Trade, Diffusion and the Gains from Openness - Lecture Notes

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1 Motivation

- Using the Eaton and Kortum model of Ricardian trade, Alvarez and Lucas estimate that a country with 1% of the world's GDP has gains from *frictionless trade* of 41% of autarky income (19% with average trade costs).

- But surely the gains from *openness* are likely to be much larger

- As in Klenow and Rodríguez-Clare (2005), I think of GO as arising from a level scale effect associated with the sharing of non-rivalry of ideas

- This level scale effect is what leads to growth in quasi-endogenous growth models (Jones, Kortum)

- The observed growth rate then has strong implications on the size of GO, which turn out to be very large

- But what share of these gains arise through trade?

- Need a model that is consistent with observed growth and trade volumes

- Here I construct a quantitative model that is consistent with trade and growth data and use it to explore the role of trade and pure diffusion in determining the gains from openness.

- The main result is that the gains from trade are smaller than those quantified by Alvarez and Lucas (23% vs 41%) whereas the gains from openness are very large (292%).

- Thus, trade contributes with only a small part of the overall gains from openness.

- Including both trade and diffusion represents a departure from the previous literature
  - Here trade and diffusion are substitutes, so GT are smaller... complementarities?
  - Can compare GT with GO, helps to put numbers in context
  - Policy - what is the optimal way to integrate with RW?

2 Overview

- Romer, Jones, Kortum, aggregate scale economies, and the GO

- Trade and a puzzle: the implied rate of growth is an order of magnitude smaller than the observed growth rate.

- Diffusion allows the model to be consistent with both trade data and the observed growth rate.

- The resulting quantitative model is then used to calculate GT and GO

3 From endogenous to cuasi-endogenous growth

- Solow: growth comes from technological change

- Romer: technological change comes from profit-driven R&D

- Implication: growth is a function of the quantity of H devoted to R&D

- Jones Critique: contrary to what we observe, the growth rate would have to exhibit an upward trend

3.1 Romer

- A constant growth rate requires a constant rate of technological change. Imagine $Y = F(K, AL)$, where A is a technology index. With no population growth, then $g = g_A$

- Romer assumes $\dot{A} = AH_I = As_I L$, so $g = s_I L$

- Why is it that $\dot{A}$ increases with A? For Romer, this is because the stock of knowledge increases productivity in R&D (knowledge externalities)

- But, what happens if this benefit is not as strong? One could even think that sustaining a level of $\dot{A}$ is harder when A is higher, since the easy ideas have already been exploited!

3.2 Jones

- Jones assumes $\dot{A} = A^{\gamma} s_I L$, $\gamma < 1$, which implies

$$g = A^{\gamma - 1} s_I L$$

- When $A \longrightarrow \infty$ then $A^{\gamma - 1} \longrightarrow 0$ and $g \longrightarrow 0$. But a growing L can overcome this effect.

- In steady state,

$$g = \left(\frac{1}{1 - \gamma} \right) g_L$$

3.3 Kortum

- The following is a simple version of Kortum (1997).

- There is a continuum of intermediate goods $u \in [0, 1]$.

- The final good is produced from these intermediate goods with a CES σ.

- Intermediate goods are produced with labor, with unit-labor cost $x(u)^{\theta}$.

- There is an instantaneous rate of arrival ϕ of ideas per person (exogenous research).

- The stock of ideas is λ, with $\dot{\lambda} = R \equiv \phi L$. In steady state: $\dot{\lambda}/\lambda = g_L$ and $\lambda = R/g_L$.

- Ideas have two elements: the good to which they apply and their "quality."

  - The good to which an idea applies is drawn from a uniform distribution in $u \in [0, 1]$

  - The quality q is drawn from a Pareto distribution with parameter one

- The economy's technology is determined by the best idea available for the production of each good.

