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Directed Technological Change

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"Productivity Differences"

Motivation

- Disparities in per capita income mirror disparities in technology and TFP
- In principle, ideas can flow rapidly, and machines can be imported
- But research happens predominantly in the advanced countries, “the North”

Directed Research

- Research may be targeted to the conditions of the North, such as climate, culture, etc.
- Focus on skill scarcity: the North is relatively abundant in skills and will develop "skill-biased" technologies
- LDCs, "the South", can exploit these technologies only imperfectly; skilled workers are scarce

Overview

- Model technology-skill mismatch: Unskilled workers cannot realize gains from (imported) technology, even without barriers to transfer
- Test model with productivity data: TFP gaps are largest in unskilled-labor intensive sectors, as modeled, but contrary to intuition
- Calibrate model with data on skill supplies: outperforms simple neoclassical model

Model: Production

- Labor supply: skilled (H^c) and unskilled (L^c); assume $\frac{H^{north}}{L^{north}} > \frac{H^{south}}{L^{south}}$
- Two production technologies:

$$y(i) = \left[\int_0^{N_L} k_L(i,v)^{\alpha} dv \right] \cdot [(1-i) \cdot l(i)]^{1-\alpha} + \left[\int_0^{N_H} k_H(i,v)^{\alpha} dv \right] \cdot [i \cdot Z \cdot h(i)]^{1-\alpha}$$

  - *i* indexes sectors from 0 (labor-intensive) to 1 (skill-intensive)
  - *l* is unskilled labor, *h* is skilled labor
  - N_L and N_H measure available machines
  - *Z* augments skilled labor (exogenous)

Production 2

- Demand for skill-complementary machines $k_H(i,v)$ depends on skill supply $h(i)$; analogously, $k_L(i,v)$ depends on $l(i)$
- Machines are produced by monopolists, who innovate by increasing N_L and N_H
- Skilled workers are relatively more productive in high-index sectors, so there is a "threshold sector" $J \in [0,1]$; only unskilled workers produce in $i < J$, only skilled workers in $i > J$

Production 3

- We can solve for (the share of the sectors which employ unskilled workers)

$$J = \left(1 + \left(\frac{N_H}{N_L} \cdot \frac{ZH}{L} \right)^{\frac{1}{2}} \right)^{-1}$$

- The skill premium is:

$$\frac{w_H}{w_L} = Z \left(\frac{N_H}{N_L} \right)^{\frac{1}{2}} \left(\frac{ZH}{L} \right)^{-\frac{1}{2}}$$

- And output is

$$Y = \frac{\left(\sqrt{N_L L} + \sqrt{N_H ZH} \right)^2}{\text{cost of machines}}$$

R&D 1

- There will be no R&D activity in the South, but Southern imitators will copy technology and sell machines as local monopolists
- This implies that N_L and N_H (the innovation frontier) are determined in the North alone
- Along a BGP, N_L and N_H must grow at the same rate, from which we can derive: $$\frac{N_H}{N_L} = \frac{ZH^{north}}{L^{north}}$$

R&D 2

- There exists a unique and stable BGP; income, consumption, N_L and N_H grow at rate

$$g = \frac{\text{constant} \cdot (L^n + ZH^n) - \rho}{\vartheta}$$

- The BGP value $\frac{N_H}{N_L} = \frac{ZH^{north}}{L^{north}}$ maximizes consumption in the North, but not in the South or in the whole world

Productivity 1

- We derive TFP a_L and a_H from the production function; in the North along the BGP, these must be the same
- But $\frac{H^{north}}{L^{north}} > \frac{H^{south}}{L^{south}}$ implies $a_L^s(i \leq J^s) < a^n < a_H^s(i \geq J^s)$, i.e. TFP in skilled sectors is larger in the South!
- Aggregate TFP is higher in the north: $J^n < J^s$, and in sectors between J^n and J^s the North is more productive

Productivity 2

- Output per worker and output per efficiency unit will also be higher in the North, because N^H/N^L is chosen according to North's needs
- This output gap widens if
  - N^H/N^L increases ("skill-biased" change)
  - the cost of capital is higher in the South
- The output gap decreases if
  - Northern innovators sell directly to Southern producers (they will invest in unskilled technologies)
  - the South performs R&D (same reason)

Cross-country Patterns in Industry TFPs

- Calculate sectoral TFPs
  - UN General Industrial Statistics, 1986-1990
  - 27 manufacturing sectors, 22 countries
  - Use local prices, as in model
- Use number of nonproduction workers as proxy for skilled labor; then, rank sectors
- Hypothesis: TFP gap between LDCs and US should be smaller in skill intensive sectors

