14.461: Technological Change, Lecture 11 Misallocation and Productivity Differences across Countries

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Introduction

- Could large differences across countries (or sectors) be due to the fact that there is "misallocation" across plants, firms or sectors?
- We have already seen the potential important role of misallocation of innovation resources.
- But the problem is probably deeper: McKinsey Global Institute country and sector studies found large differences across firms within the same sector in many developing countries (South Korea, Brazil, Turkey, India). In fact, in many of these cases, the most productive firms within most sectors have productivity levels comparable to those in Western Europe or the United States, but there is a long tail of very low productivity firms.
  - Could this be important?
  - Why are these firms not upgrading their productivity?
  - More importantly, why aren't you more productive firms expanding to replace them?

Empirical Framework

- One possible empirical framework to investigate how important this is has been proposed by Hsieh and Klenow (2009) based on (highly parametric) assumptions on preferences and production technology.
- Though these assumptions are problematic, the issue is important and the patterns are very interesting.
- These assumptions also enable a clean representation of the potential impact of "misallocation" on sectoral or aggregate productivity.

Preferences and Technology

- Consider an economy consisting of S sectors, and aggregate output defined as

$$Y = \prod_{s=1}^{S} Y_s^{\theta_s} \text{ with } \sum_{s=1}^{S} \theta_s = 1.$$

- Each sector is a CES aggregate of differentiated products:

$$Y_s = \left(\sum_{j=1}^{M_s} Y_{sj}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

and each firm in sector s has production function

$$Y_{sj} = A_{sj} K_{sj}^{\alpha_s} L_{sj}^{1-\alpha_s}.$$

Preferences and Technology (continued)

- Hsieh and Klenow (2009) assume (following a practice that has become popular) that there are firm-specific "wedges" affecting total production and capital, essentially modeled as "taxes".
  - What are these? Certainly not taxes.
- As a result of these wedges, firms produce different amounts than what would be dictated by their productivity and also may have different capital-labor ratios.

How to Measure TFP?

- One measure of TFP is given by

$$TFPQ_{sj} = A_{sj},$$

as this is the difference in "physical productivity" across firms (or plants).

- But as Foster, Haltiwanger and Syverson (2008) point out, this is not what we obtain when we use industry price deflator (rather than plant or firm specific price deflators), revenue includes firm or plant specific prices, so what we would estimate is not TFPQ, but "revenue productivity," measured as

$$TFPR_{sj} = P_{sj} A_{sj},$$

where P_{sj} is the price of the product of firm/plant j.

The Different Behavior of TFP Measures

- Given that we have a constant elasticity of demand structure, without firm/plant specific distortions and all firms and plants within a sector should have the same markup.
- Think of A_{sj} as the inverse marginal cost of firm j in sector s (or alternatively, think of effective markups corrected for quality). Then P_{sj} should be proportional to $1/A_{sj}$, implying that $TFPR_{sj}$ should be constant — equalized across firms/plants within a sector.
- Therefore, variation of TFPR within a sector can be viewed as a measure of misallocation.

Sectoral TFPs

- Given constant returns and constant markups, we can aggregate across firms and across sectors (in the latter case particularly easy because Cobb-Douglas), writing

$$Y = \prod_{s=1}^{S} \left(TFP_s \cdot K_s^{\alpha_s} \cdot L_s^{1-\alpha_s} \right)^{\theta_s},$$

where K_s and L_s are total stock of capital and amount of labor used in sector s.
- Then, the relevant measure of sectoral TFP can be written the abstain as the (dual) CES aggregator of firms' TFPs and misallocation:

$$TFP_s = \left(\sum_{j=1}^{M_s} \left(TFPQ_{sj} \cdot \frac{\overline{TFPR_s}}{TFPR_{sj}} \right)^{\sigma-1} \right)^{\frac{1}{\sigma-1}},$$

where $\overline{TFPR_s}$ is the geometric average of the average marginal revenue product of capital and labor in sector s.

