Idea Flows, Economic Growth, and Trade

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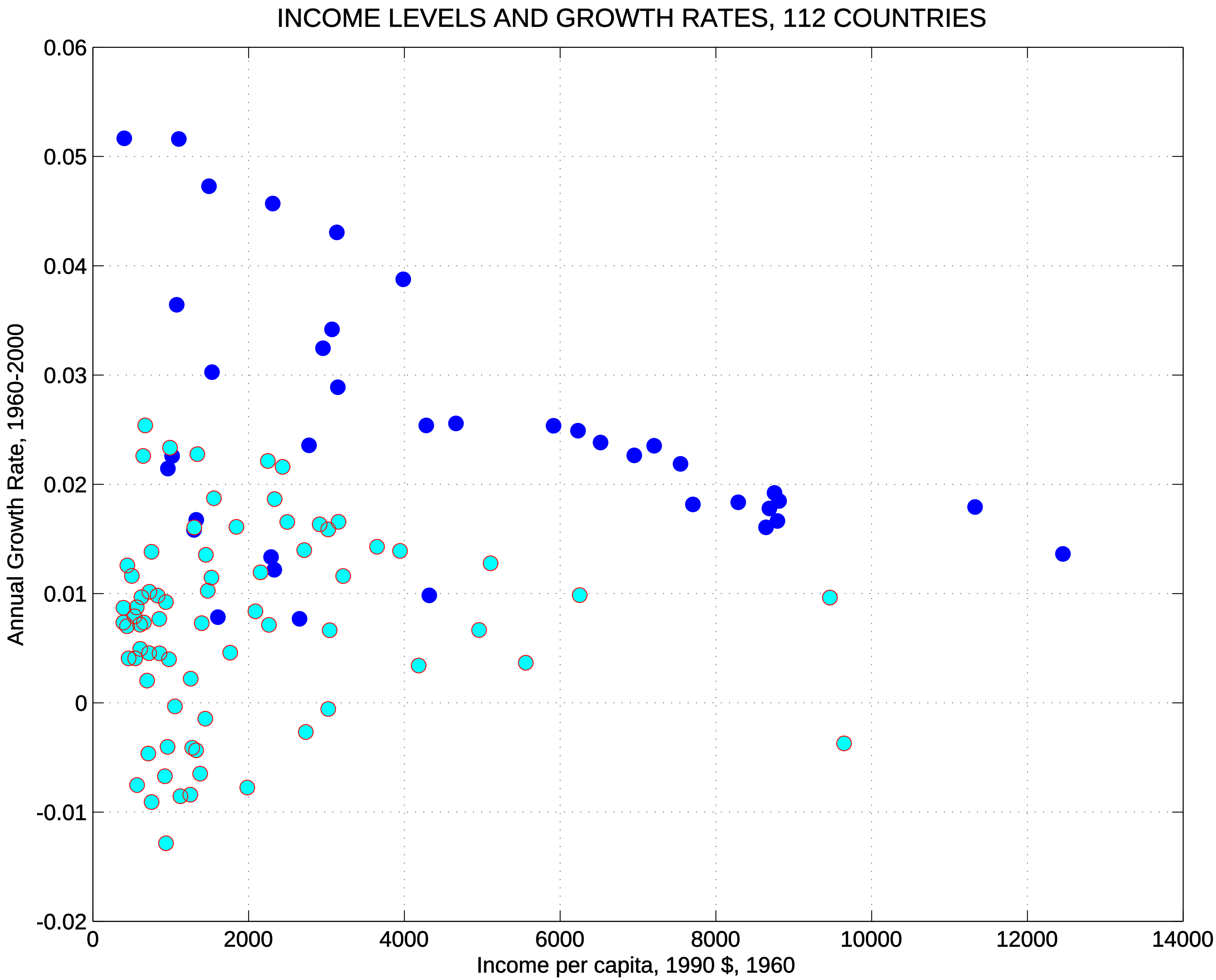
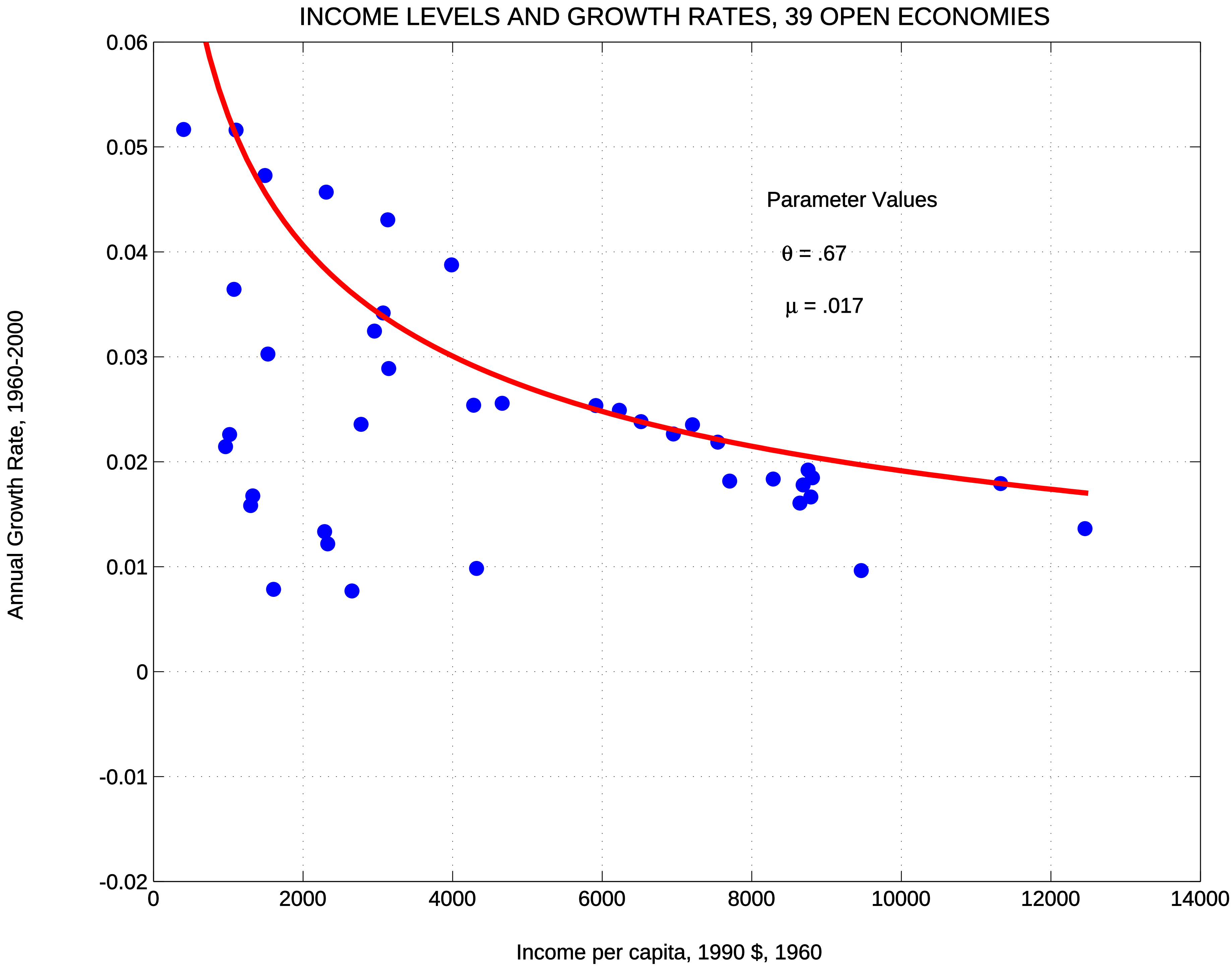
- Economists have long believed that international trade serves as a vehicle for the diffusion of technology—of ideas

