1 Motivation

- Countries that were slow to adopt or imitate outside ideas experienced slower growth. Example: Britain vs. Germany, US, Japan
- Why research occurs in different countries? (patents)
- How the research gives rise to innovations?
- Where these innovations generate increase in productivity? (adoption rate in different countries)

  Related Literature

- Gerschenkron (1962) - economy of backwardness; Rosenberg (1982)
- Romer (1990) - endogenous growth, Jones (1995)
- Diamond of *Gun, Germs, and Steel,* describe that only 4 countries independently developed writing while the other adopt.

Historian Rosenburg attribute Britain's decline in the 20th century as its slowness to adopt other countries ideas. Had they immitated German or US innovations, they would have grown faster. Japan owes its growth to its williness to imitate designs for its export industry. So this Eaton and Kortum model include this feature: that countries more willing to adopt ideas will grow faster.

2 Overview: What will this paper do?

- Present a model of world growth driven by endogenous innovation, countries will depend on each other for research activities and growth
- Characterize steady state as balanced growth path – countries grow at the same rate, but faster to adopt countries lead in GDP
- Fit model to data after estimating some key parameters. It will predict for 5 countries:

  -Number of researchers

  -Productivity relative to US

  -Direction of patents for protection in each of the 5 countries (5 x 5 matrix)

- Decompose individual country growth as sources from diffused ideas from other countries

- Decompose the value of ideas by its foreign and home markets
- Counterfactual experiments - patterns of diffusion (autarky vs. borderless) and rigor of patent protection

Note: How do they measure the patterns of diffusion and rigor of patent protection (imitation rate, how specified)?

3 Key Results

- Individual countries - while adopted ideas usually originated from research done in the home countries, productivity growth in each countries can be most attributed to ideas diffused from United States.
- Ideas derived most of their value from home markets, especially for the United States

4 Model Features: Data

- Scale matters in research: more than half of researchers work in the United States, and most the rest in Japan
- National growth rate not related to research effort, and productivity levels differences not as dispersed as research efforts.
- Domestic inventors constitute main source of patents
- Scale matters in patents requested by foreign inventors: United States inventors dominate the foreign patents in other countries

5 Model: Production

- Final good Y_{nt}, produced by country $n = 1, ..N$, at time t
- Final goods produced with Cobb-Douglas technology, from a continuum of intermediate goods $X_{nt}(j)$ of different quality $Z_{nt}(j)$

$$\ln(\frac{Y_{nt}}{J}) = J^{-1} \int_0^J \ln\left[Z_{nt}\left(j\right) X_{nt}\left(j\right)\right] dj$$

- Intermediate goods produced with Cobb-Doublas technology with capital and labor

$$X(j) = K(j)^{\phi} L(j)^{1-\phi}$$

where $\phi \in [0, 1]$ =capital elasticity

- Assumptions:
  - Output is homogeneous and tradable across countries
  - Inputs are nontraded
  - Range of inputs, J, is fixed over time
  - capital elasticity same across ipnuts, countries, and time

6 Model: Ideas

- Idea: a unit of research output, the result of research effort
- research input: s_{ti} (share of labor force in research)
- ideas production/arrival rate: $\alpha_{it} s_{it}^{\beta} L_{it}$
  - where
  - α_{it} =overall productivity of research effort in country i at time t
  - $\beta =$ rate at which research productivity declines as less talented workers become researchers
  - L_{it} =labor force in country i at time t
- 3 dimensions – Quality, Adoption, Diffusion Lag

6.0.1 (1) Quality

- $Q\tilde{\ } F(Q)$
- Assume Pareto distribution. So $F(Q)$ =Prob($x < Q$)= $1 - Q^{-\theta}$
- An idea of quality q is adopted if its quality is higher than current state of the art z, thus

$$\text{Prob of adopting idea} = P(q > z) = z^{-\theta}$$

6.1

6.2 (2) Diffusion Lag

- Ideas diffuse from country i to country n at rate ϵ_{in}

$$\epsilon_{in} = \text{speed of diffusion from country i to country n}$$

- Assume that diffusion lags, τ_{in}, follows exponetial distribution

$$\tau_{in}\tilde{\ }\text{exponential } (\epsilon_{in})$$

- This means that the probability that an idea invented at country i take less than periods x to diffuse to country n is

$$\Pr(\tau_{in} \leq x) = 1 - e^{-\epsilon_{in}x}$$

- Mean diffusion time is

$$\text{average time it takes to diffuse from i to n} = \frac{1}{\epsilon_{in}}$$

