ME2708 Economic Growth

Lecture 7: Technology Diffusion and Trade

Luis Perez

KTH Royal Institute of Technology

April 26, 2018

Outline

Introduction I

- Important shortcoming in the models presented thus far: each country is treated in isolation, ruling out interactions with other nations
- This is problematic because it rules out important phenomena:
  - Technological interdependences across countries
  - International trade
- In the models presented thus far technology is either exogenous or endogenously-generated within a country's boundaries
- But should we think of technology differences between developed and less-developed countries (e.g. Mexico vs. Morocco) as resulting from lower R&D in the latter?
  - Most likely not! many of their technologies imported from elsewhere
- Frameworks in which *frontier* technologies are produced in advanced economies and then copied/adopted by "follower" countries provide a better approximation to reality

Introduction II

- Emphasis should not only be placed on differential rates of endogenous technology generation but also on:
    - *Technology adoption*
    - *Efficient technology use*
- Exogenous growth models may easily incorporate these features, although not satisfactorily
    - Technology is exogenous (in contrast, we know that tech. advances are far from "*manna from heaven*")
    - Decisions only concern investments in physical capital (*part of, but far from, the answer*)
- Models in which the *world* growth rate is endogenous and coexists with technology adoption may provide richer frameworks

Introduction III

- Important and interesting economic questions:
  - Which factors affect the speed and nature of technology adoption?
  - Are world-frontier technologies *appropriate* for the needs of less-developed countries?
  - Are there barriers to technology adoption and potential inefficiencies in the organization of production leading to apparent technology differences across countries?
- Technology adoption involves many challenging features:
  - Considerable differences in technologies across firms within the same narrowly-defined sector even in the same country
  - Some countries fail to import and use technologies that would significantly increase their productivity

Productivity Differences and Technology I

- Longitudinal micro-data studies (often for manufacturing) conclude:
  - Productivity and technology differences are *significant* and *persistent* even across firms within narrow sectors in the same country (Bartelsman and Doms, 2000; Bailey *et al.*, 1992)

- Little consensus on the causes:
  - Correlation between plant productivity and plant/firm size, measures of technology, capital intensity, skill level of the workforce, managerial practices. . . (Davis and Haltiwanger, 1991; Doms *et al.*, 1997; Black and Lynch, 2005)
  - All of these variables represent firms' choices and correlations cannot thereof be taken as casual

- Although technology differences seem to be an important factor

- A key determinant of technology adoption seems to be the skill level of the workforce, although new technology adoption does not typically lead to significant changes in employment structures

Productivity Differences and Technology II

- Productivity differences appear to be related to the entry of new and more-productive firms and the exit of less productive ones (*in line with Schumpeterian theory*)
- Important contribution of entry and exit of firms to industry productivity growth: approx. 25% of average TFP growth
  - Remaining share accrues to incumbents, highlighting the role of continuous investments in technology for productivity differences
- New and more productive technologies diffuse and are gradually adopted by more firms
  - The literature on technology diffusion studies this process
  - Similarities between technology diffusion across countries and firms

Productivity Differences and Technology III

- Pioneering contribution is Griliche's (1957) paper on technology (*hybrid corn*) adoption in the US:
  - Diffusion affected by local/regional economic conditions
  - Likelihood of adoption positively related to productivity contribution of technology, market size, skill level of the workforce, etc.
  - *S*-shape of diffusion: technology first spreads slowly until it reaches a critical level, then it starts spreading much more rapidly until the rate of adoption eventually declines

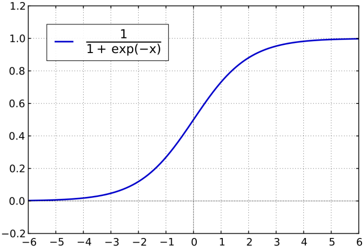


Figure: Diffusion phenomenon well-proxied by a logistic function

Technology Transfer and Club Convergence I

- The phenomenon of technology transfer and adoption has also cutting-edge power for explaining club convergence
  - Recall Quah's (1996) paper on the world income distribution
- History of cross-country income differences present mixed patterns of convergence and divergence:
  - Pritchett's (1997) great divergence, 1870–1990: gap in living standards between richest and poorest countries increased more than fivefold
  - Recent evidence (Barro and Sala-i-Martin, 1992; MRW, 1992) points to convergence (1960–), although many poor countries continue to diverge (Mayer-Foulke, 2002; Madison, 2001)
  - Club convergence, 1950–: most rich and middle-income countries belong to the convergence club (*common long-run growth rate*) whilst most poor countries do not (*significantly lower long-ruin growth rates*)

