14.452 Economic Growth: Lecture 13, Technology Diffusion, Trade and World Growth

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Introduction I

- In the models thus far each country is treated as an "island"; its technology is either exogenous or endogenously generated within its boundaries.

- A framework in which *frontier* technologies are produced in advanced economies and then copied or adopted by "follower" countries provides a better approximation.

- Thus, should not only focus on differential rates of endogenous technology generation but on *technology adoption* and *efficient technology use*.

- Exogenous growth models have this feature, but technology is exogenous. Decisions in these models only concern investment in physical capital. In reality, technological advances at the world level are not "manna from heaven".

Introduction II

- Technology adoption involves many challenging features:
    1. Even within a single country, we observe considerable differences in the technologies used by different firms.
    2. It is difficult to explain how in the globalized world some countries may fail to import and use technologies.

Review: Productivity and Technology Differences within Narrow Sectors I

- Longitudinal micro-data studies (often for manufacturing): even within a narrow sector there are significant and persistent productivity differences across plants.
- Little consensus on the causes.
  - Correlation between plant productivity and plant or firm size, various measures of technology (in particular IT technology), capital intensity, the skill level of the workforce.
  - But these correlations cannot be taken to be causal.
- But technology differences appear to be an important factor.
- A key determinant seems to be the skill level of the workforce, though adoption of new technology does not typically lead to a significant change in employment structure.

Review: Productivity and Technology Differences within Narrow Sectors II

- Productivity differences appear to be related to the entry of new and more productive plants and the exit of less productive plants (recall Schumpeterian models).

- But entry and exit account for only about 25% of average TFP growth, with the remaining accounted for by continuing plants.

- Thus models in which firms continually invest in technology and productivity are important for understanding differences across firms and plants and also across countries.

Technology Diffusion: Exogenous World Growth Rate I

- Endogenous technological change model with expanding machine variety and lab equipment specification.
- Aggregate production function of economy $j = 1, ..., J$ at time t:

$$Y_j(t) = \frac{1}{1-\beta} \left[\int_0^{N_j(t)} x_j(v, t)^{1-\beta} dv \right] L_j^{\beta}, \qquad (1)$$

- L_j is constant over time, x's depreciate fully after use.
- Each variety in economy j is owned by a technology monopolist; sells machines embodying this technology at the profit maximizing (rental) price $p_j^x(v, t)$.
- Monopolist can produce each unit of the machine at a cost of $\psi \equiv 1 - \beta$ units on the final good.

Technology Diffusion: Exogenous World Growth Rate II

- No international trade, so firms in country j can only use technologies supplied by technology monopolists in their country.
- Each country admits a representative household with the same preferences as before except $n_j = 0$ for all j.
- Resource constraint for each country:

$$C_j(t) + X_j(t) + \zeta_j Z_j(t) \leq Y_j(t), \tag{2}$$

- ζ_j: potential source of differences in the cost of technology adoption across countries (institutional barriers as in Parente and Prescott, subsidies to R&D and to technology, or other tax policies).

Technology Diffusion: Exogenous World Growth Rate III

- *Innovation possibilities frontier*:

$$\dot{N}_j(t) = \eta_j \left(\frac{N(t)}{N_j(t)} \right)^{\phi} Z_j(t), \tag{3}$$

  where $\eta_j > 0$ for all j, and $\phi > 0$ and is common to all economies.
- World technology frontier of varieties expands at an exogenous rate $g > 0$, i.e.,

$$\dot{N}(t) = gN(t). \tag{4}$$

- Flow profits of a technology monopolist at time t in economy j:

$$\pi_j(t) = \beta L_j.$$

Steady State Equilibrium I

- Suppose a steady-state (balanced growth path) equilibrium exists in which $r_j(t)$ is constant at $r_j^* > 0$. Then the net present discounted value of a new machine is:

$$V_j^* = \frac{\beta L_j}{r_j^*}.$$

- Next note that the long-run growth rate cannot differ across countries, and in particular all countries have to grow at the same rate as the rate of growth of $N(t)$. Otherwise, from (3), the country in question would have to spend permanently growing (or permanently shrinking) share of output on R&D, ultimately violating BGP.

- But then because $N_j(t)$ grows at the rate g, then in the long run $N_j(t)/N(t)$ will be constant at some level, say at ν_j^*.

Steady State Equilibrium II

- In that case, an additional unit of technology spending will create benefits equal to $\eta_j \left(v_j^* \right)^{-\phi} V_j^*$ counterbalanced against the cost of ζ_j. Free-entry (with positive activity) then requires

$$v_j^* = \left(\frac{\eta_j \beta L_j}{\zeta_j r^*} \right)^{1/\phi},$$
(5)

where given the preferences, equal growth rate across countries implies that r_j^* will be the same in all countries ($r^* = \rho + \theta g$).

Steady State Equilibrium III

- Higher ν_j implies that country j is technologically more advanced and thus richer

- Thus (5) shows that countries with higher η_j and lower ζ_j, will be more advanced and richer.

- A country with a greater labor force will also be richer (scale effect): more demand for machines, making R&D more profitable.

Summary of Equilibrium

Proposition   Consider the model with endogenous technology adoption
described in this section. Suppose that $\rho > (1 - \theta) g$. Then
there exists a unique steady-state world equilibrium in which
relative technology levels are given by (5) and all countries
grow at the same rate $g > 0$.