Sectoral TFPs (continued)

- This expression shows the role of misallocation:
  - In particular, if plants with lower physical productivity, TFPQ, have also lower TFPR (i.e., lower $P_{sj}A_{sj}$), this would imply that meaning that their prices are lower than they should be (P_{sj} low), which implies that they are producing more than they should. This implies lower aggregate TFP.
- To see this more clearly, considered a special case where $TFPQ_{sj}$ and $TFPR_{sj}$ are jointly log normally distributed, then the previous expression implies:

$$\ln TFP_s = \frac{1}{\sigma - 1} \ln \left(\sum_{j=1}^{M_s} TFPQ_{sj}^{\sigma-1} \right) - \frac{\sigma}{2} var\left(\ln TFPR_{sj} \right),$$

so that this allocation shows up only in the variance of "revenue productivity" across firms slash fans (recall that the first term is fixed by technology).

Empirical Implementation

- Hsieh and Klenow (2009) compute these measures (using essentially these expressions, only with adjustment for labor quality differences by using wage bills) on Chinese, Indian and US manufacturing data.
- They been in for the extent of misallocation and its contribution to aggregate productivity.
- What could go wrong with this empirical approach? What are the challenges?

Summary of Results

- They find that there is greater dispersion of TFPR in India and China than in the United States (this is also true for TFPQ, but less so).
  - For example, for TFPR, the 90-10 ratio is 1.59 in China, 1.60 in India and 1.19 in the United States.
- They estimate that this could account for lower aggregate productivity. In particular, there estimates suggest that this type of misallocation could increase TFP in China by 30%-50% and in India by 40%-60% (which would also imply comparable or twice as large output gains depending on whether capital at the plant/firm level responds).
- They also find evidence for more rapid reallocation towards firms/plants with higher TFPQ in China than even in the United States, possibly reflecting rapid reallocation as less efficient state-owned enterprises are being weeded out there. But reallocation away from less efficient firms seems slower in India.

Summary of Results (continued)

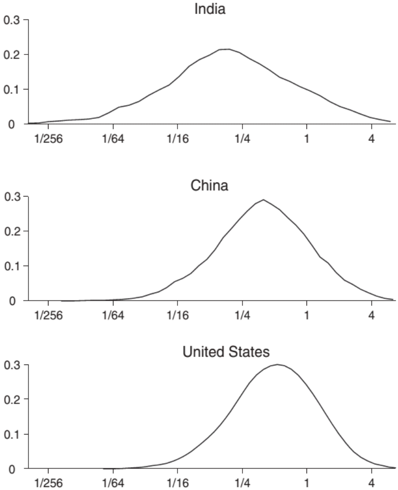


FIGURE I
Distribution of TFPQ

Summary of Results (continued)

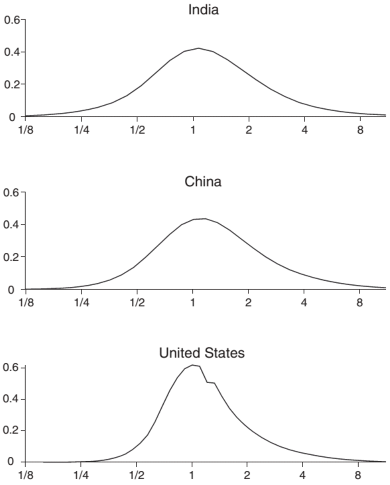


FIGURE II
Distribution of TFPR

Summary of Results (continued)

TABLE IV
TFP GAINS FROM EQUALIZING TFPR WITHIN INDUSTRIES

China	1998	2001	2005
%	115.1	95.8	86.6
India	1987	1991	1994
%	100.4	102.1	127.5
United States	1977	1987	1997
%	36.1	30.7	42.9

Notes. Entries are $100(Y_{\text{efficient}}/Y - 1)$ where $Y/Y_{\text{efficient}} = \prod_{s=1}^{S}[\sum_{i=1}^{M_s}(\frac{A_{si}}{\bar{A}_s}\frac{\overline{\text{TFPR}}_s}{\text{TFPR}_{si}})^{\sigma-1}]^{\theta_s/(\sigma-1)}$ and $\text{TFPR}_{si} \equiv \frac{P_{si}Y_{si}}{K_{si}^{\alpha_s}(w_{si}L_{si})^{1-\alpha_s}}$.

- China: better allocation over time?
- India: why is TFPQ also so dispersed?

What Could Be Wrong?