- Much evidence of important growth effects of openness, trade

- Example is Lucas (2009) replication of Sachs/Warner (1995)

- Next slides, based on Maddison data, 1960 - 2000


INCOME LEVELS AND GROWTH RATES, 112 COUNTRIES
Annual Growth Rate, 1960-2000
Income per capita, 1990 $, 1960
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
2000
4000
6000
8000
10000
12000
14000



INCOME LEVELS AND GROWTH RATES, 39 OPEN ECONOMIES
Parameter Values
θ = .67
μ = .017
Annual Growth Rate, 1960-2000
Income per capita, 1990 $, 1960
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
2000
4000
6000
8000
10000
12000
14000

- What we do not have is good understanding of how this trade/diffusion effect works

- What is the process that links trade policy to diffusion, growth?

- What are the key parameters of this process?

- What evidence do we have on their magnitudes?

- Seek a framework that can help make progress on these questions

- We develop an endogenous growth model with many countries that explicitly connects trade and trade policy to sustained growth rates and transition dynamics

- Model is built on work of Eaton, Kortum in two ways:

  – (2002) static theory of technology-based trade, adapted in Alvarez, Lucas (2007)

  – vision of technology diffusion proposed in Kortum (1997), Eaton and Kortum (1999), adapted in Alvarez, Buera, Lucas (2008), Lucas (2009)

- View technology as distribution of productivity-related knowledge held by heterogeneous, individual people, firms, countries

- Construct a model of n country world, engaged in continuously balanced trade

- Many goods, many people in each: details later

- State variables are $F_1, F_2, ..., F_n$: right cdfs of "cost" in $\mathbb{R}_+$

$$F_i(z) = \text{Pr}\{\text{randomly chosen good has cost } \geq z \text{ if produced in } i\}$$

- Densities $f_i = -\partial F_i(z,t)/\partial x$

(In E/K, A/L F_i's are Weibull RVs. Not so here.)