- More ideas (higher λ) $->$ better technology frontier (higher z). Formally, $x \equiv 1/z \sim \exp(\lambda)$

- Letting

$$p^{1-\sigma} = \int p(u)^{1-\sigma} du$$

and assuming $1 + \theta(1 - \sigma) > 0$ then

$$w/p = C_S^{-1} \lambda^{\theta}$$

- The growth rate is then

$$g = \theta g_L$$

  - Quasi-endogenous growth
  - Role of θ

3.4 Quantitative version and implications

- Alvarez and Lucas (2005) enrich the production structure and calibrate the model

- Two changes:

  - Intermediate goods are used to produce intermediate goods - labor share β

  - Labor is used to produce the final good with share α

- The only change is that now

$$g = \theta \left(\frac{1 - \alpha}{\beta} \right) g_L$$

  - $1/\beta$ is a multiplier resulting from the circularity in the use of intermediate goods

  - $1 - \alpha$ is the importance of intermediate goods in the production of the final good

Note

- Recall the result in the closed economy that

$$c = w/p = \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}(AB)^{-(1-\alpha)/\beta}\lambda^{\theta(1-\alpha)/\beta}$$

- Differentiating we immediately see that

$$g = \theta\left(\frac{1-\alpha}{\beta}\right)g_L$$

- AL parameters: $\alpha = 0.75$ and $\beta = 0.5$, so $(1-\alpha)/\beta = 1/2$

- Using $g_L = 4.8\%$ and $g = 1.5\%$, then need $\theta = 0.63$, hence

$$g = \theta \left(\frac{1-\alpha}{\beta} \right) g_L = 0.315 g_L$$

- In levels, $y \sim L^{0.315} \;\rightarrow\;$ scale effect (Diamond, GGS)

  – If 100 economies integrate perfectly, the income under integration is $100^{0.315} = 4.3$ times higher than under isolation

- Why? Because there is a higher "stock of ideas," which implies that the best ideas are more productive
  - Note: growth rate pins down GO

- The GO arise through the exchange of ideas via trade and diffusion (frictions lower GO)

- What share of these gains arise through trade?

4 Trade and Growth with No Diffusion

- Intermediate goods are tradable.

- All countries grow at g_L.

- Transportation costs are of the iceberg type, with $k_{ij} \leq 1$ of a good sent from j making it to i, $k_{ii} = 1$, $k_{ij} = k_{ji}$, and the triangular inequality holds.

4.1 Equilibrium

- Relabeling goods by $x \equiv (x_1, x_2 ... x_n)$ rather than u, then the price of good x in country i is

$$p_i(x) = \min_j \left\{ \left(c_j / k_{ij}\right)^{1/\theta} x_j^{\theta} \right\}$$

so

$$p_{mi} = BC_S \psi_i^{-\theta}$$

where

$$\psi_i \equiv \sum_j \psi_{ij} \text{ and } \psi_{ij} \equiv \left(w_j^{\beta} p_{mj}^{1-\beta} / k_{ij}\right)^{-1/\theta} \lambda_j$$

- To determine wages we introduce the trade-balance conditions (using $D_{ij} \equiv \psi_{ij}/\psi_i$)

$$L_i w_i = \sum_j L_j w_j D_{ji}$$

4.2 The Gravity Equation

- Let the normalized bilateral imports of country i from country j be D_{ij}/D_{jj}. Then

$$D_{ij}/D_{jj} = \left(\frac{p_{mj}}{p_{mi}k_{ij}}\right)^{-1/\theta}$$

- Taking logs, and letting $m_{ij} \equiv \ln(D_{ij}/D_{jj})$ and $d_{ij} = \ln(p_{mj}/p_{mi}k_{ij})$, then

$$m_{ij} = -(1/\theta)d_{ij}$$

- EK estimate θ from this and obtain $\theta = 0.12$.

4.3 The Growth Puzzle

- $\theta = 0.12 < 0.63$ needed to match $g = 1.5\%$

- Implied growth is $g = 0.29\%$

5 Introducing diffusion

- One possible solution: diffusion. Assume instantaneous rate of diffusion δ_S: national $\longrightarrow$ global

- Then $\dot{\lambda}_i = R_i - \delta_S \lambda_i$ and $\dot{\lambda}_T = \delta_S \sum \lambda_i$, and in steady state

$$\begin{aligned} \lambda_i &= R_i/(g_L + \delta_S) \\ \lambda_T &= (\delta_S/g_L) \sum \lambda_i \end{aligned}$$

- For each intermediate good there are n best national ideas (one for each country) plus a best global idea.