Table 1: Descriptive statistics

	low skill rich	low skill poor	medium skill rich	medium skill poor	high skill rich	high skill poor
value added per worker	36,951 (15,152)	4,563 (4,813)	66,272 (36,778)	6,722 (7,489)	78,374 (33,984)	9,530 (10,376)
capital per worker	25,027 (17,450)	14,227 (13,012)	56,687 (54,901)	24,561 (31,814)	55,814 (39,599)	27,694 (23,439)
nonprod per worker	0.26 (0.18)	0.14 (0.04)	0.33 (0.15)	0.21 (0.07)	0.41 (0.10)	0 .29 (0.10)
TFP^{CW}	1.01 (0.28)	0.22 (0.11)	1.02 (0.25)	0.27 (0.20)	1.04 (0.21)	0.30 (0.20)
TFP^{CD}	1.01 (0.26)	0.22 (0.11)	1.02 (0.23)	0.26 (0.19)	1.03 (0.19)	0.30 (0.20)
TFP^{R}	1.32 (0.75)	0.34 (0.24)	1.25 (0.37)	0.49 (0.35)	1.21 (0.41)	0.64 (0.52)

Notes: 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 $6,500 in 1988. These are Australia, Austria, Canada, Cyprus, Denmark, Finland, Greece, Ireland, Japan, Korea, Portugal, Spain, United Kingdom and USA. The LDCs are Columbia, Ecuador, India, Indonesia, Malaysia, 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 U.S.), and the averages are weighted by value added. Standard deviations are given in parentheses.

Cross-country Patterns in Industry TFPs

- Regress log TFP on log Northern skill composition

Table 2: 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
# obs.	213	186	213	344	344	557	530	557

Notes: The dependent variable in all regressions is $\log(\text{TFP}^{CW})$ relative to the U.S. All regressions include fixed country effects. pn_North is the log proportion of nonproduction workers in total employment in either the U.S. or the G3, that is the U.S., 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 U.S. 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 $\log(\text{GDP90}^{avg}/\text{GDP90}^{c})*\log(\text{pn}^{i}_{\_North}/\text{pn}^{avg}_{\_North})$, 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.

Aggregate Productivity Differences

- Technology-skill mismatch probably does not account for all the variation in output per worker across countries, but we can provide an upper bound by abstracting from other sources of productivity
- K, L, H, α are drawn from the data
- Z depends on the cutoff between skilled and unskilled workers – with a variety of assumptions, Z ranges from 1.3 to 2

- “Neoclassical model”:

$$Y = Q \cdot (K^c)^\alpha \cdot (L^c + ZH^c)^{1-\alpha}$$

where Q is chosen to normalize $y_{US} = 1$.

- Our model:

$$Y = (K^c)^\alpha \cdot \left((N_L L^c)^{1/2} + (N_H Z H^c)^{1/2} \right)^{2-2\alpha}$$

where N_L and N_H are chosen to normalize $y_{US} = 1$.

Table 4: The neoclassical model vs. directed technical change

		Neoclassical model			Our model(North=US)		
H/L	Z	$\hat{y}_{NC}^{LDC}$	$\hat{y}_{NC}^{5th-}$	$\Re_{NC}^2$	$\hat{y}_{AZ}^{LDC}$	$\hat{y}_{AZ}^{5th-}$	$\Re_{AZ}^2$
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

Notes: $\hat{y}^{LDC}$ 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 5th 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.