- Constant trade costs matrix $K = [\kappa_{ij}] : \kappa_{ij} =$ units of goods arriving in i per unit shipped from j

- Populations $L = (L_1, ..., L_n)$

- Given K, L and technology profile F, can solve for static trade equilibrium, including wage rates $w = (w_1, ..., w_n)$

- Theory also gives us equilibrium distributions of the costs of producers in j who sell in country i, all i, j.

- From these, can calculate right cdfs $G_1, G_2, ..., G_n$ where

$$G_i(z, t) = \text{Pr}\{\text{seller active in } i \text{ at } t \text{ has cost} \geq z\}$$

- We will use these to motivate a law of motion for $F_1, F_2, ..., F_n$ of the form

$$\frac{\partial \log(F_i(z,t))}{\partial t} = \alpha_i \log(G_i(z,t)) \qquad (*)$$

- Trade theory tells us how F, K determine G; gives autonomous system

- Simulatable model of world trade, economic growth

- Law of motion (*) is main new idea of this paper

PLAN OF TALK

1. Technology Diffusion, Closed Economy

2. Technology Diffusion, n-Country World

3. Numerical Illustrations

4. Conclusions

1 Diffusion in Closed Economy

- Consumers have identical preferences over $[0, 1]$ continuum of goods

$$C = \left[\int_0^1 c(s)^{1-1/\eta} ds \right]^{\eta/(\eta-1)}$$

- Good s is produced with a linear, labor-only technology

$$y(s) = \frac{l(s)}{z(s)}$$

- $l(s)$ is labor input–1 unit per person– and $z(s)$ is cost (labor requirement)

- Exploit symmetry of utility function

- Re-label goods by their costs z and write time t utility as

$$C(t) = \left[\int_{\mathbb{R}_+} c(z)^{1-1/\eta} \; f(z,t) \; dz \right]^{\eta/(\eta-1)}$$

- Here $f(\cdot, t)$ is the density of costs.

- Use $F(z,t)$ for the **right** cdf of cost, so density is $f(z,t) = -\partial F(z,t)/\partial z$

- In competitive equilibrium, price of good z is $p(z) = wz$

- Ideal price index for the economy at date t is

$$p(t) = \left[\int_{\mathbb{R}_+} p(z)^{1-1/\eta} f(z,t) dz \right]^{\eta/(\eta-1)}$$

- Real per capita GDP $y(t)$ is real wage $w/p(t)$:

$$y(t) = \left[\int_{\mathbb{R}_+} z^{1-1/\eta} f(z,t) dz \right]^{-\eta/(\eta-1)}$$

- Now need to describe evolution of f, F

- Model technological diffusion as process of search involving *technology managers*

- One manager per good, each identified with current cost z

- Technology management requires no time, earns no private return

- Manager of good z operates the CRS, zero profit production described earlier

- Or others imitate him and do so: Who cares?

- Each manager z meets others at given rate α per unit of time

- Each meeting a random draw from the population f, F of managers of all goods

- When he meets another with cost $z' < z$ he adopts z' for his own good

- Motivate law of motion for F as

$$\begin{aligned} F(z, t+\Delta) &= \text{Pr}\{\text{my cost } > z \text{ at } t+\Delta\} \\ &= \text{Pr}\{\text{my cost } > z \text{ at } t\} \times \text{Pr}\{\text{no lower draw in } (t, t+\Delta)\} \\ &= F(z,t)F(z,t)^{\alpha\Delta}. \end{aligned}$$

- Continuous draws, not Poisson arrivals

- Let $\Delta \to 0$ to obtain:

$$\frac{1}{F(z,t)}\frac{\partial F(z,t)}{\partial t} = \alpha \log\left(F(z,t)\right) \qquad \text{(DE)}$$

- Write out general solution:

$$\log(F(z,t)) = \log(F(z,0))e^{\alpha t}$$

where $F(z,0)$ is any given initial distribution (right cdf)

- Clear that model implies GDP growth of some kind.

- Easy to compute. How to interpret results, characterize possibilities?

- For empirical reasons, interest is in sustained growth of economies that either grow at a constant rate or will do so asymptotically

- Central construct is *balanced growth path* (BGP): right cdf $\Phi(z)$ (density $\phi = -\Phi'(z)$) and a growth rate $\nu > 0$ such that $F(z,t) = \Phi(e^{vt}z)$ and

$$\log(\Phi(e^{vt}z)) = \log(\Phi(z))e^{\alpha t}$$

- On BGP

$$f(z,t) = -\frac{\partial F(z,t)}{\partial z} = \phi(e^{vt}z)e^{vt}$$

- Then real GDP path is

$$
\begin{aligned}
y(t) &= \left[\int_{\mathbb{R}_+} z^{1-1/\eta}\phi(e^{vt}z)e^{vt}dz\right]^{-\eta/(\eta-1)} \\
&= e^{vt}\left[\int_{\mathbb{R}_+} x^{1-1/\eta}\phi(x)dx\right]^{-\eta/(\eta-1)}
\end{aligned}
$$

