Fourth Summer School in Trade, Industrialisation, and Development 2005

Gargnano, Italy

Trade, Innovation, and Technology Diffusion: Implications for Developing Countries

Lecture 6: Innovation, Diffusion, and Trade

September 2005

Issues:

- Effect of Diffusion on Welfare in an Open Economy (Krugman, Samuelson, Gomery and Baumol)
- Effect of Trade and Diffusion on the Incentive to Innovate in different countries.
- Diffusion and Trade as Substitutes: Diffusion eliminates differences in comparative advantage
- Effect of Intellectual Property Regimes on the incentive to innovate (Helpman, Lai, Dinopoulos and Segerstrom)

Various pieces of evidence:

- Research Concentration
- Trade and Diffusion Barriers
- Parallel Growth

Previous Work:

- Grossman-Helpman (1991)
- Krugman (1979) Helpman (1993) North South models
- Diffusion: EK (1996, 1999)
- Trade: EK (2001,2002,2005).
- Here: an integration
- Why has it taken so long?

The Static Model:

- Technology for final goods production:

$$Q_n = \left[\int_0^1 x_n(j)^{(\sigma-1)/\sigma} dj \right]^{\sigma/(\sigma-1)}$$

Here $x_n(j)$ is the amount of intermediate j used for production in n and σ is the elasticity of substitution across intermediates.

- M countries

- Q is costlessly tradable and numeraire.

- $M+1$ types of technologies for each intermediate good. Each country i has a technology that is exclusive to it and there is a commonly available technology C.

- TFP $z_i(j)$ for technology $i = 1, ..., M, C$.

Distributional Assumptions:

- Fréchet distributions of $z_i(j)$.

$$\Pr[Z_i \leq z] = \exp(-T_i z^{-\theta})$$

  independent across $i = 1, ..., M, C$.

- Exclusive technologies can only be used in country of invention. C technology is footloose.

Other assumptions:

- Labor is only input, with wage w_i.
- Iceberg transport costs $d_{ni} \geq 1$ for intermediates.
- Market Structure: Bertrand (to allow for profits, as in quality ladders).

Inevitable Ricardian taxonomy:

1. Type I: $w_n/w_i < d_{ni}\ \forall n, i \rightarrow C$ goods made with C technologies not traded (multiple advanced countries)

2. Type II: If $\exists\ i$ st $w_n/w_i > d_{ni} \rightarrow C$ technologies not used in n. (North-South models)

3. Type III: $\max_i\{w_n/w_i\} = d_{ni} \rightarrow C$ technologies potentially used in both i and n with potential export from i to n (intermediate case)

Type I (Multiple Advanced Economies)

- Unit costs

$$c_n(j) = \min\{\min_i\{w_i d_{ni}/z_i(j)\}, w_n/z_C(j)\} \quad n = 1, ..., M$$

- Cost distribution in country n:

$$\begin{aligned} H_n(c) &= \Pr[C_n(j) \leq c] \\ &= 1 - \exp\left[-\Phi_n c^{\theta}\right] \quad n = 1, ..., M \end{aligned}$$

where $\Phi_n = \sum_{i=1}^{M} T_i(w_i d_{ni})^{-\theta} + T_C w_n^{-\theta}$

- Output price index:

$$P_n = \gamma \Phi_n^{-1/\theta}$$

which must equal 1, the price of the final good, if it is produced in a positive amount in country n. For simplicity we assume that parameter values always keep us in this case. The parameter γ is complicated but depends only on market structure and the parameters θ and σ.

- The solution to

$$P_n = \gamma \Phi_n^{-1/\theta} = \gamma \left[\sum_{i=1}^{M} T_i (w_i d_{ni})^{-\theta} + T_C w_n^{-\theta} \right]^{-1/\theta} = 1 \;\; n = 1, ..., M$$

determines wages w_n in terms of the technology parameters T_i and geography parameters d_{ni}.

- To be in a type I equilibrium we need that the w_i that solve the conditions for labor market equilibrium satisfy $w_n/w_i < d_{ni} \; \forall n, i$.