Technology Transfer and Club Convergence II

- Schumpeterian growth theory can account for club convergence by taking into account technology transfer and adoption, and the idea of *distance to the frontier*
  - Gerschenkron's (1962) *advantage of backwardness*: countries far from the technology frontier can grow rapidly by adopting technologies that have already been developed in more advanced countries
  - Technology transfer from innovating- to follower- countries
  - Technology transfer may stabilize the gap between rich and poor countries, allowing poor countries to grow as fast as rich ones, conditional on the poor devoting resources to innovation (transfer mechanism)
  - Innovation, key for technology transfer: tech- knowledge cannot *simply* be copied and transported costlessly; it requires the receiving country to master the technology and to adapt it to the local environment

A Simple Model of Growth and Development I

- We build on Romer's (1990) model, incorporating technology transfer
- We endogenize the mechanism by which countries develop the ability to use various technologies (intermediate capital goods)
- Production *greatly* resembles product-variety models:

$$Y(t) = L(t)^{1-\alpha} \int_0^{h(t)} x_j(t)^\alpha dj \tag{1}$$

  where Y is the final, homogenous good, L denotes labor, and there is a range of capita goods x_j limited by the skill level h of the workforce

- Workers with higher skills can use more capital goods (e.g. you w/ vs. you w/o MSc)

A Simple Model of Growth and Development II

- Different approach in comparison with Romer:
  - Romer: invention of new capital goods as growth engine
  - Now: Single, small country which is far from the technological frontier. The growth engine for this economy resides on learning how to use *a larger number of* intermediate capital goods developed elsewhere
- One unit of intermediate capital good x_j can be produced with one unit of raw capital (*as before*!):

$$\int_0^{h(t)} x_j(t)dj = K(t) \tag{2}$$

- Intermediate goods treated symmetrically: $x_j = x, \forall j$
- Combining eq. (1) and eq. (2) we get,

$$Y(t) = K(t)^\alpha [h(t)L(t)]^{1-\alpha} \tag{3}$$

where the level of skills h takes the role of (*labor-augmenting*) technological change

A Simple Model of Growth and Development III

- The capital-accumulation equation is the same as in previous models,

  $$\dot{K}(t) = s_K K(t) - \delta K(t)$$

  where $s_K, \delta \in (0,1)$ are the constant fraction of income invested in physical capital and the exponential rate of depreciation, respectively

- We now introduce the skills-accumulation equation,

  $$\dot{h}(t) = \mu e^{\psi u} A(t)^{\gamma} h(t)^{1-\gamma} \tag{4}$$

  where h is the range of intermediate goods that someone has learned to use, u is the time spent accumulating skills, A captures the world technology frontier, $\mu > 0$ and $0 < \gamma \leq 1$

- Interestingly: 1) additional time accumulating skills, u, increases skills proportionally; and 2) change in skills is a geometric weighted average of the technological frontier, A, and individuals' skills, h

A Simple Model of Growth and Development IV

- Equation (4) can be conveniently rearranged,

$$\frac{\dot{h}(t)}{h(t)} = \mu e^{\psi u} \left[\frac{A(t)}{h(t)} \right]^{\gamma} \tag{5}$$

- It is harder to learn to use technologies closer to the frontier:
    - the closer skills h are to the technological frontier A, the slower skill accumulation $\dot{h}$ is
    - beautiful implication: takes much longer to learn to use radical innovations than incremental ones

- We assume that the technological frontier is advanced *à la Jones* by advanced countries that we do not model, taking this result as given:

$$\frac{\dot{A}(t)}{A(t)} = g_A$$

A Simple Model of Growth and Development V

- Technology is *freely* available but countries must learn to use it prior to adoption
- Population grows at the constant, exponential and exogenous rate n

$$\frac{\dot{L}(t)}{L(t)} = n > 0$$

- We can now solve the model. It is key to start by solving for the growth rate of accumulation of skills along a *BGP*!
- Along a *BGP*, variables grow at constant rates so that we can take logs and time derivatives of eq. (5) and impose the *BGP* condition,

$$\gamma \left[\frac{\dot{A}(t)}{A(t)} - \frac{\dot{h}(t)}{h(t)} \right] = 0$$

which implies that $g_A = g_h$, using simpler notation

A Simple Model of Growth and Development VI

Solving the Model I

- This last result pins down the growth rate of all other quantities in the model,

$$g_{\tilde{y}} = g_{\tilde{k}} = g_h = g_A = g$$

- To solve the model we proceed as usual, i.e. by transforming the aggregate production function and the capital accumulation equation to per effective units of labor

- Define output- and capital- per effective unit of labor, respectively, as,

$$\widehat{y}(t) \equiv \frac{Y(t)}{h(t)L(t)} \quad \text{and} \quad \widehat{k}(t) \equiv \frac{K(t)}{h(t)L(t)}$$