- We show that BGP takes Weibull form

$$\Phi(z) = \exp(-\lambda z^{\theta})$$

for some pair $\lambda, \theta > 0$ and $\nu = \alpha\theta$

- Note that Weibull RV is just exponential RV raised to power θ

- Also show that if initial distribution $F(z,0)$ satisfies

$$\lim_{z \to 0} \frac{f(z,0)z}{1 - F(z,0)} = \frac{1}{\theta}$$

for some $\theta > 0$ and

$$\lim_{z \to 0} \frac{\log\left[F(z^{\theta},0)\right]}{z} = -\lambda$$

for some $\lambda > 0$ then

$$\lim_{t \to \infty} \log\left[F(e^{-\alpha\theta t}z,t)\right] = -\lambda z^{1/\theta} \quad \text{for all} \quad z > 0$$

- Parameter θ measures mass near $z = 0$

- Costs are headed to zero so long run behavior determined by “left tail”

- High θ value means more low cost ideas waiting to be discovered

- Inverse of cost is productivity so high θ means thick “right tail” of productivity distribution, high growth rate

- Power Law

2 Diffusion in World Economy

- An n country world. Populations $L_1, ..., L_n$

- Each country in autarky exactly as discussed

- Now open all of them to Eaton-Kortum trade in all goods

- Rename each good by its cost profile $z = (z_1, ..., z_n)$

$$C_i(t) = \left[\int_{\mathbb{R}_+^n} c_i(z)^{1-1/\eta} f(z,t) dz \right]^{\eta/(\eta-1)}$$

where $f(z,t) = \Pi_{i=1}^n f_i(z,t)$ is joint density

- Given fixed trade costs K, technologies $F = (F_1, ..., F_n)$, solve for balanced growth equilibrium wages $w = (w_1, ..., w_n)$

- See E/K (2002), A/L (2007), this paper for details

- Turn to dynamics. Technology managers native to i now draw ideas from all managers, foreign and domestic, whose goods are currently being sold in i

- Searching managers include all managers in i, good and bad

- They meet managers from all j, but only those good enough to sell goods in i

- Want to replace autarky law of motion

$$\frac{\partial \log(F_i(z,t))}{\partial t} = \alpha_i \log(F_i(z,t))$$

with

$$\frac{\partial \log(F_i(z,t))}{\partial t} = \alpha_i \log(G_i(z,t)) \qquad (*)$$

where

$$G_i(z,t) = \Pr\{\text{seller active in } i \text{ at } t \text{ and has cost} \geq z\}$$

- Theory tells us who these sellers are, given K, F, and w

- Distributions G_i stochastically dominate F_i

- Statement of familiar static gains from trade

- Also key to dynamic gains: G_i provides people in i a better intellectual environment than F_i does

- Formula is

$$G_i(z,t) = \sum_{j=1}^{n} \int_z^{\infty} f(z_j,t) \prod_{k \neq j} F_k \left[\frac{w_j(t)\,\kappa_{ik}}{w_k(t)\,\kappa_{ij}} z_j \right] dz_j$$

- Can show that if (i) some F_i consistent with sustained growth under autarchy, and (ii) trade is possible between any pair, then for all i

$$\lim_{z \to 0} \frac{z g_i(x)}{1 - G_i(x)} = \frac{1}{\theta} \quad \text{where} \quad \theta = \max_i \theta_i$$

- That is $G_i's$ inherit common, fattest left tail from $F_i's$

- Can also show that all countries have common BGP growth rate $\nu = \theta \sum_{i=1}^{n} \alpha_i$ where $\theta = \max_i \theta_i$

- Scale economy? Yes. And note that trade costs not in the formula

- Does not take much trade for the **really** good ideas to get around: think of Marco Polo and pasta

3 Numerical Illustrations

- Begin with world of n identical countries; symmetric trade cost κ
- Already know a lot from general theory:
  - Relative wages identical: set $w = 1$, all countries
  - common BGP growth rate: $\nu = \theta \sum_{i=1}^{n} \alpha_i$, where $\theta = \max_i \theta_i$
  - ν independent of κ value

- Like to know more:
  - what do the distributions F and G look like on a BGP?
  - how do trade volumes and GDP levels vary with trade costs κ and substitution elasticities η?
- Consider world of identical economies, $n = 50$, $\theta = 0.2$, $\alpha = .002$, $\nu = 0.02$