- Model misspecification: if the world is not Cobb-Douglas...
  - Part of the variation due to specification error — some firms/sectors have a different elasticity, which will show up as differences in TFP;
  - Also the specification error might change with the level of development or even with the level of reallocation in the economy.

What Could Be Wrong? (continued)

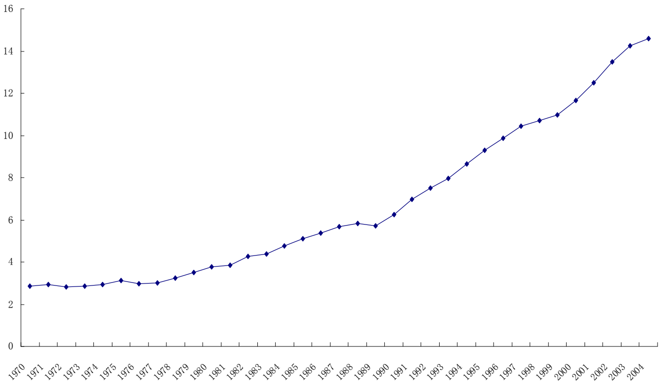
- Wedges are not an innocent assumption.
  - Peters (2013) constructs a model similar to Acemoglu-Akcigit we saw earlier in the lectures, with endogenous markups due to differences between leader and follower in that sector.
  - Suppose that two firms with the leading-edge technology in their subsector have the same A_{sj} and $A_{sj'}$, but one of them has a close-by follower and the other not. Then we will have $P_{sj} < P_{sj'}$, and thus differences in TFPR.
  - Therefore, firms and sectors with greater markup will appear as if they have greater wedges (identification problem: monopoly markups and wedges are indistinguishable). Is this misallocation?

What Could Be Wrong? (continued)

- Is this methodology focusing on the most important part of the problem?
- Two potential omissions:
  1. What determines the distribution of TFPQ? Why aren't less efficient firms exiting? This framework is not a good one for thinking about this, because of the CES structure with no fixed costs, which implies that all firms should produce. In practice, exit of inefficient firms may be as important as TFPR/wedge issues.
  2. Why aren't less efficient firms becoming more efficient? Innovation and productivity improvements.
     - Misallocation and other distortions can play a first-order role by changing incentives for innovation and productivity improvements.
     - That can be misallocation/distortions/mispricing and resources relevant for innovation (as we have already seen).

Reallocation and Chinese Growth

- China: a case of growth due to reallocation?



Reallocation and Chinese Growth (continued)

- Rapid reallocation from rural sector to urban sector and from inefficient state-owned enterprises to other firms (private or state owned).
- No sign of slowing down as would be predicted by the standard neoclassical convergence story.
- Also:
  - Wage growth below productivity growth. Growing inequality
  - High saving rates (total 50%, household 28%)
  - Foreign imbalance ($2.5 trillion foreign reserves built up since 1992).

Reallocation and Chinese Growth: Questions

- How this type of reallocation takes place?
- Why is it slow? Why is it sustained?
- Is it related to high savings rates and foreign imbalances?
- Song, Storeslettten and Zilibotti (2010): a model of sustained, slow reallocation due to credit market constraints.
  - Consistent with certain cross-sectional pattern (rapid growth and labor-intensive sectors)
  - Consistent with high savings rates and foreign imbalances.

Model

- Two type of firms, E-firms (*entrepreneurial*) and F-firms (*financially integrated*)
- E-firms and F-firms produce identical goods, but differ in technology and access to capital markets
- E-firms have higher TFP but are at disadvantage in financial markets:
  - F-firms have a deep pocket (e.g., owned by the state or financial intermediaries)
  - Entrepreneurs' returns are non-verifiable: they *can only* pledge a fraction of their profit cash-flow
- Extreme scenario: entrepreneurs *cannot* borrow at all and must finance investments out of their personal savings

Model (continued)

- E-firms choose the more productive technology

$$y_{Et} = (k_{Et})^{\alpha} (\chi A_t n_{Et})^{1-\alpha}$$

$$y_{Ft} = (k_{Ft})^{\alpha} (A_t n_{Ft})^{1-\alpha}$$

where $\chi > 1$ (E firms are more productive) and

$$A_{t+1} = (1+z) A_t$$

(exogenous technical progress)