- Probability country n uses technology i for a good j:

$$\begin{aligned}\pi_{ni} &= \frac{T_i\left(w_i d_{ni}\right)^{-\theta}}{\Phi_n} \quad i,n=1,...,M \\ \pi_{nC} &= \frac{T_C w_n^{-\theta}}{\Phi_n} \quad n=1,...,M\end{aligned}$$

- Full employment:

$$w_i L_i^P = \frac{\theta}{1+\theta} \sum_{n=1}^{M} \pi_{ni} Q_n + \pi_{iC} Q_i \quad i = 1, ..., M$$

- Given L_i^P, w_i, and the parameters inside π_{ni}, the solution determines final outputs Q_i.

Type II (North-South)

- Two types of technologies, N and C.

- Costs in N and S:

$$\begin{aligned} c_N &= \min\{w_N/z_N(j), w_S d_{NS}/z_C(j)\} \\ c_S &= \min\{w_N d_{SN}/z_N(j), w_S/z_C(j)\} \end{aligned}$$

- Cost distributions

$$H_n(c) = \Pr[C_n \leq c] = 1 - \exp\left[-\Phi_n c^{\theta}\right] \quad n = N, S$$

where

$$\begin{aligned}
\Phi_N &= T_N w_N^{-\theta} + T_C \left(w_S d_{NS}\right)^{-\theta} \\
\Phi_S &= T_N \left(w_N d_{SN}\right)^{-\theta} + T_C w_S^{-\theta}
\end{aligned}$$

- For positive production of Q in N and S requires:

$$\begin{aligned}
P_N &= \gamma \Phi_N^{-1/\theta} = \gamma \left[\sum_{i=1}^{N} T_N w_N^{-\theta} + T_C \left(w_S d_{SN}\right)^{-\theta} \right]^{-1/\theta} = 1 \\
P_S &= \gamma \Phi_S^{-1/\theta} = \gamma \left[\sum_{i=1}^{N} T_S \left(w_N d_{NS}\right)^{-\theta} + T_C w_S^{-\theta} \right]^{-1/\theta} = 1
\end{aligned}$$

  the solution to which determines w_N and w_S.

- To be in a type II equilibrium we need that $w_N / w_S > d_{NS}$.

- Probability country n uses technology i for a good j:

$$\pi_{ni} = \frac{T_i \left(w_i d_{ni}\right)^{-\theta}}{\Phi_n} \quad i = N, C,\ n = N, S$$

- Full employment:

$$\begin{aligned} w_N L_N^P &= \frac{\theta}{1+\theta} \sum_{n=1}^{N} \pi_{NN} Q_N + \pi_{SN} Q_S \\ w_S L_S^P &= \frac{\theta}{1+\theta} \sum_{n=1}^{N} \pi_{NC} Q_N + \pi_{SC} Q_S \end{aligned}$$

- The solution determines outputs Q_N and Q_S.

Market Structure and Innovation

Ideas: a way to make a good j with efficiency q, realization of a r.v. Q with Pareto distribution:

$$F(q) = 1 - q^{-\theta}.$$

Only an idea that lowers cost somewhere will be used. Initially ideas are exclusive to the country of invention.

Growth and Diffusion

- Labor force growth rate n.

- Rate of diffusion out of exclusive into common technologies ϵ.

- Ratio of exclusive technologies to labor forces:

$$t_i = T_i/L_i$$

- Research productivity α_i.

- Growth of t_i:

$$\frac{\dot{t}_i}{t_i} = \frac{\dot{T}_i}{T_i} - \frac{\dot{L}_i}{L_i} = \frac{\alpha_i r_i^{\beta}}{t_i} - (n + \epsilon)$$

- Steady state:

$$t_i^* = \frac{\alpha_i r_i^\beta}{n + \epsilon}$$

- Steady state ratio of common to exclusive technologies:

$$t_C^* = \frac{T_C}{\sum_{i=1}^N T_i} = \frac{\epsilon}{n}$$

- Discount factor ρ, IP strength $\lambda_{ni} \in [0, 1]$.