A Simple Model of Growth and Development VI

Solving the Model II

- We can rewrite now the production function as,

$$\begin{aligned}\widehat{y}(t) &= F\left[\frac{K(t)}{h(t)L(t)}, 1\right] \\ &= f\left[\widehat{k}(t)\right] \\ &= \widehat{k}(t)^{\alpha} \qquad (6)\end{aligned}$$

- Taking logs and time derivatives of $\widehat{k}(t) \equiv K(t)/h(t)L(t)$ we get,

$$\frac{\dot{\widehat{k}}(t)}{\widehat{k}(t)} = \frac{\dot{K}(t)}{K(t)} - \left[\frac{\dot{h}(t)}{h(t)} - \frac{\dot{L}(t)}{L(t)}\right]$$

- Now it's crucial that we make use of the result $g_A = g_h$

A Simple Model of Growth and Development VII

Solving the Model III

- Doing so we can rewrite the previous equation as,

$$\begin{aligned}\frac{\dot{\widehat{k}}(t)}{\widehat{k}(t)} &= \frac{s_K Y(t) - \delta K(t)}{K(t)} - (g_A + n) \\ &= \frac{s_K Y(t)}{K(t)} - (\delta + g_A + n) \\ &= \frac{s_K \widehat{y}(t)}{\widehat{k}(t)} - (\delta + g_A + n)\end{aligned}$$

- Multiplying both sides of this equation by $\widehat{k}(t)$ we get,

$$\dot{\widehat{k}}(t) = s\widehat{y}(t) - (\delta + g_A + n)\widehat{k}(t) \tag{7}$$

A Simple Model of Growth and Development VIII

Solving the Model IV

- We can now impose the steady-state condition and solve for the steady-state capital and output:

$$\dot{\widehat{k}}(t) = 0 \quad \Rightarrow \quad s_K \widehat{y}(t) = (\delta + g_A + n)\widehat{k}(t)$$

- Plugging in $\widehat{y}(t) = \widehat{k}(t)^\alpha$ we get,

$$s_K \widehat{k}(t)^\alpha = (\delta + g_A + n)\widehat{k}(t)$$

- Solving for $\widehat{k}(t)$,

$$\widehat{k}^* = \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{1}{1-\alpha}}$$

our usual expression!

A Simple Model of Growth and Development IX

Solving the Model V

- We can now solve for $\widehat{y}(t)$,

$$\begin{aligned}\widehat{y}^{*} &= \widehat{k}^{*^{\alpha}} \\ &= \left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha}}\end{aligned}$$

another expression we are familiar with!

- Since our interest resides in per capita variables we slightly transform this expression,

$$\begin{aligned}\tilde{y}^{*}(t) &= h(t)\widehat{y}^{*} \\ &= h(t)\left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha}}\end{aligned}$$

A Simple Model of Growth and Development X

Solving the Model VI

- A very relevant question is how technologically-far is our economy, along a *BGP*, from the frontier

- To answer this question we just need to rearrange eq. (5),

$$\left(\frac{h}{A}\right) = \left(\frac{\mu}{g_h} e^{\psi u}\right)^{1/\gamma}$$

  - Countries that spend more time accumulating skills are closer to the frontier!

- We can also make us of this result to re-express output per capita

$$\begin{aligned} \tilde{y}^*(t) &= h(t)\widehat{y}^* = A(t)\left(\frac{h}{A}\right)\widehat{y}^* \\ &= A(t)\left(\frac{\mu}{g_h} e^{\psi u}\right)^{1/\gamma}\left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha}} \qquad (8) \end{aligned}$$

A Simple Model of Growth and Development XI

- Equation (8) has a very nice interpretation

$$\tilde{y}^*(t) = \underbrace{A(t)\left(\frac{\mu}{g_h}e^{\psi u}\right)^{1/\gamma}}_{<A(t)}\left(\frac{s_K}{\delta + g_A + n}\right)^{\frac{\alpha}{1-\alpha}}$$

  - Economies grow because they learn to use technologies invented throughout the world
    - ⋆ The ability to learn to use technologies positively depends on the time spent in accumulating skills
  - As in Solow: higher investment rates and lower depreciation- and population growth- rates make countries richer! Also, it is tech. progress what generates long-run growth
  - Important insight *wrt* population growth!!!
    - ⋆ Isn't this result in opposition to Romer/Jones' results?

