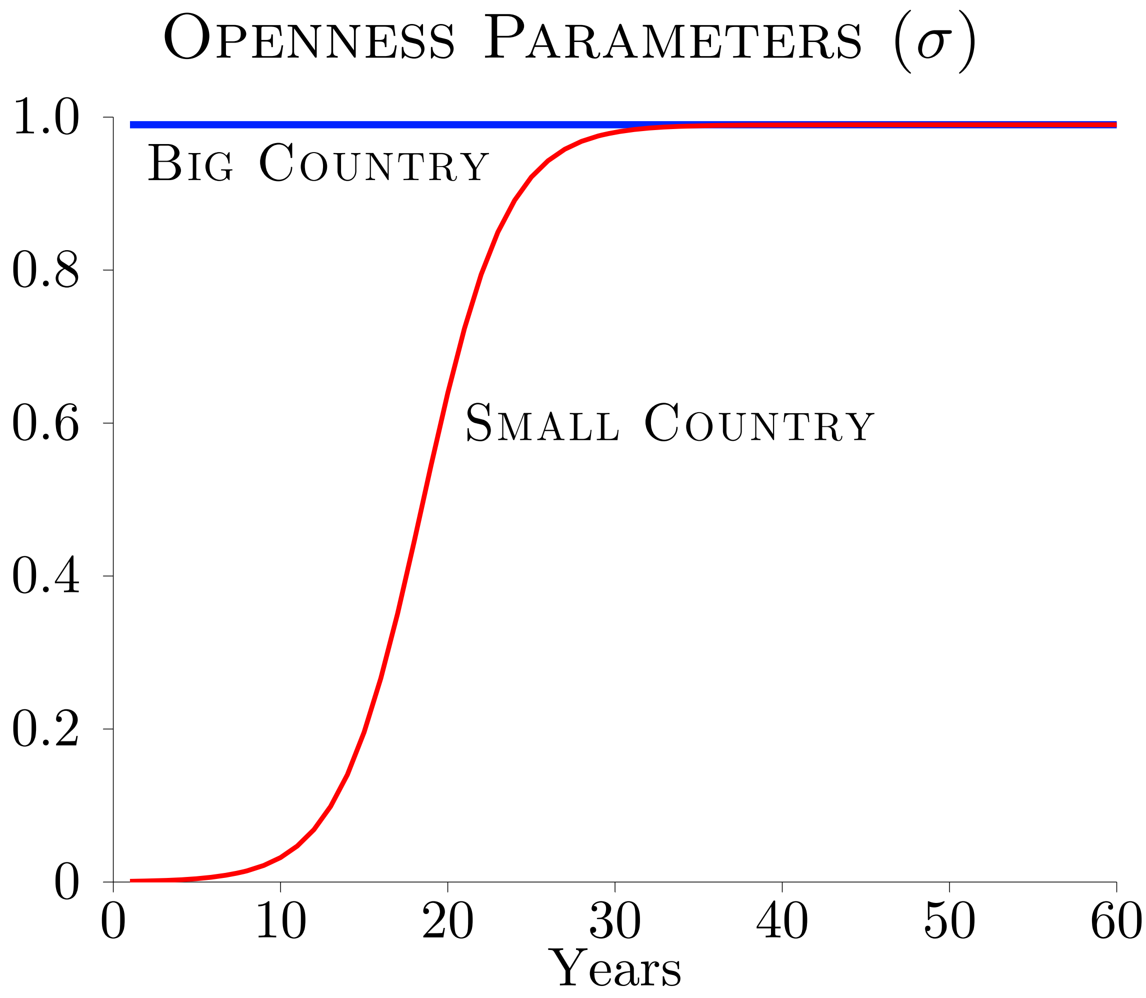
- Mixed results in regressions of growth on FDI
- Not surprising in light of our theory which
  - Predicts level effects rather than growth effects
  - Points to FDI *incomes*, not investments as key variables
  - Requires knowledge of openness policies over time