- The s.s. value of an idea:

$$
\begin{aligned}
V_i &= \sum_{n=1}^{M} \left[\frac{1}{(\rho + \epsilon)\,\theta - n} \lambda_{ii} \left(w_i d_{ni} \right)^{-\theta} \right. \\
&\quad \left. + \left(\frac{1}{\rho\theta - n} - \frac{1}{(\rho + \epsilon)\,\theta - n} \right) \lambda_{ni} w_n^{-\theta} \right] Q_n
\end{aligned}
$$

- Labor-market equilibrium:

$$
\alpha_i r_i^{\beta - 1} V_{it} = w_{it} \quad r_{it} \in [0, 1]
$$

Type 1 Simulations

Five major OECD research economies: Germany, France, UK, Japan, USA:

Base parameters (based on EK 1999 and fitting research shares):

θ	σ	n	ρ	ϵ	β
11	11	.02	.08	.09	.16

Research shares (OECD):

r_{DE}	r_F	r_{UK}	r_J	r_{USA}
.00345	.00164	.00264	.00474	.00400

Research productivities (to fit research shares):

α_{DE}	α_F	α_{UK}	α_J	α_{USA}
364	210	293	447	340

Labor forces, in millions (Summers Heston)

L_{DE}	L_F	L_{UK}	L_J	L_{USA}
29	25	28	61	120

IP strength: $\lambda_{ii} = 1,\ \lambda_{ni} = .5\ n \neq i.$

Geography d_{ni} (θ dependent) from EK (2002):

to\from	DE	F	UK	J	USA
DE	1	1.20	1.24	1.80	1.70
F	1.31	1	1.35	1.95	1.85
UK	1.27	1.69	1	1.83	1.65
J	1.69	1.69	1.69	1	1.60
USA	1.46	1.46	1.38	1.46	1

Baseline wages:

DE	F	UK	J	USA
9.15	9.13	9.14	9.19	9.21

(too similar because of extent of diffusion, but note roles of size, geography, and research productivity)

Counterfactuals:

1. Stricter foreign IP ($\lambda_{ni} = 1 \; \forall n, i$) : r rises trivially, slightly higher wage in USA

2. Weaker foreign IP ($\lambda_{ni} = 0$, $n \neq i$) similar.

3. Proportionately higher cross-country geographic barriers: slightly lower wages and less research.

4. All countries as isolated as France from Japan: slightly more US research.

5. Slower diffusion ($\epsilon = .009$):

	DE	F	UK	J	USA
r_{base}	.0033	.0017	.0026	.0046	.0039
$r_{\epsilon=.009}$	.0023	.0012	.0018	.0038	.0041
w_{base}	9.15	9.13	9.14	9.19	9.21
$w_{\epsilon=.009}$	8.44	8.33	8.39	8.68	8.87

Note shift of research to the USA and greater wage dispersion favoring large countries.

6. Proportionally higher research productivities (α's rise in proportion): wages rise, but little other effects.

7. All countries have top (Japanese) R and D productivity $\alpha_J = 447$:

	DE	F	UK	J	USA
r_{base}	.0033	.0017	.0026	.0046	.0039
$r_{\alpha=447}$	.0032	.0032	.0032	.0035	.0041
w_{base}	9.15	9.13	9.14	9.19	9.21
$w_{\alpha=447}$	9.38	9.37	9.38	9.40	9.45

More research in larger countries, and a shift from Japan to the USA. The US wage rises the most.

8. All countries have the largest US labor force $L_{USA} = 120,000$ thousand:

	DE	F	UK	J	USA
r_{base}	.0033	.0017	.0026	.0046	.0039
$r_{L=120,000}$	.0039	.0021	.0031	.0049	.0039
w_{base}	9.15	9.13	9.14	9.19	9.21
$w_{L=120,000}$	9.94	9.92	9.93	9.95	9.93

More research in countries that had been small before.

Type 2 Simulations

Stricter IP in the South can lead to more research.

Summary

1. There are many ways to model the interaction of innovation, diffusion, and trade.

2. A reasonable model suggests that who does research depends on the interaction of relative research productivity, market size, and patterns of diffusion.

3. Absolute productivity and barriers to trade don't seem to matter much.

4. The treatment of foreign IP doesn't seem to matter much, although tougher protection does seem to increase research slightly.