A Simple Model of Growth and Development XII

- Also, implicit in eq. (8), heterogenous propensities to accumulate skills may have long-run economic impacts

$$\tilde{y}^*(t) = \underbrace{A(t)\left(\frac{\mu}{g_h}e^{\psi u}\right)^{1/\gamma}}_{<A(t)}\left(\frac{s_K}{\delta+g_A+n}\right)^{\frac{\alpha}{1-\alpha}}$$

  - ⋆ Put simply, if parameter $u_{rich} > u_{poor}$, we expect to observe substantial economic differences across countries because the level of skills is higher in rich countries than in poorer ones, allowing the former to employ more technologies than the latter

- A more satisfactory framework would arguably factor in institutions, which could influence incentives for skill accumulation

1. Introduction
2. Productivity Differences and Technology
3. Technology Transfer and Club Convergence
4. A Simple Model of Growth and Development
5. Technology Transfer
   - Appropriateness of Technology and Skill-mismatch
   - International Patent Protection
6. Globalization and Trade
7. Summary

Technology Transfer

- We now dig deeper into some of the problematics associated with technology transfer

- Thus far we have assumed that technologies are freely available and that individuals just need to learn to use this new (*intermediate capital goods*) technologies

- Technology transfer is in practice much more complicated than that:
    - technologies need to be adapted to local environments (e.g. transportation systems, voltage of electrical devices. . .)
        - This raises the question of appropriateness of technology
    - international patent protection

- We slightly explore these two issues

1. Introduction
2. Productivity Differences and Technology
3. Technology Transfer and Club Convergence
4. A Simple Model of Growth and Development
5. Technology Transfer
    - Appropriateness of Technology and Skill-mismatch
    - International Patent Protection
6. Globalization and Trade
7. Summary

Appropriateness of Technology and Skill-mismatch I

Based on the *mandatory read* Acemoglu and Zilibotti (2001):

- Difficult to understand large cross-country differences in technology
  - Ideas can flow rapidly across countries; and
  - Better technologies can be imported
- Many technologies used in LDCs (South) are developed in advanced economies (North)
- These countries design (optimal) technologies to exploit their factors and conditions of production
  - If countries are heterogeneous in these variables, technologies need not be equally productive across countries
- A technology can be "inappropriate" because of available conditions (climate, geography, culture, etc.) or skill-mismatch (the workforce cannot fully exploit the potential of the technology)

Appropriateness of Technology and Skill-mismatch II

- Acemoglu and Zilibotti (2001) examine the second possibility:
  - Advanced economies (North), which are relatively skill-intensive, develop *skill-biased* or *skill-complementary* technologies
  - *Skilled-biased* technologies are of limited use in the LDCs (South) because of skill scarcity
- To illustrate this point empirically, AZ use the example of *Cummins Engine Co.*, a US company which contracted *Komatsu* (Japanese) and *Kirloskar* (Indian) to manufacture the same truck engine
  - Japanese company quickly reached US standards (quality and costs) but the Indians did not because they did not possess…

    "*the high degree of technical skills required*" $\sim$ Baranson (1972)

  - Further evidence (Chen, 1983) suggests that multinationals in textiles, garments, plastics and electronics decide not to introduce advanced technologies in markets with skill shortages

Appropriateness of Technology and Skill-mismatch III

Model I

- North (large advanced country) and South (set of small LDCs)
- North and South are identical except in size and abundance of skills
  - North is more skilled-abundant

$$\frac{H^n}{L^n} > \frac{H^s}{L^s}$$

- Technological progress originates in North but can be *freely* adopted in South (IPRs are not enforced)
- N_L and N_H are the number of machines that can be used with unskilled and skilled labor, respectively
- The ratio N_H/N_L measures the extent of skill-biased in the economy: it determines the relative productivity of skilled and unskilled techs

Appropriateness of Technology and Skill-mismatch IV

Model II

- Technical progress takes the form of increases over time in N_L and N_H and allows for technical change to be skill- or labor- complementary
- Technical change is *directed* and endogenous (the type and amount of technologies depend on existing conditions)
- Cross-country differences in climate, if any, could be introduced through heterogenous depreciation rates δ
- There is no international trade
- The fraction of sectors employing skilled workers and using skilled-biased technology is large when:
  - technology is either highly skilled-biased (large N_H/N_L);
  - or when there is relatively large supply of skilled labor (high H/L)

Appropriateness of Technology and Skill-mismatch V

Model III

- Technical progress takes the form of increases over time in N_L and N_H and allows for technical change to be skill- or labor- complementary
- Technical change is *directed* and endogenous (the type and amount of technologies depend on existing conditions)
- Cross-country differences in climate, if any, could be introduced through heterogenous depreciation rates δ
- There is no international trade
- The fraction of sectors employing skilled workers and using skilled-biased technology is large when:
  - technology is either highly skilled-biased (large N_H/N_L);
  - or when there is relatively large supply of skilled labor (high H/L)