5.1 Equilibrium

- A country i can buy a good produced in country j with either the best national idea or the best global idea.

- Labeling goods by $\widetilde{x} = (x_1, x_2, ..., x_n, x_S)$, the price of good $\widetilde{x}$ in country i is then

$$p_i(\widetilde{x}) = \min\left\{\min_j\left\{\left(\frac{c_j}{k_{ij}}\right)x_j^\theta\right\}, \min_j\left\{\left(\frac{c_j}{k_{ij}}\right)x_S^\theta\right\}\right\}$$

- For every country i there is a country $\hat{\jmath}(i)$ with least cost of delivering goods produced with global technologies. This is $\hat{\jmath}(i) = \arg\min_j \left\{c_j/k_{ij}\right\}$.

- Using this in the expression for $p_i(\widetilde{x})$ above and letting

$$\xi_i(\widetilde{x}) \equiv \min\left\{\min_j\left\{\left(\frac{c_j}{k_{ij}}\right)^{1/\theta} x_j\right\}, \left(\frac{c_{\hat{\jmath}(i)}}{k_{i\hat{\jmath}(i)}}\right)^{1/\theta} x_S\right\}$$

then $p_i(\widetilde{x}) = \xi_i(\widetilde{x})^\theta$.

- Given the properties of the exponential distribution, ξ_i is distributed exponentially with parameter $\hat{\psi}_i$ where

$$\hat{\psi}_i \equiv \sum_j \hat{\psi}_{ij} \quad \text{and} \quad \hat{\psi}_{ij} \equiv \begin{cases} \left(w_j^{\beta} p_{mj}^{1-\beta}/k_{ij}\right)^{-1/\theta} \lambda_j & if \quad j \neq \hat{\jmath}(i) \\ \left(w_j^{\beta} p_{mj}^{1-\beta}\right)^{-1/\theta} (\lambda_j + \lambda_T) & if \quad j = \hat{\jmath}(i) \end{cases}$$

Thus, assuming $1 + \theta(1 - \sigma) > 0$, then

$$p_{mi} = BC_S \hat{\psi}_i^{-\theta}$$

- Wages w are determined by the trade-balance conditions but with $D_{ji} = \hat{\psi}_{ji}/\hat{\psi}_j$.

5.2 The NTG Condition

- If trade costs are sufficiently low, countries with a low research intensity would have lower wages and specialize in the production of goods for which the best idea is a global idea
  - From now on I refer to these goods as "global goods".

- Trade in global goods is problematic since it implies that the model doesn't generate a well behaved gravity equation: given that absolute productivities for global goods are the same across countries, then each country buys *all* its global goods from one single country (i.e., country i buys global goods only from $\hat{j}(i)$).

- This limitation of the model is due to the way in which diffusion is modeled.
  - If instead of "global diffusion" one assumed that different technologies diffuse to different countries, the model could be consistent with the gravity equation even in the presence of trade in goods with diffused best technologies.

- But my purpose here is not to explore the impact of diffusion on the geography of trade flows but rather to study the effect of diffusion on the gains from trade and the gains from openness.

- I thus retain the assumption of global diffusion but focus on a class of cases in which there is no trade in global goods in equilibrium. I refer to this as the NTG condition.