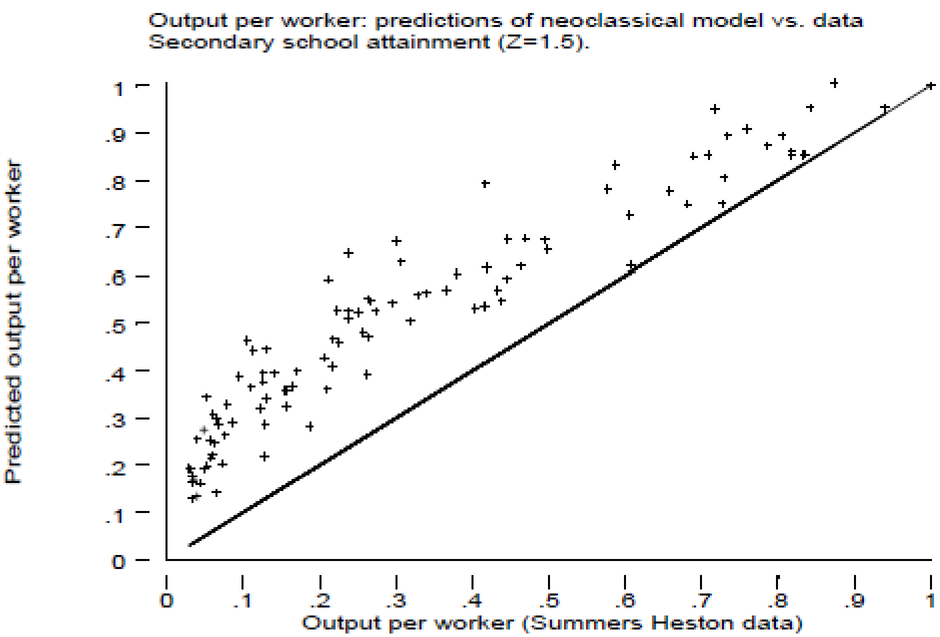

Figure 4: Output per worker: y^c_{NC} vs. y^c.

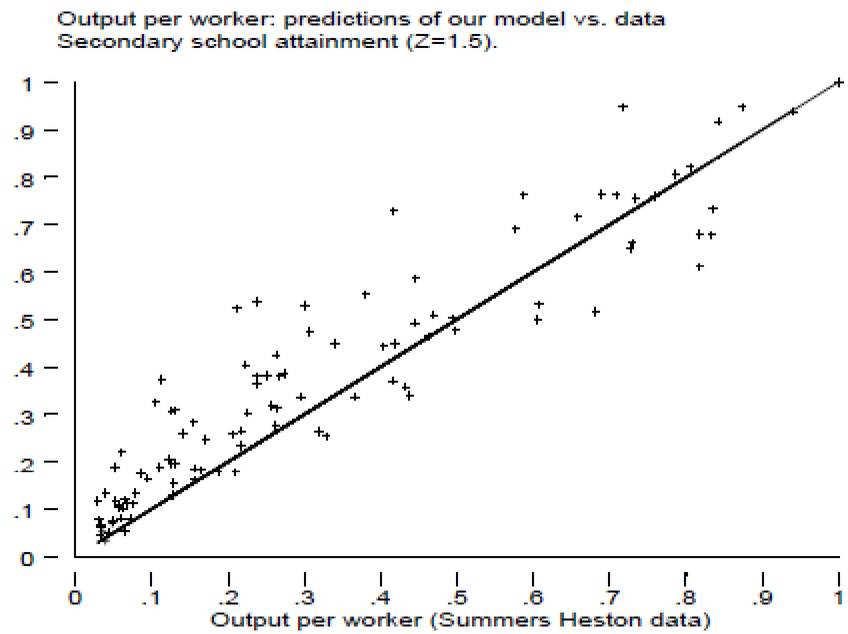

Figure 5: Output per worker: y^c_{AZ} vs. y^c.

Proposed Extensions

- International trade
  - induces skill-biased technical change
  - amplifies income differences
  - removes TFP differences (factor price equalization)
- IP rights enforced in the South
  - mitigate skill-bias in research
  - other frictions will limit this in practice
  - Southern countries may not have sufficient incentives to enforce IP rights

Conclusion

- Productivity differences arise even in the absence of barriers to technology transfer
  - Technologies are developed in the North, and directed to the North's needs
- This mismatch can explain some of the cross-country income differences
- Further study: North and South differ in more than skill composition

Discussion

- Country and sector selection
- BGP conditions for N_L and N_H
- Assumptions on relative productivity

Caselli & Coleman, 2006: “The World Technology Frontier”

- Allow “Z” to vary across countries and over time, and estimate that it is higher in rich countries
- In the notation of A&Z, QZ is higher in rich countries, while Q is equal or lower in rich countries

- Skill premium in A&Z: $\frac{w_H}{w_L} = Z\left(\frac{H^{north} \cdot L}{L^{north} \cdot H}\right)^{\frac{1}{2}}$

- Skill premium in C&C: $\frac{w_H}{w_L} = \left(\frac{A_H}{A_L}\right)^{\sigma}\left(\frac{H}{L}\right)^{\sigma-1}$

“Many technologies used by the LDCs are developed in the OECD economies and are designed to make optimal use of the skills of these richer countries’ workforces.

“Differences in the supply of skills create a mismatch between the requirements of these technologies and the skills of LDC workers, and lead to low productivity in the LDCs.

“Even when all countries have equal access to new technologies, this technology-skill mismatch can lead to sizable differences in total factor productivity and output per worker.

“We provide evidence in favor of the cross-industry productivity patterns predicted by our model, and also show that technology-skill mismatch could account for a large fraction of the observed output per worker differences in the data.”

D. Acemoglu & F. Zilibotti, 2001: “Productivity Differences”