Appropriateness of Technology and Skill-mismatch VI

Model IV

- There is *skill premium*, which is larger the more skill-biased techs are or the scarcer skilled workers are
- The state of technology (N_H/N_L) is the same in North and South but relative supply of skills is not $(H^s/L^s < H^n/L^n)$. Implications:
  1. More sectors use unskilled labor and labor-complementary technologies in South, $J^s > J^n$
  2. Relative price of skill-intensive goods higher in South, $P_H^s/P_L^s > P_H^n/P_L^n$
  3. Skill premium is higher in South, $w_H^s/w_L^s > w_H^n/w_L^n$
- Since IPRs are not enforced and international trade is not allowed, North only considers the local market when developing technologies
  - The reason why North develops skill-biased technologies is the market-size effect (greater clientele)
- Technologies are immediately copied by Southern countries and thereof they have access to the same (North) technology

Appropriateness of Technology and Skill-mismatch VII

Model V

- There is a unique and stable BGP. Starting from any N_H and N_L, the economy converges to this BGP
- Along a BGP both N_H and N_L grow at the common rate g, which implies that the relative productivity of skilled and unskilled labor is constant
  - As usual, changes can happen along the transition path
- Predictions of the model:
  1. Sectoral TFPs should be larger in developed- relative to LDCs in labor-intensive rather than in skill-intensive sectors.
  2. Aggregate productivity (TFP or $\tilde{y}$) should be higher in advanced rather than in LDCs

Appropriateness of Technology and Skill-mismatch VIII

Empirical Assessment I

- TFPs calculated from UN data in 27 disaggregated manufacturing sectors in 22 countries

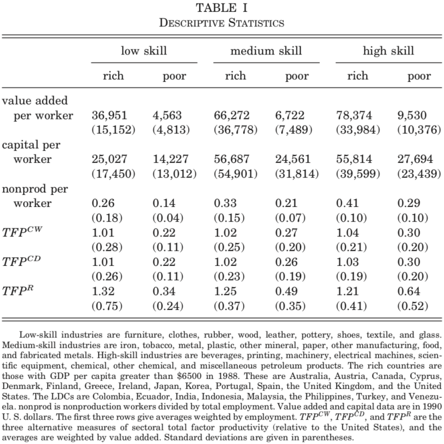


TABLE I

DESCRIPTIVE STATISTICS

	low skill		medium skill		high skill	
	rich	poor	rich	poor	rich	poor
value added per worker	36,951	4,563	66,272	6,722	78,374	9,530
	(15,152)	(4,813)	(36,778)	(7,489)	(33,984)	(10,376)
capital per worker	25,027	14,227	56,687	24,561	55,814	27,694
	(17,450)	(13,012)	(54,901)	(31,814)	(39,599)	(23,439)
nonprod per worker	0.26	0.14	0.33	0.21	0.41	0.29
	(0.18)	(0.04)	(0.15)	(0.07)	(0.10)	(0.10)
TFP^{CW}	1.01	0.22	1.02	0.27	1.04	0.30
	(0.28)	(0.11)	(0.25)	(0.20)	(0.21)	(0.20)
TFP^{CD}	1.01	0.22	1.02	0.26	1.03	0.30
	(0.26)	(0.11)	(0.23)	(0.19)	(0.19)	(0.20)
TFP^{R}	1.32	0.34	1.25	0.49	1.21	0.64
	(0.75)	(0.24)	(0.37)	(0.35)	(0.41)	(0.52)

Low-skill industries are furniture, clothes, rubber, wood, leather, pottery, shoes, textile, and glass. Medium-skill industries are iron, tobacco, metal, plastic, other mineral, paper, other manufacturing, food, and fabricated metals. High-skill industries are beverages, printing, machinery, electrical machines, scientific equipment, chemical, other chemical, and miscellaneous petroleum products. The rich countries are those with GDP per capita greater than $6500 in 1988. These are Australia, Austria, Canada, Cyprus, Denmark, Finland, Greece, Ireland, Japan, Korea, Portugal, Spain, the United Kingdom, and the United States. The LDCs are Colombia, Ecuador, India, Indonesia, Malaysia, the Philippines, Turkey, and Venezuela. nonprod is nonproduction workers divided by total employment. Value added and capital data are in 1990 U. S. dollars. The first three rows give averages weighted by employment. TFP^{CW}, TFP^{CD}, and TFP^{R} are the three alternative measures of sectoral total factor productivity (relative to the United States), and the averages are weighted by value added. Standard deviations are given in parentheses.