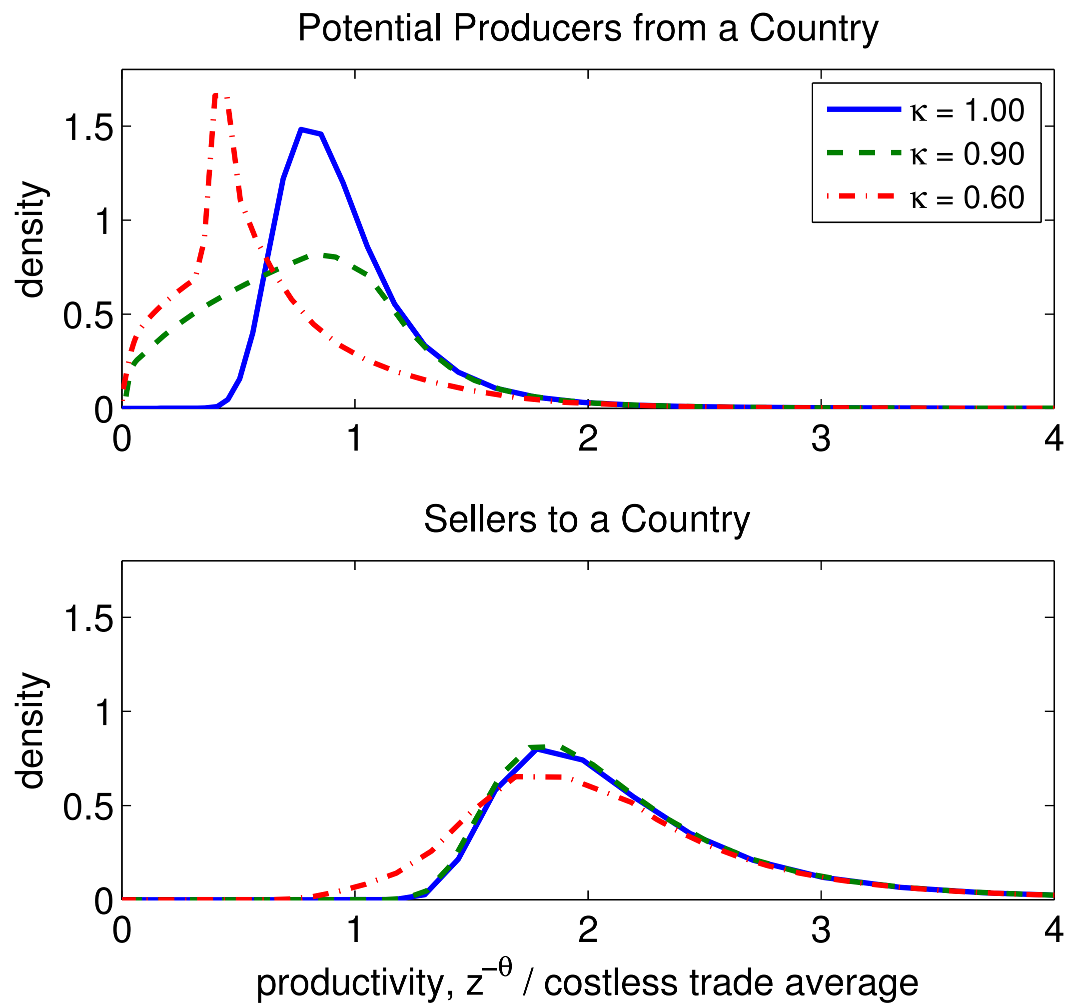
- Next figure describes the distributions F and G

- Have plotted distributions of productivities, $1/z$, rather than costs z

- x -axis on both panels is BGP productivity relative to mean of 1 for $\kappa = 1$ (costless trade) world

- Top panel shows productivity densities of each country (F) at different κ levels. Bottom panel shows densities of sellers' productivities (G) at different κ levels

- Both are Frechet distributions in right tail: note common tails on each panel


Potential Producers from a Country
density
κ = 1.00
κ = 0.90
κ = 0.60
0
0.5
1
1.5
0
1
2
3
4
Sellers to a Country
density
0
0.5
1
1.5
0
1
2
3
4
productivity, $z^{-\theta}$ / costless trade average