6.3 (3) Idea Adoption

- An idea is diffused doesn't mean it is adopted by the recipient country
- An idea of quality q is adopted/used only if:

$$q > Z(j)$$

  The idea's quality is higher than the current state of the art for producing that intermedate good j

7 Technological Frontier

- define the highest quality for each intermediate good j in country n at time t as, $Z_{nt}(j)$−the "State of the Art"
- "The State of the Art" across all intermediate goods in that country form that technological frontier
- The technological frontier in country n at time t is summarized by the cumulative distribution of the state of the arts

  $Z_{nt}(j)\tilde{\ }H_n(z;t)$ (Fraction of inputs whose state of the art is below z)

- How does this H cumulative distribution look like? It changes over time because of the arrival of newly diffused countries and subsequent adoption of some of those ideas. We want to find a stationary distribution for the state of the art, taking into account diffusion and adoption of new ideas.

8 Technological Frontier ~ $\mathbf{H}_n(z;t)$

8.1 Step (1): Dynamics of diffusion of ideas into country n

- Define the stock of ideas at country n $\mu_{nt} = \int_{-\infty}^{t} \dot{\mu}_{ns} ds$
- $\dot{\mu}$ is the stochastic rate at which ideas diffuse to country n from research done all over the world and domestically:

$$\dot{\mu}_{nt} = J^{-1} \sum_{i=1}^{N} \int_{-\infty}^{t} \underbrace{\epsilon_{in} e^{-\epsilon_{in}(t-s)}}_{\text{fraction diffused to country n in remaining time}} \cdot \underbrace{\alpha_{is} s_{is}^{\beta} L_{is}}_{\text{\# of ideas produced at country i at time s}} ds$$

8.2

8.3 Step (2): Adoption of some of the diffused ideas

- Ideas are adopted if $q > Z$, we know that qualitity is distributed Pareto, thus the adoption time of the diffused ideas is distributed exponentially, with rate

$$\dot{\mu} \times \text{Prob}(q > z) = \dot{\mu} \cdot z^{-\theta}$$

- Now we can solve for $H(z;t)$

9 Solving for $\mathbf{H}_n(z;t)$

- Let x =time adopting new ideas (changing the technology frontier)
- By the memoryless property of the exponential distribution

$$\begin{aligned} P(x &< t+s) = P(x<t) \cdot P(x<s) \\ H_n(z;t+dt) &= H_n(z;t) \cdot H_n(z;dt) \end{aligned}$$

- $H_n(z;dt)$ can be interpreted as the probability of having no new adoption within the period dt

$$\begin{aligned} H_n(z;dt) &= P(\text{no adoption in } dt) \\ &= P(x > dt) \\ &= e^{-\dot{\mu} z^{-\theta} dt} \end{aligned}$$

- Rewrite, giving us a differential equation.

$$H_n(z;t+dt) = H_n(z;t) \cdot e^{-\dot{\mu} z^{-\theta} dt}$$

- Solve the differential equation, with two boundary conditions

$$\begin{aligned}\lim_{s\to-\infty} H_n(z;s) &= 1 \qquad \forall z \geq 1 \\ \lim_{s\to-\infty} \mu_{ns} &= 0\end{aligned}$$

- Gives

$$H_n(z;t) = e^{\mu_{tn} z^{-\theta}}$$

10 Production

- Now we can rewrite the production technology, taking account of the technology frontier with expression for TFP

$$Y_{nt} = A_{nt} K_{nt}^{\phi} \left[L_{nt}(1 - s_{nt})\right]^{1-\phi}$$

where the TFP is the geometric mean of the technological frontier

$$A_{nt} = \exp\left\{\int_1^{\infty} \ln(z) dH_n\left(z;t\right)\right\}$$

- EK shows that as μ_{nt} becomes large, TFP is proportional to gorwth in the stock of ideas diffused to the country

$$A_{nt} = e^{\Psi/\theta} \mu_{nt}^{1/\theta}$$

11 Market Structure

- All producers of intermediates in a country face the same w and cost of capital r'. So they have the same unit cost

$$c = \left(\frac{r'}{\phi}\right)^{\phi} \left(\frac{w}{1-\phi}\right)^{1-\phi}$$