5.3 Gravity with Diffusion

- There is NTG if $\phi_i = \phi$ for any k_{ij} or - assuming that $k_{ij} = k$ for all i, j - if k is sufficiently large

- Under the NTG, the equilibrium is very similar to the one without diffusion, except that

$$\widetilde{\psi}_i \equiv \sum_j \widetilde{\psi}_{ij} \text{ and } \widetilde{\psi}_{ij} \equiv \begin{cases} \left(w_j^{\beta} p_{mj}^{1-\beta} / k_{ij}\right)^{-1/\theta} \lambda_j & if \quad j \neq i \\ \left(w_j^{\beta} p_{mj}^{1-\beta}\right)^{-1/\theta} (\lambda_j + \lambda_T) & if \quad j = i \end{cases}$$

- The gravity equation now has an intercept

$$m_{ij} = -\ln\left(1 + (\delta_S/g_L)R_T/R_j\right) - (1/\theta)d_{ij}$$

- Estimating $1/\theta$ and δ_S through a NLS regression yields precise estimates: $1/\theta = 4.6$ (s.e. 0.36) and $\delta_S = 0.008$ (s.e. 0.002)

- The positive diffusion parameter actually helps in matching import shares...

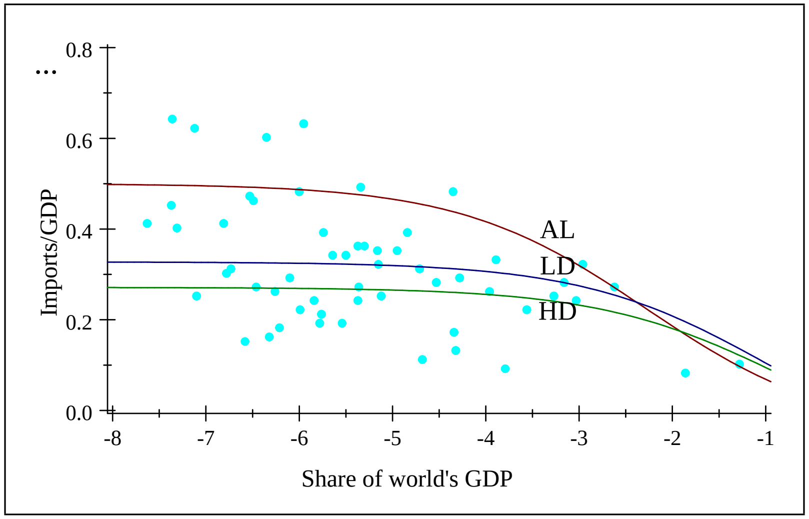

Figure 1: Import shares and size

	$\theta = 0.15$ and $\delta_S = 0$	$\theta = 0.22$ and $\delta_S = 0.005$	$\theta = 0.22$ and $\delta_S = 0.008$
Whole sample	1.86	0.86	1.04
OECD	0.35	0.1	0.13

Table 1: Sum of square residuals for import shares

5.4 The Growth Puzzle remains

- But growth still too low: $1/\theta = 4.6 \rightarrow \theta = 0.22 \rightarrow g = 0.53\%$

- Cannot increase θ... need another source of growth that doesn't affect trade volumes

6 NT-ideas

- Assume that there is a continuumm of non-tradeable consumption goods indexed by $v \in [0,1]$, which enter utility through a CES function with σ.

- These goods are produced with a Cobb-Douglas production function from labor and the composite intermediate good at cost $Az(v)^{\gamma} w^{\alpha} p_m^{1-\alpha}$, where $A \equiv \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$ and $z(v)$ is a cost parameter associated with good v.

  – Note that the parameter γ plays the same role in affecting the cost of non-tradeable consumption goods as the parameter θ plays in affecting the cost of the tradeable intermediate goods.

- The modelling of the creation and diffusion of NT-ideas is analogous to that for T-ideas.

  - Letting η_i represent the stock of NT-ideas originated in country i that have not diffused, and letting δ_G be their rate of diffusion, then $\dot{\eta}_i = \phi_i L_i - \delta_G \eta_i$.

  - Letting η_T be stock of diffused NT-ideas, then in steady state we have $\eta_T = (\delta_G / g_L) \sum \eta_i$, and the stock of NT-ideas that country i can use is $\widetilde{\eta}_i \equiv \eta_i + \eta_T$, which grows at rate g_L for all i.

  - Finally, and analogous to the results of the previous section, the cost parameter $z(v)$ in country i is distributed exponentially with parameter $\widetilde{\eta}_i$.