Appropriateness of Technology and Skill-mismatch IX

Empirical Assessment II

- Regression analysis to document the relationship between relative TFPs and skill intensity

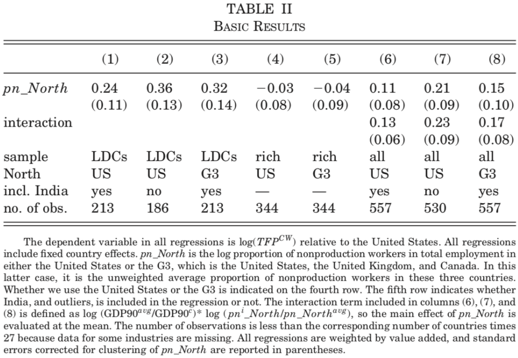


TABLE II
BASIC RESULTS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
pn_North	0.24	0.36	0.32	−0.03	−0.04	0.11	0.21	0.15
	(0.11)	(0.13)	(0.14)	(0.08)	(0.09)	(0.08)	(0.09)	(0.10)
interaction						0.13	0.23	0.17
						(0.06)	(0.09)	(0.08)
sample	LDCs	LDCs	LDCs	rich	rich	all	all	all
North	US	US	G3	US	G3	US	US	G3
incl. India	yes	no	yes	—	—	yes	no	yes
no. of obs.	213	186	213	344	344	557	530	557

The dependent variable in all regressions is log(TFP^{CW}) relative to the United States. All regressions include fixed country effects. *pn_North* is the log proportion of nonproduction workers in total employment in either the United States or the G3, which is the United States, the United Kingdom, and Canada. In this latter case, it is the unweighted average proportion of nonproduction workers in these three countries. Whether we use the United States or the G3 is indicated on the fourth row. The fifth row indicates whether India, and outliers, is included in the regression or not. The interaction term included in columns (6), (7), and (8) is defined as log ($\mathrm{GDP90}^{avg}/\mathrm{GDP90}^{c}$)* log ($pn^{i}\_North/pn\_North^{avg}$), so the main effect of *pn_North* is evaluated at the mean. The number of observations is less than the corresponding number of countries times 27 because data for some industries are missing. All regressions are weighted by value added, and standard errors corrected for clustering of *pn_North* are reported in parentheses.

- TFPs are higher the more skill-intensive sectors are!

Appropriateness of Technology and Skill-mismatch X

Empirical Assessment III

- TFP gaps are smaller then between LDCs and the US in this most skill-intensive sectors