- Bertrand Competition - new idea compete against the previous state of the art
- Cobb Douglas technology implies unit elastic demand for the input
- Owner of the inventoin charges the highest price at which it remains the only seller of that input

12 Implication of Market Structure for Input Prices

- Think about cost per quality. With Bertrand Competition, prices driven down to perfect competition.
- Equating the cost per quality of the previous state of the art and the counter part with the new quality

$$\frac{c}{z} = \frac{p_q}{q}$$

- Thus prices for inputs differ across inputs, depending on the "step of invention"

$$p(j) = \left(\frac{q(j)}{z(j)}\right) c$$

- $\frac{q(j)}{z(j)}$ is the "step of invention" for the input j

13 Value of an Idea

- An idea has positive value only if $q \geq z$
- ideas face a hazard rate of ι of being imitated, in which case it loses all of its value
- The expected discounted value of the right to use an idea from country i of quality q in country n, given that the previous state of the art z

$$V_{int}(z,q) = \int_0^\infty \underbrace{\pi_{n,t+s}(z,q)}_{\text{profits}} \cdot \underbrace{e^{-rs}}_{\text{discount}} \cdot \underbrace{e^{-\iota s}}_{\text{probability of not being imitated}} \cdot \underbrace{\left(1 - e^{-\epsilon_{in} s}\right)}_{\text{probability of diffusion by t+s}} \cdot \underbrace{e^{-(\mu_{nt+s}}}_{\text{probability of not be}}$$

where

$$\pi_{n,t+s}(z,q) = \frac{Y}{J}\left[1 - \frac{z}{q}\right]$$

because

$$\begin{aligned} X(j) &= \frac{P \cdot Y}{J \cdot P(j)} = \frac{Y}{J \cdot P(j)} \\ \text{and } \pi &= P(j)X(j) - cX(j) \\ &= \frac{Y}{J} - \frac{Yz}{Jq} \\ &= \frac{Y}{J}\left[1 - \frac{z}{q}\right] \end{aligned}$$

- Assumption: at the time of invention research knows the quality of his idea, but not the quality of the competiing input in any country
- The expected value of an idea of quality q from country i in country n,

$$V_{int}(q) = \int_1^q V_{int}(z,q)dh_n(z;t)$$

14 Decision to Patent

- Having a patent decreases the hazard rate of imitation

$$\iota^{pat} < \iota^{not}$$

- The cost of the patent for inventor in country i in country n should equal to

$$V_{int}^{pat}(q) - V_{int}^{not}(q) = f_{int}$$

- The equation above determines the threshold $\overline{q}_{int}$ above which inventors in country i patent in country n

  For $q > \overline{q}_{int}$, patent

  For $q < \overline{q}_{int}$, don't patent

- The return to patent increase with q
- The rate inventors in country i patent in country n is

$$P_{int} = \underbrace{\alpha_{it} s_{it}^{\beta} L_{it}}_{\text{ideas produced in i}} \cdot \underbrace{(\overline{q}_{int})^{-\theta}}_{\text{probability of } q > \overline{q}}$$

15 Value of an Idea: Return to R&D

- Value of an idea: $\max\left\{V_{int}^{pat}(q) - f_{int}, V_{int}^{not}(q)\right\}$
- Before the quality is known, the expected value of an idea for country i in country n is

$$V_{int} = \int_1^{\overline{q}_{int}} V_{int}^{not}(q)\, dF(q) + \int_{\overline{q}_{int}}^{\infty} V_{int}^{pat}(q)\, dF(q) - f_{int}(\overline{q}_{int})^{-\theta}$$