- Consumption goods are sold at cost, hence the price of consumption good v is $Az(v)^{\gamma}w^{\alpha}p_m^{1-\alpha}$. The price index for the consumption bundle is then

$$p = Aw^{\alpha}p_m^{1-\alpha}\left(\int_0^1 z(v)^{\gamma(1-\sigma)}dv\right)^{1/(1-\sigma)}$$

Since $z(v)$ is distributed exponentially with parameter $\widetilde{\eta}_i$, then (assuming that $1+\gamma(1-\sigma)>0$)

$$p_i = AC_G\widetilde{\eta}_i^{-\gamma}w_i^{\alpha}p_{mi}^{1-\alpha}$$

where $C_G \equiv \Gamma(1+\gamma(1-\sigma))^{1/(1-\sigma)}$.

- The introduction of NT-ideas doesn't affect trade, nor the expression for p_{mi}. Hence growth is now

$$g = \left[\theta\left(\frac{1-\alpha}{\beta}\right) + \gamma\right] g_L$$

- Calibration: $\theta = 0.22$ and $\gamma = 0.2$ imply $g = 1.5\%$.

- How about δ_G?

6.1 Calibrating diffusion

- Recall the estimation of $\delta_S = 0.008$. This seems low: it implies $1/0.008 = 125$ years mean diffusion lag!

- Eaton and Kortum (1999) use international patent data to think about diffusion

  – If diffusion is "country-pair specific" and exogenous (think δ_{ij}) then holders of patents will want to patent in countries where their ideas diffuse. Then we can use patenting in foreign countries to estimate diffusion rates

  – Use stock of foreign patents to stock of national patents to estimate δ. This leads to $\delta \approx 0.09$... but this rate of diffusion would imply very little trade!

- How to reconcile the estimated $\delta_S = 0.008$ with $\delta_{EK} = 0.09$?
  - Not all ideas are patented; the ones that are more likely to diffuse would be the ones patented. Upward bias in $\delta_{EK} = 0.1$ relative to δ_S.
  - Drop the NTG condition, and have diffusion first to a club of rich countries, and then to poor countries. Diffusion to poor countries leads to more trade –> 2nd Mid-Term Exam.

- For now, use $\delta_G = \delta_S = \delta = 0.008$.

7 Gains from Trade and Diffusion

- The gains from trade and diffusion are determined by the effect of these forces on the real wage.

- We want to compare three scenarios:

1. autarky with no diffusion,

2. autarky with diffusion,

3. and frictionless trade with diffusion.

- Note that

$$p_i = AC_G \widetilde{\eta}_i^{-\gamma} w_i^{\alpha} p_{mi}^{1-\alpha}$$

which implies

$$w_i/p_i = (AC_G)^{-1} \widetilde{\eta}_i^{\gamma} \left(w_i/p_{mi}\right)^{1-\alpha}$$

- There are two separate ways in which openness affects the real wage:

1. by increasing $\widetilde{\eta}_i$ through diffusion of NT-ideas, and

2. by increasing w_i/p_{mi} through trade and diffusion of T-ideas.

7.1 Autarky with no diffusion

- Consider first autarky with no diffusion. In this case, the stock of T-ideas is simply $\lambda_i + (\delta/g_L)\lambda_i$ (ideas created in i that have and have not diffused), which is equal to

$$(1+\delta/g_L)\left(\frac{R_i}{g_L+\delta}\right) = R_i/g_L$$

For future reference, note that this is also the stock of NT-ideas. On the other hand, autarky implies

$$\widetilde{\psi}_i \equiv \left(w_i^\beta p_{mi}^{1-\beta}\right)^{-1/\theta} R_i/g_L$$

Hence

$$\begin{aligned} p_{mi} &= BC_S\widetilde{\psi}_i^{-\theta} = BC_S w_i^\beta p_{mi}^{1-\beta}\left(R_i/g_L\right)^{-\theta} \\ &\rightarrow w_i/p_{mi} = \left(BC_S\right)^{-1/\beta}\left(R_i/g_L\right)^{\theta/\beta} \end{aligned}$$