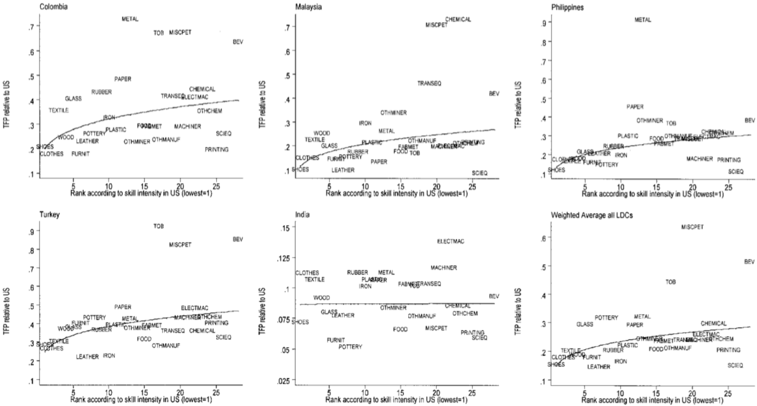


FIGURE III

TFP Gap across 27 Industries in Selected LDCs

Appropriateness of Technology and Skill-mismatch XI

Empirical Assessment IV: Predictive power of neoclassical- vs. *AZ* model I

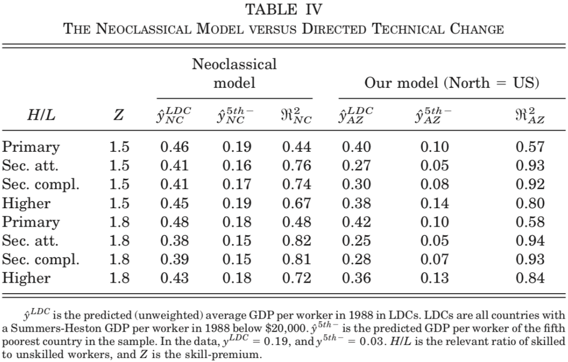


TABLE IV

THE NEOCLASSICAL MODEL VERSUS DIRECTED TECHNICAL CHANGE

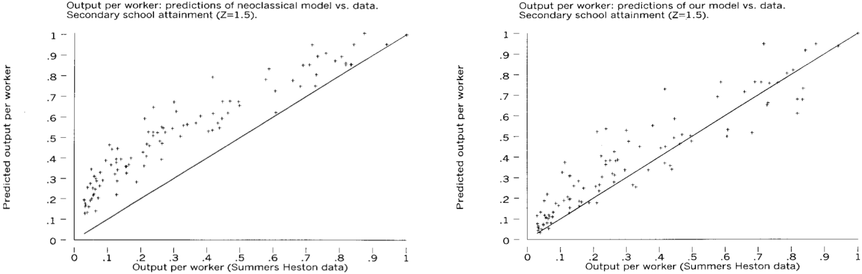
		Neoclassical model			Our model (North = US)		
H/L	Z	$\hat{y}^{LDC}_{NC}$	$\hat{y}^{5th-}_{NC}$	$\Re^2_{NC}$	$\hat{y}^{LDC}_{AZ}$	$\hat{y}^{5th-}_{AZ}$	$\Re^2_{AZ}$
Primary	1.5	0.46	0.19	0.44	0.40	0.10	0.57
Sec. att.	1.5	0.41	0.16	0.76	0.27	0.05	0.93
Sec. compl.	1.5	0.41	0.17	0.74	0.30	0.08	0.92
Higher	1.5	0.45	0.19	0.67	0.38	0.14	0.80
Primary	1.8	0.48	0.18	0.48	0.42	0.10	0.58
Sec. att.	1.8	0.38	0.15	0.82	0.25	0.05	0.94
Sec. compl.	1.8	0.39	0.15	0.81	0.28	0.07	0.93
Higher	1.8	0.43	0.18	0.72	0.36	0.13	0.84

$\hat{y}^{LDC}$ is the predicted (unweighted) average GDP per worker in 1988 in LDCs. LDCs are all countries with a Summers-Heston GDP per worker in 1988 below \$20,000. $\hat{y}^{5th-}$ is the predicted GDP per worker of the fifth poorest country in the sample. In the data, $y^{LDC} = 0.19$, and $y^{5th-} = 0.03$. H/L is the relevant ratio of skilled to unskilled workers, and Z is the skill-premium.

- Sample data: avg. output per worker in LDCs is about 19% of that of the US
- Both *NC* and *AZ* models underestimate the productivity gap, but the *NC* model substantially more (50% *wrt* 28% of that of the US)

Appropriateness of Technology and Skill-mismatch XII

Empirical Assessment V: Predictive power neoclassical- vs. *AZ* model II



Output per worker: predictions of neoclassical model vs. data.
Secondary school attainment (Z=1.5).

Output per worker: predictions of our model vs. data.
Secondary school attainment (Z=1.5).

FIGURE IV
Output per Worker: y^c_{NC} versus y^c

FIGURE V
Output per Worker: y^c_{AZ} versus y^c

Figure: Fit of *NC* (*left*) and *AZ*- (*right*) models

Appropriateness of Technology and Skill-mismatch XIII

Take Outs From Acemoglu and Zilibotti (2001)

- If the next (plausible) assumptions hold:
  1. Most new technologies are developed in advanced countries
  2. Technical change is directed towards the most profitable technologies
  3. Advanced economies' are relatively skill-intensive but LDCs are not
- Then,
  - New technologies are skill-biased
  - Skill-mismatch in LDCs when these technologies are adopted (their workforces are not skilled enough to *fully* exploit these techs)
  - Skill-mismatch helps explaining productivity differences between developed and LDCs
  - A tendency toward skill-biased techs may amplify income gaps
    - Encouraging the development of more labor-complementary techs and raising the supply of LDCs could counterbalance the amplification of income gaps

1. Introduction
2. Productivity Differences and Technology
3. Technology Transfer and Club Convergence
4. A Simple Model of Growth and Development
5. Technology Transfer
    - Appropriateness of Technology and Skill-mismatch
    - International Patent Protection
6. Globalization and Trade
7. Summary

International Patent Protection

- A crucial assumption in Acemoglu and Zilibotti's (2001) paper is that IPRs are not enforced internationally

- This implies that technology producers (innovators) do not have any incentive to consider LDCs' demands

- If this assumption is modified, market-size effects could (powerfully) act as an incentive for producers to react to these demands

- If appropriate technologies are developed for LDCs, the income gap could (in principle) be narrowed or stabilized
  - ⋆ This is indeed the conclusion that emanates from most IPR protection studies on growth

- Helpman (1993) explores this issue and concludes that IPR protection is beneficial for North but not for South
  - ⋆ The creation of LDCs-adapted technologies is not enough to compensate the constraints placed on (imitation) behavior