An Example Transition to Illustrate the Point

An Example Transition

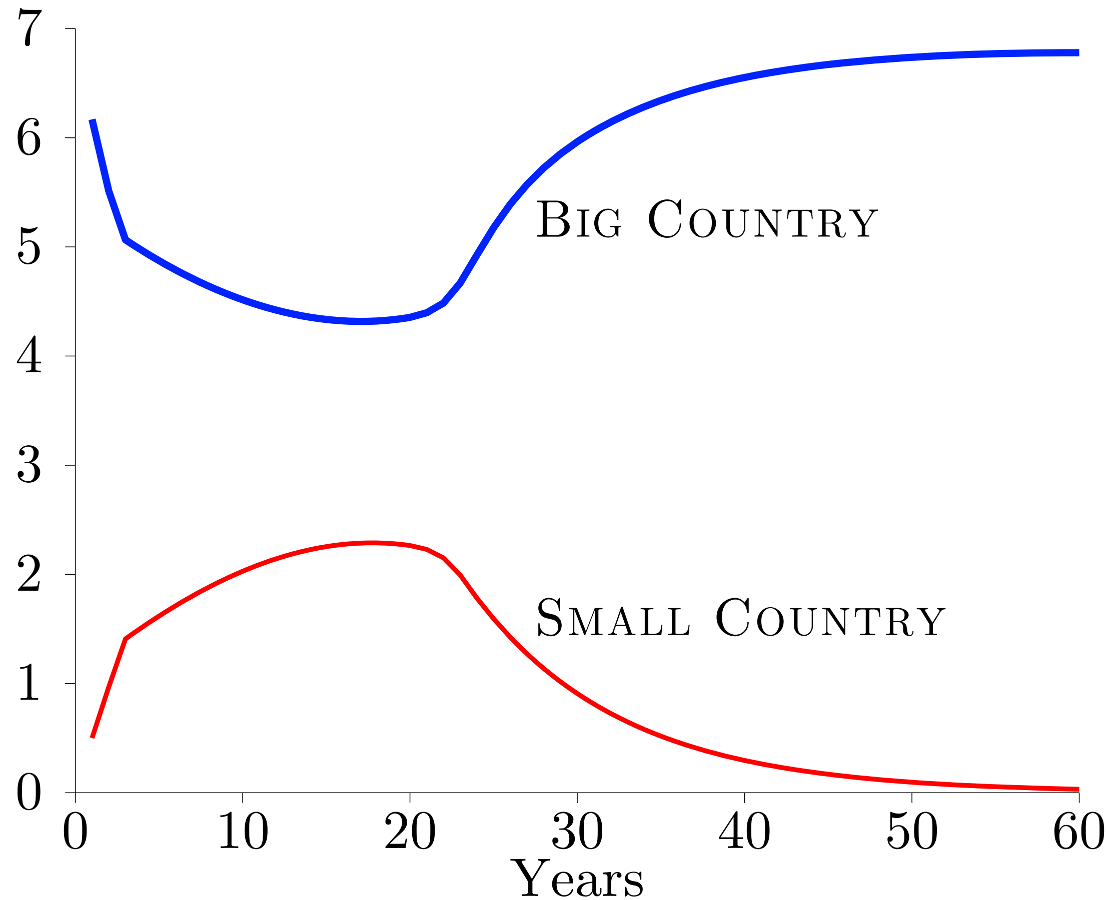
- Two countries, closed at date 0
- In date 1,
  - Big country ($\mathcal{A}N = 10$) opens up rapidly
  - Small country ($\mathcal{A}N = 1$) opens up gradually

Small Country Opens Gradually



Small Country Opens Gradually

Technology Capital/ $Y_{2,0}(1+\gamma_Y)^t$



Small Country Opens Gradually

- Initially, small country
  - Takes advantage of new markets in big country
  - Invests more in technology capital
  - Experiences a drop in measured productivity
  - Scares observers at the IMF
- Eventually exploits big country's technology capital stock

Summary

- Paper extends neoclassical growth model by adding
  - Locations
  - Technology capital
- These additions are critical in assessing
  - Gains from opening to FDI
  - US current account flows/balances

Appendix:

A Decentralization to Match to BEA Accounts

HOUSEHOLDS IN i SOLVE

$$\max \sum_t \beta^t \, U\left(\frac{C_{it}}{N_{it}}, \frac{L_{it}}{N_{it}}\right) N_{it}$$

subject to budget constraint

$$\sum_t p_t\Big[(1+\tau_{c,it})C_{it} + \sum\nolimits_j V_t^j (S_{i,t+1}^j - S_{it}^j) + B_{i,t+1} - B_{it}\Big]$$

$$\leq \sum_t p_t\Big[(1-\tau_{l,it})W_{it}L_{it} + (1-\tau_{d,t}) \sum\nolimits_j S_{it}^j D_t^j + r_{b,t}B_{it} + \kappa_{it}\Big]$$

$S_i^j =$ equity shares of companies in j

$B_i =$ foreign debt

Multinationals Incorporated in Country j Solve

$$\max \sum_t p_t(1-\tau_{d,t})D_t^j$$

where dividends D_t^j satisfy

$$D_t^j + \underbrace{\sum\nolimits_i K^j_{T,i,t+1} - K^j_{T,it}}_{\textit{Reported}\ \text{reinvested earnings}}$$

$$= \underbrace{\sum\nolimits_i \{(1-\tau_{p,it})(Y^j_{it} - W_{it}L^j_{it} - \delta_T K^j_{T,it} - X^j_{I,it} - \chi^j_i X^j_{M,t})}_{\textit{Reported}\ \text{profits less expensed investments and taxes}}$$

where $\chi_i^i = 1$ and $\chi_i^j = 0$, $j \neq i$

Multinationals Incorporated in Country j Solve

$$\max \sum_t p_t(1-\tau_{d,t})D_t^j$$

given definition of dividends,

$$D_t^j + \underbrace{\sum\nolimits_i K_{T,i,t+1}^j - K_{T,it}^j}_{\textit{Reported}\text{ reinvested earnings}}$$

$$= \underbrace{\sum\nolimits_i \{(1-\tau_{p,it})(Y_{it}^j - W_{it}L_{it}^j - \delta_T K_{T,it}^j - X_{I,it}^j - \chi_i^j X_{M,t}^j)}_{\textit{Reported}\text{ profits less expensed investments and taxes}}$$

$\Rightarrow$ expensing done at home

Multinationals Incorporated in Country j Solve

$$\max \sum_t p_t(1-\tau_{d,t})D_t^j$$

given definition of dividends,

$$D_t^j + \underbrace{\sum\nolimits_i K^j_{T,i,t+1} - K^j_{T,it}}_{\textit{Reported} \text{ reinvested earnings}}$$

$$= \underbrace{\sum\nolimits_i \{(1-\tau_{p,it})(Y^j_{it} - W_{it}L^j_{it} - \delta_T K^j_{T,it} - X^j_{I,it} - \chi^j_i X^j_{M,t})}_{\textit{Reported} \text{ profits less expensed investments and taxes}}$$

Key result: accounting profits are not equal to true profits