7.2 Autarky with diffusion

- Now consider autarky with diffusion. Now the stock of either NT-ideas or T-ideas is

$$\lambda_i + (\delta/g_L)\sum \lambda_j = \frac{R_i}{g_L+\delta} + (\delta/g_L)\frac{\sum R_j}{g_L+\delta}$$

Hence the stock of NT-ideas and also T-ideas is

$$\frac{R_i + (\delta/g_L)R_T}{g_L+\delta}$$

- This implies

$$w_i/p_{mi} = (BC_S)^{-1/\beta}\left(\frac{R_i + (\delta/g_L)R_T}{g_L+\delta}\right)^{\theta/\beta}$$

7.3 Diffusion and frictionless trade

- Finally, consider trade with diffusion. The stock of T- and NT-ideas is as before, but frictionless trade together with $\phi_j = \phi$ implies equal wages and

$$p_{mi} = p_m = BC_S w^\beta p_m^{1-\beta} \left(\sum \lambda_j + \lambda_T\right)^{-\theta}$$

and hence

$$w/p_m = (BC_S)^{-1/\beta} (R_T/g_L)^{\theta/\beta}$$

7.4 Gains from Trade and Diffusion

- The gains from diffusion in both T and NT ideas is obtained by comparing w_i/p_i in autarky with no diffusion to autarky with diffusion. This results in

$$
\begin{aligned}
& \left(\frac{\frac{R_i+(\delta/g_L)R_T}{g_L+\delta}}{R_i/g_L}\right)^{\gamma}\left(\frac{\frac{R_i+(\delta/g_L)R_T}{g_L+\delta}}{R_i/g_L}\right)^{\theta(1-\alpha)/\beta} \\
= & \left(\frac{1+(\delta/g_L)R_T/R_i}{1+\delta/g_L}\right)^{\gamma+\theta(1-\alpha)/\beta}
\end{aligned}
$$

- The gains from trade are obtained by comparing $(w_i/p_{mi})^{1-\alpha}$ in autarky and under frictionless trade, both with diffusion of T-ideas. This yields

$$\left(\frac{R_T/g_L}{\frac{R_i+(\delta/g_L)R_T}{g_L+\delta}}\right)^{\theta(1-\alpha)/\beta} = GT_i = \left(\frac{1+\delta/g_L}{r_i+\delta/g_L}\right)^{\theta(1-\alpha)/\beta}$$

where $r_i \equiv R_i/R_T$.

- Note that if $\delta = 0$ then $GT_i = r_i^{-\theta(1-\alpha)/\beta}$, as in Alvarez and Lucas. But an increase in δ decreases these gains. Why?

- Finally, the gains of openness (from autarky with no diffusion to frictionless trade with diffusion) are

$$GO_i = \left(\frac{1+(\delta/g_L)R_T/R_i}{1+\delta/g_L}\right)^{\gamma} r_i^{-\theta(1-\alpha)/\beta}$$

- Consider a country with $r_i = 1\%$. The gains from diffusion are (using $\delta/g_L = 0.008/0.048 = 0.17$)

$$\left(\frac{1+(\delta/g_L)R_T/R_i}{1+\delta/g_L}\right)^{\gamma+\theta(1-\alpha)/\beta} = \left(\frac{1+0.17*100}{1+0.17}\right)^{0.31} = 2.33$$

whereas

$$GT_i = \left(\frac{1+\delta/g_L}{r_i+\delta/g_L}\right)^{\theta(1-\alpha)/\beta} = \left(\frac{1+0.17}{0.01+0.17}\right)^{0.11} = 1.23$$

Finally,

$$\begin{aligned} GO_i &= \left(\frac{1+(\delta/g_L)R_T/R_i}{1+\delta/g_L}\right)^{\gamma} r_i^{-\theta(1-\alpha)/\beta} \\ &= \left(\frac{1+0.17*100}{1+0.17}\right)^{0.2} 0.01^{-0.11} = 2.87 \end{aligned}$$