Moreover, this steady-state equilibrium is globally
saddle-path stable, in the sense that starting with any strictly
positive vector of initial conditions $N(0)$ and
$(N_1(0), ..., N_J(0))$, the equilibrium path of
$(N_1(t), ..., N_J(t))$ converges to $(\nu_1^* N(t), ..., \nu_J^* N(t))$.

Technology Diffusion: Endogenous World Growth Rate I

- More satisfactory to derive the world growth rate from the technology adoption and R&D activities of each country.
- Modeling difficulties:
  - Degree of interaction among countries is now greater.
  - More care needed so that the world economy grows at a constant endogenous rate, while there are still forces that ensure relatively similar growth rates across countries. Modeling choice:
    - Countries grow at permanently different long run rates, e.g. to approximate long-run growth differences of the past 200 or 500 years
    - Countries grow at similar rates, e.g. like the past 60 years or so.
- Since long-run differences emerge straightforwardly in many models, focus here on forces that will keep countries growing at similar rates.

Technology Diffusion: Endogenous World Growth Rate II

- Replace the world growth equation (4) with:

$$N(t) = \frac{1}{J} \sum_{j=1}^{J} N_j(t). \tag{6}$$

- $N(t)$ is no longer the "world technology frontier": it represents average technology in the world, so $N_j(t) > N(t)$ for at least some j.
- Disadvantage of the formulation: contribution of each country to the world technology is the same. But qualitative results here do not depend on this.
- Main result: pattern of cross-country growth will be similar to that in the previous model, but the growth rate of the world economy, g, will be endogenous, resulting from the investments in technologies made by firms in each country.

Steady State Equilibrium I

- Suppose there exists a steady-state world equilibrium in which each country grows at the rate g.
- Then, (6) implies $N(t)$ will also grow at g.
- The net present discounted value of a new machine in country j is

$$\frac{\beta L_j}{r^*},$$

- No-arbitrage condition in R&D investments: for given g, each country j's relative technology, ν_j^*, should satisfy (5).

Steady State Equilibrium II

- Dividing both sides of (6) by $N(t)$ implies that in the steady-state world equilibrium:

$$\frac{1}{J} \sum_{j=1}^{J} v_j^* = 1$$

$$\frac{1}{J} \sum_{j=1}^{J} \left(\frac{\eta_j \beta L_j}{\zeta_j (\rho + \theta g)} \right)^{1/\phi} = 1, \qquad (7)$$

which uses v_j^* from (5) and substitutes for r^* as a function of the world growth rate.

- The only unknown in (7) is g.
- Moreover, the left-hand side is clearly strictly decreasing in g, so it can be satisfied for at most one value of g, say g^*.

Steady State Equilibrium IIII

- A well-behaved world equilibrium would require the growth rates to be positive and not so high as to violate the transversality condition. The following condition is necessary and sufficient for the world growth rate to be positive:

$$\frac{1}{J} \sum_{j=1}^{J} \left(\frac{\eta_j \beta L_j}{\zeta_j \rho} \right)^{1/\phi} > 1. \tag{8}$$

- By usual arguments, when this condition is satisfied, there will exist a unique $g^* > 0$ that will satisfy (7) (if this condition were violated, (7) would not hold, and we would have $g = 0$ as the world growth rate).

Summary of Steady State Equilibrium

Proposition   Suppose that (8) holds and that the solution g^* to (7) satisfies $\rho > (1 - \theta) g^*$. Then there exists a unique steady-state world equilibrium in which growth at the world level is given by g^* and all countries grow at this common rate. This growth rate is endogenous and is determined by the technologies and policies of each country. In particular, a higher η_j or L_j or a lower ζ_j for any country $j = 1, ..., J$ increases the world growth rate.

Remarks

1. Taking the world growth rate given, the structure of the equilibrium is very similar to that beore.

2. The same model now gives us an "endogenous" growth rate for the world economy. Growth for each country appears "exogenous", but the growth rate of the world economy is endogenous.

3. Technological progress and economic growth are the outcome of investments by all countries in the world, but there are sufficiently powerful forces in the world economy through technological spillovers that pull relatively backward countries towards the world average, ensuring equal long-run growth rates for all countries in the long run.

4. Equal growth rates are still consistent with *large level differences* across countries.

5. Several simplifying assumptions: same discount rates and focus on steady-state equilibriua (transitional dynamics are now more complicated, since the "block recursiveness" of the dynamical system is lost).

Trade, Specialization and the World Income Distribution

- Similar interdependences because of trade.
- Model based on Acemoglu and Ventura (2001). Ricardian features: each country will specialize in subset of available goods and affect their prices.
- Hence each country's terms of trade will be endogenous and depend on the rate at which it accumulates capital.
- Model can allow for differences in discount (and saving) rates and has richer comparative static results.
- Also now exhibit endogenous growth, determined by the investment decisions of all countries.
- International trade (without any technological spillovers) will create sufficient interactions to ensure a common long-run growth rate.

Main Lessons I

1. We can make considerable progress in understanding technology and productivity differences across nations by positing a slow process of technology transfer across countries, where technology in the less advanced economies catches up only slowly to the frontier.

2. An important aspect of models of international technology diffusion is that it necessitates an analysis of the world equilibrium, not simply the equilibrium of each country on its own.

3. An important element of models of technology diffusion is that they create a built-in advantage for countries (or firms) that are relatively behind, which ensures that differences between poor and rich nations will be in terms of income level not growth rates.

4. Similar issues, arise because of trade interactions. Ricardian trade leads to similar dynamics to those obtained from ecological interdependencies.

Main Lessons II

5. More realistic and richer trade models lead to a more complex dynamics.