- Summing across countries n, the expected return to an idea of unknown quality is

$$V_{it} = \sum_{n=1}^{N} V_{int}$$

16 Equilibrium Number of Reseachers

Equalization of wages between the research and production sector in country i gives the equilibrium s_{it}, the share of labor force who are researchers

$$\alpha_{it}\beta V_{it}s_{it}^{\beta-1} = w_{it}$$

17 Technology and Income

- Aggregate output in country i at time t is

$$Y_{it} = \frac{\kappa_1(\theta)}{\kappa_2(\theta)}A_{it}k_{it}^{\phi}L_{it}(1-s_{it})$$

- Cobb Douglas assumption implies that the capital to labor ratio k is

$$k_{it} = \frac{\phi}{1-\phi}\frac{w_{it}}{r'}$$

- Rewrite the aggregate output in terms of wage and cost of capital

$$Y_{it} = \frac{1}{\kappa_2(\theta)}\left[\kappa_1(\theta)A_{it}\left(\frac{\phi}{r'}\right)^{\phi}\right]^{\frac{1}{1-\phi}}L_{it}(1-s_{it})$$

18 Wages

- production wage is

$$w_{it} = (1-\phi)\kappa_1(\theta)A_{it}k_{it}^{\phi}$$

- Rewrite wages in terms of cost of capital

$$w_{it} = (1-\phi)\left[\kappa_1(\theta)A_{it}\left(\frac{\phi}{r'}\right)^{\phi}\right]^{\frac{1}{1-\phi}}$$

International Technology Diffusion: Theory and Measurement

–they build a growth model that allows countries whose growth simultaneously depend on inventing or adopting other's inventions.

innovation is endogenous to countries and not independent across countires (allow for interdependence–address how?)
-in steady state, world growth rate is either semiendogenous or fully endogenous

-fit the steady state of model to research employment, product levels, international patenting among 5 countries

-Which country is getting what from which country? Data on internatoinal patenting which indicate who is coming with ideas and where those ideas are patented answer this question.

Questions that the model of this paper seek to answer or capture:

1. To what extent does the SHARING of ideas among countries contribute to world growth?

2. How do countries decide to adopt ideas, or innovate and use the idea in which countries?

3. To what extent do countries depend on each other for their growth? (see equation 15, decoming growth into source country and source country ideas)

What does data tell us?

1. Research: research is related to scale. The largest countries indicate the most amount of research.

18.1 2. Productivity: all countries have similar level of productivity, measured as manufacturing value added per hour in 1990 relative to United States

3. Patents: the amount of foreign patents depends most on patent costs

Steady State defined as:

1. stock of ideas grow at a constant common rate
2. population grow at constant rate
3. relative productivity of researchers proportional to relative level of technology in that country
4. patenting costs constant proportion of output
5. interest rate and cost of capital constant across countries
6. constant fraction of workers in each country works as researchers
7. patenting is constant
8. TFP, wage, output grow at constant rate

We want to get the steady-state patent, and then solve for how much research will be done.

Parameters for the Model

1. imitation rates-same for all products

2. diffusion rates-10 paremeters to account for 25 diffusion rates between and within 5 countries. Diffusion rate from country i to n is the product of parameter governing the speed at which country n adopts new ideas, a parameter governing the speed at which ideas from country i are ready for adoption, and a parameter governing the percentage increase in adoption speed for domestic ideas

$$\varepsilon_{in} = \varepsilon_n \cdot \varepsilon_i \cdot \varepsilon_d$$

3. interest rate - stock market return

4. capital elasticity - 0.3 (based on Lysko)

5. $\alpha =$ so that given all the other parameters the model predicts the mean growth of TFP i n US german French manufacturing sectors.

The other parameters are estimated by nonlinear least squares

Fitting the Model

The steady state model is fitted to data to predict the following categories in 5 countries:

1. Number of researchers
2. Productivity relative to US
3. The matrix of patents
4. Fraction of potentially useful ideas that are ever adopted in each country (for research originated from each country)
5. Fraction of productivity growth in each country attributable to research performed in other countries
6. Fraction of invention value in each country attributable to foreign marketsn

The model section of the paper is divided into the following sections:

1. Production
2. Ideas
3. Technological frontier
4. Productivity
5. Market structure
6. Value of an idea
7. Decision to patent
8. Return to R & D
9. Equilibrium R & D
10. Technology, wages, and income

Estimation is done assuming steady state is reached.