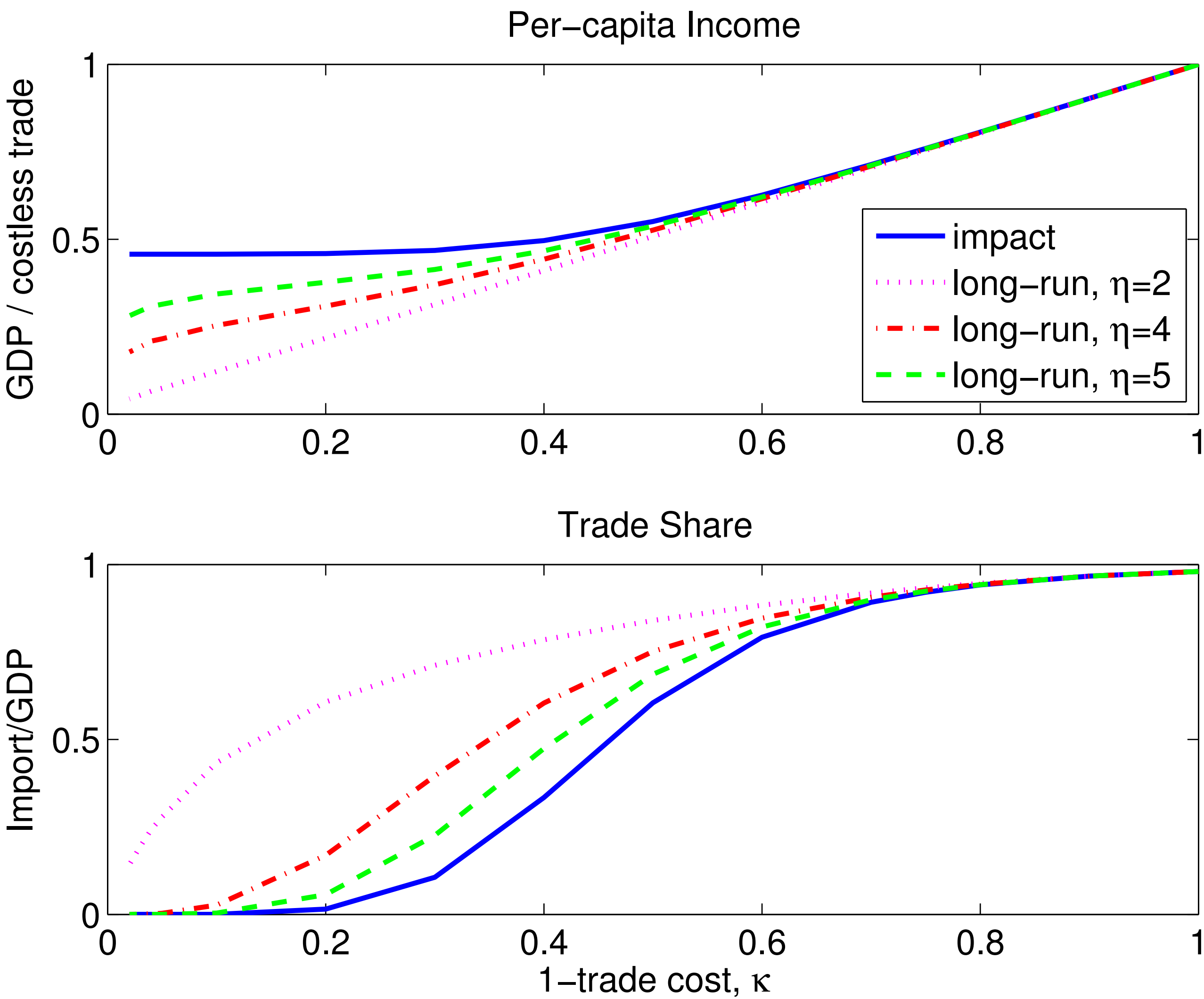
- Next figure also describes the symmetric world economy: the effects of changes in trade costs on real incomes and trade shares

- The x-axis shows trade costs, varying from autarky for all ($\kappa = 0$) to costless trade ($\kappa = 1$).

- Top panel plots per capita gdp levels, relative to gdp with costless trade

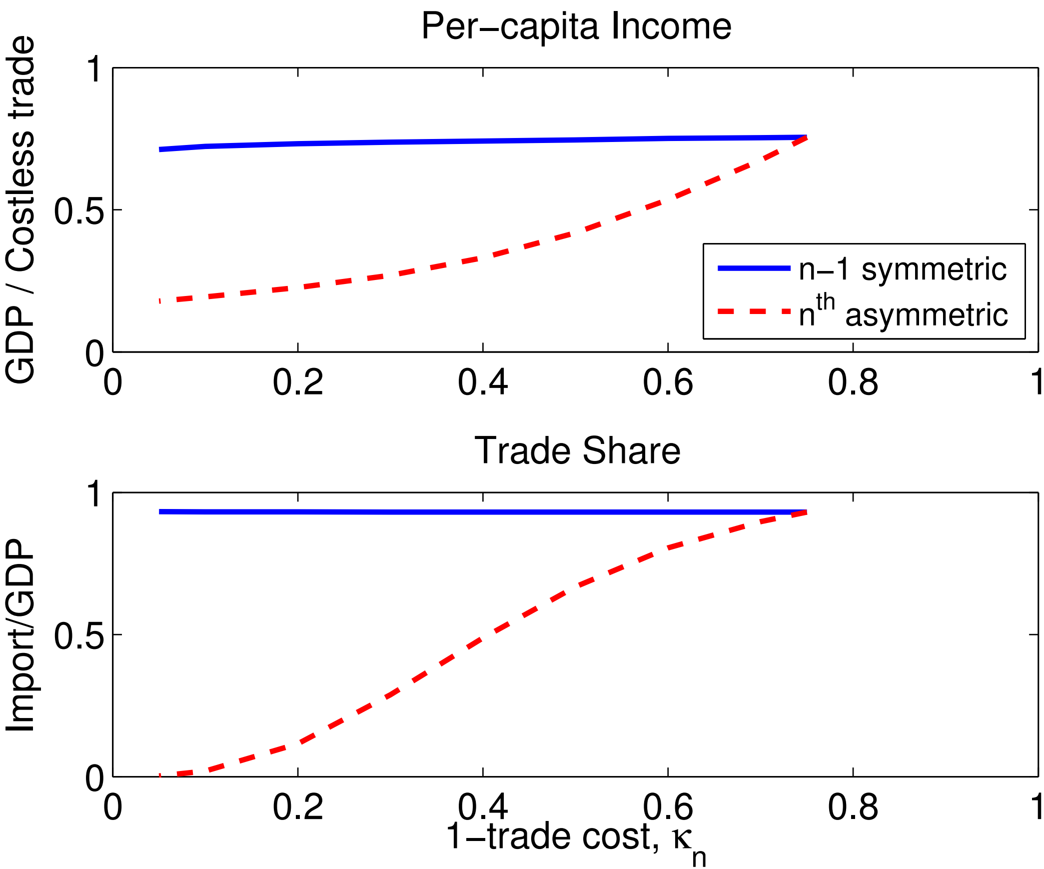
- Bottom panel plots trade volumes, relative to the costless trade case