1. Introduction

2. Productivity Differences and Technology

3. Technology Transfer and Club Convergence

4. A Simple Model of Growth and Development

5. Technology Transfer
    - Appropriateness of Technology and Skill-mismatch
    - International Patent Protection

6. **Globalization and Trade**

7. Summary

Globalization and Trade I

- We can very easily incorporate international trade into our basic model
  - We allow trade in intermediate goods
- The motivation to do is that openness has been positively associated to growth over recent years
- The primary change is imposed upon the production function, which now takes the form,

$$Y(t) = L(t)^{1-\alpha} \int_0^{h(t)+m(t)} x_j(t)^\alpha dj \tag{9}$$

where the # of varieties of intermediate goods is limited by the ability to learn to use new technologies, h, and the varieties imported, m

Globalization and Trade II

- We again treat *all* intermediate goods symmetrically: $x_j = x, \forall j$
- You can easily see that, in a closed economy ($m = 0$), the model nests to our previous specification

$$Y(t) = L(t)^{1-\alpha} \int_0^{h(t)+m(t)} x_j(t)^\alpha dj$$

- With trade this needs not be the case. Allow z to be the amount produced of learnt-technology h. Domestically,

$$h(t)z(t) = K(t)$$

- The economy keeps some amount of this production and exports the rest to import other technologies,

$$\begin{aligned} K(t) - h(t)x(t) &= m(t)x(t) \qquad (10) \\ \Leftrightarrow \; h(t)[z(t) - x(t)] &= m(t)x(t) \end{aligned}$$

Globalization and Trade III

- This last equation can be interpreted in two intuitive ways:

$$h(t)[z(t) - x(t)] = m(t)x(t)$$

  1. **Pure exchange**: $h[z - x]$ goods are exchanged for mx foreign intermediate goods
  2. **FDI**: home country owns K units of capital (hx located at home and mx elsewhere). In this case there is trade in ownership rather than in goods and equilibrium in the FDI market rather than in the goods market

- Eq. (10) can be rearranged,

$$K(t) = x(t)[h(t) + m(t)]$$

Globalization and Trade IV

- We then get the production function,

$$Y(t) = K(t)^{\alpha}\left[(h(t)+m(t))L(t)\right]^{1-\alpha}$$

$h+m$, instead of simply h, enters now as labor-augmenting tech

- We can already see that more foreign intermediate goods raise output
- We re-express the production function in a more convenient manner,

$$\begin{aligned} Y(t) =& K(t)^{\alpha}\left[[(h(t)+m(t)]L(t)\right]^{1-\alpha} \\ =& K(t)^{\alpha}\left[h(t)L(t)+m(t)L(t)\right]^{1-\alpha} \\ =& K(t)^{\alpha}[h(t)L(t)]^{1-\alpha}\left(1+\frac{m(t)}{h(t)}\right)^{1-\alpha} \end{aligned}$$

this expression is identical to eq. (3) except for the fact that m scales up production

Globalization and Trade V

- Solving the model as we did in the previous section,

$$\begin{aligned}\tilde{y}(t)^* &= A(t)\left(\frac{A}{h}\right)\widehat{y}^* \\ &= A(t)\left(\frac{\mu}{g_h}e^{\psi u}\right)^{1/\gamma}\left(1+\frac{m(t)}{h(t)}\right)\left(\frac{s_K}{\delta+g_A+n}\right)^{\frac{\alpha}{1-\alpha}} \qquad (11)\end{aligned}$$

- In the autarky case, nothing is changed *wrt* to Eq. (8)
- In the non-autarky case, trade has positive effects: $m/h > 0$
  - This is indeed similar to increases in savings rate (s_K) or time spent in accumulating skills (u)
- The (positive) effect of trade eventually becomes negligible *unless* the economy continually imports new goods
  - Along a *BGP*, h grows at rate g but we cannot infer anything about g_m

Take Outs I

- A key implication of the models covered in this lecture is that *all* countries share the same long-run growth rate: the exogenous growth rate g_A at which the world technology frontier expands

- Relevance of technology transfer:
    - neither all countries push the technological frontier nor does exist a country that does not benefit from other countries' technologies
    - the likelihood of being (more) successful at adopting and exploiting new technologies depends positively on education
    - LDCs countries, however, cannot fully absorb these technologies because they're skilled-limited

- Other beautiful insights (Acemoglu and Zilibotti, 2001): technology appropriateness (*local conditions and skill-mismatch*) and DTC

Take Outs II

- Other insights can be gained from including globalization and trade into our models
- Trade has positive effects on TFP and output per capita
    - level effects?
    - long-rung growth effects?
    - both?
- Recommended, no-mandatory reading:
    - Grossman and Helpman (*Econometrica*, 2018)
- Assignment and next-lecture announcement

Thank you for your attention!