- Solid blue lines show impact, static trade effects
- Other three curves on top panel are real gdp levels along the BGP
- Levels are shown for three values of η: elasticity of substitution
- Three curves on bottom panel are trade share levels along the BGP for three η values



Per−capita Income
GDP / costless trade
impact
long−run, η=2
long−run, η=4
long−run, η=5
0
0.5
1
0
0.2
0.4
0.6
0.8
1
Trade Share
Import/GDP
1−trade cost, κ

- Next figures describe world with n countries:
  - $n-1$ identical (as above), common trade costs $\kappa = .75$
  - one small, open, larger trade cost κ_n applied to all imports
- First figure shows BGP income levels and trade shares—relative to costless trade benchmark—for different trade cost levels of deviant



Per−capita Income
GDP / Costless trade
1
0.5
0
0
0.2
0.4
0.6
0.8
1
n−1 symmetric
n th asymmetric
Trade Share
Import/GDP
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1−trade cost, κ n

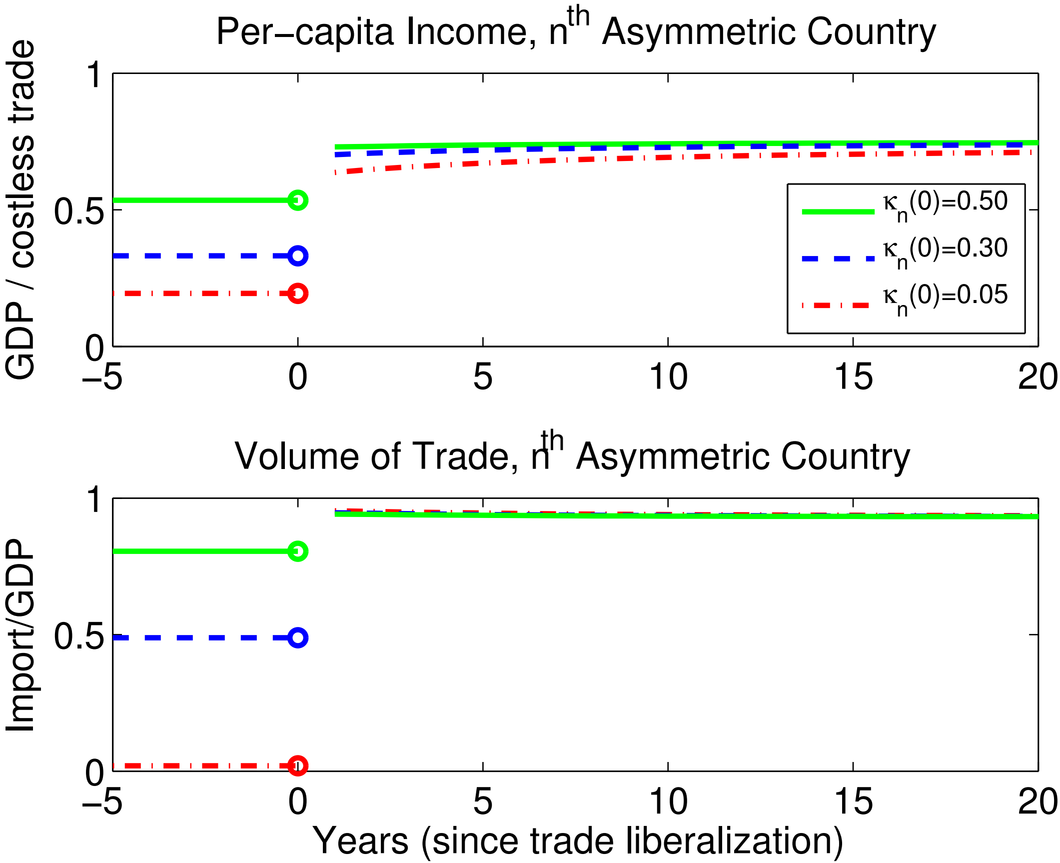
- Last figure shows time series of income and trade shares of the deviant country

- Deviant begins with higher trade costs, poorer economy

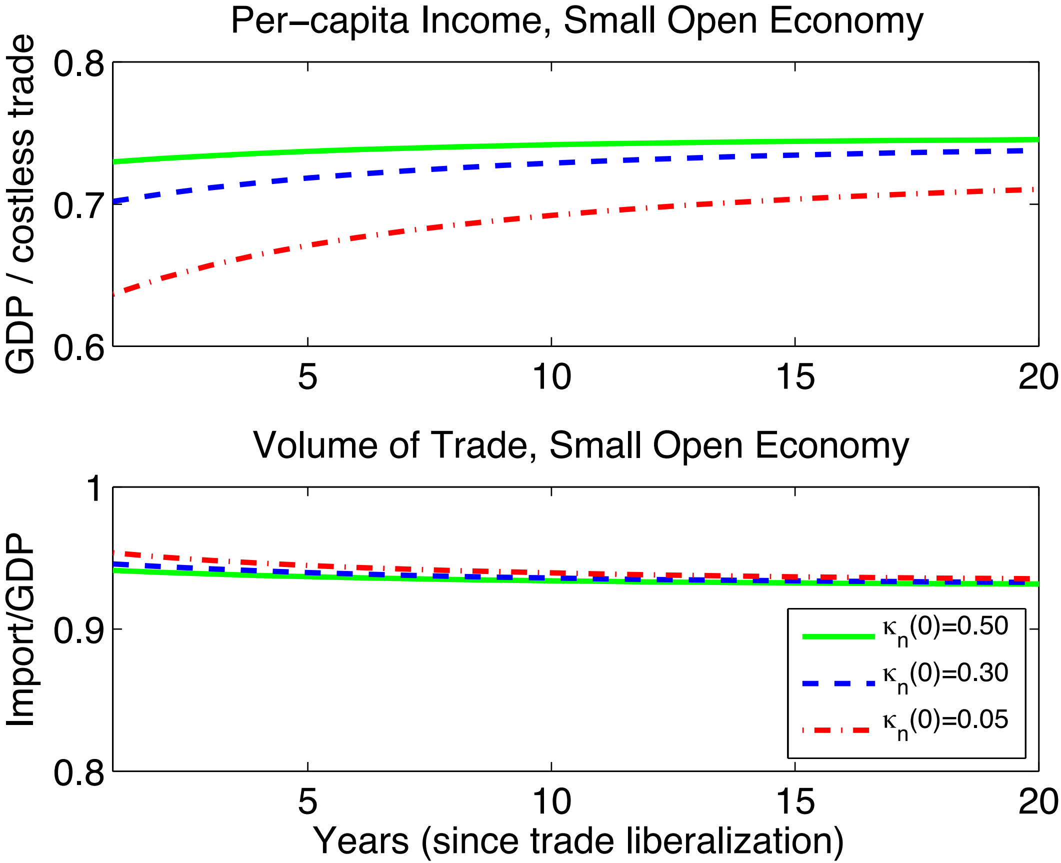
- At $t = 0$, deviant adopts trade cost $\kappa = .75$ of other countries

- Immediate jump in income, trade share shown: static trade effect

- Slow convergence to common BGP also shown



Per−capita Income, n^{th} Asymmetric Country
GDP / costless trade
1
0.5
0
−5
0
5
10
15
20
$\kappa_n(0)$=0.50
$\kappa_n(0)$=0.30
$\kappa_n(0)$=0.05
Volume of Trade, n^{th} Asymmetric Country
Import/GDP
1
0.5
0
−5
0
5
10
15
20
Years (since trade liberalization)



Per−capita Income, Small Open Economy
GDP / costless trade
0.8
0.7
0.6
5
10
15
20
Volume of Trade, Small Open Economy
Import/GDP
1
0.9
0.8
5
10
15
20
Years (since trade liberalization)
κn(0)=0.50
κn(0)=0.30
κn(0)=0.05

3 Conclusions

- Basic model general enough to support realistic calibration, policy simulations: see e.g. Alvarez/Lucas (2007)

- Our immediate goal here more modest: to understand the operating characteristics of a new, combined model of trade and growth

- General structure shares features of von Neumann (1937) or Parente/Prescott (1994): long run growth rate common to all; different policies induce different income *levels*

- Model makes operational distinction between static effects of trade policies and dynamic effects via trade related technology diffusion