- (Urban) working population grows at an exogenous rate ν
- Credit constraints will keep alive F firms

Model: Households

- OLG of two-period lived agents, who work in the first period and live off savings in the second period
- Preferences

$$U_t = \frac{(c_{1t})^{1-\frac{1}{\theta}} - 1}{1 - \frac{1}{\theta}} + \beta \frac{(c_{2t+1})^{1-\frac{1}{\theta}} - 1}{1 - \frac{1}{\theta}}$$

- Young workers earn a wage (w) and invest their savings in bank deposits paying gross returns R
  - Workers' savings rate is $\zeta^W \equiv \left(1 + \beta^{-\theta} R^{1-\theta}\right)^{-1}$
- Young entrepreneurs earn a managerial compensation (m) and can invest savings in deposits, but also in their *own* business
  - Entrepreneurs' savings rate is $\zeta^W \equiv \left(1 + \beta^{-\theta} \rho_E^{1-\theta}\right)^{-1}$

Model: Banks

- Competitive banks collect deposits and hold portfolios of loans to domestic F-firms (I_t^F) and foreign bonds (B_t)
- Domestic loans yield a gross a return R
- Foreign bonds yield a gross a return R^W
- No-arbitrage: $R^W = R$
- There are intermediation costs for lending to firms
  - For banks to receive R firms must pay a gross return

$$R^l = R/(1-\xi),$$

where ξ is an *iceberg* intermediation cost

Analysis: F-Firms

- Investments entirely financed by bank loans:

$$K_{Ft+1} = I_{Ft}$$

- Notation: $\kappa \equiv K / (AN)$
- No-arbitrage implies $R^l = \alpha \kappa_F^{\alpha-1}$, hence,

$$\kappa_F = \left(\frac{\alpha}{R^l} \right)^{\frac{1}{1-\alpha}}$$

- Wages equal the marginal product of labor:

$$w_t = (1-\alpha) \kappa_F^{\alpha} A_t.$$

Analysis: E-Firms

- E-firms are owned by old entrepreneurs and run by young *managers*
  - moral hazard problem: managers can steal share ψ of the output without being caught
- Manager's incentive constraint requires $m \geq \psi y_E$
- The optimal contract implies

$$
\begin{aligned}
\Xi_t(k_{Et}) &= \max_{n_{Et}, m_t} \left\{ (k_{Et})^{\alpha} (\chi A_t n_{Et})^{1-\alpha} - w_t n_{Et} - m_t \right\} \\
& \text{s.t.} \\
m_t &\geq \psi (k_{Et})^{\alpha} (\chi A_t n_{Et})^{1-\alpha} \\
m_t &\geq w_t
\end{aligned}
$$

Analysis: E-Firms

- The solution yields

$$
\begin{aligned}
n_{Et} &= (1-\psi)^{\frac{1}{\alpha}} \chi^{\frac{1-\alpha}{\alpha}} \left(\frac{R^l}{\alpha} \right)^{\frac{1}{1-\alpha}} \times \frac{k_{Et}}{A_t} \\
y_{Et} &= ((1-\psi)\chi)^{\frac{1-\alpha}{\alpha}} \frac{R^l}{\alpha} \times k_{Et} \\
m_t &= \psi \times y_{Et}
\end{aligned}
$$

- Thus, the value of the firm is

$$
\Xi_t(k_{Et}) = \alpha(1-\psi) \times y_{Et} = \underbrace{(1-\psi)^{\frac{1}{\alpha}} (\chi)^{\frac{1-\alpha}{\alpha}} R^l}_{\equiv \rho_E} \times k_{Et}
$$

- Note: the entrepreneurial rate of return, ρ_E, is constant
- Why does ρ_E depend on R^l?

Analysis: Growth

- Entrepreneurial savings are the driving force of the transition

$$\frac{K_{Et+1}}{K_{Et}} = \frac{\zeta^E \times M_t}{K_{Et}} = \zeta^E \psi \left((1-\psi) \chi \right)^{\frac{1-\alpha}{\alpha}} \frac{R^l}{\alpha}$$

where $M_t = \int_{\Omega_m} m_t = \psi \times Y_{Et}$.

- The E-sector features AK equilibrium dynamics

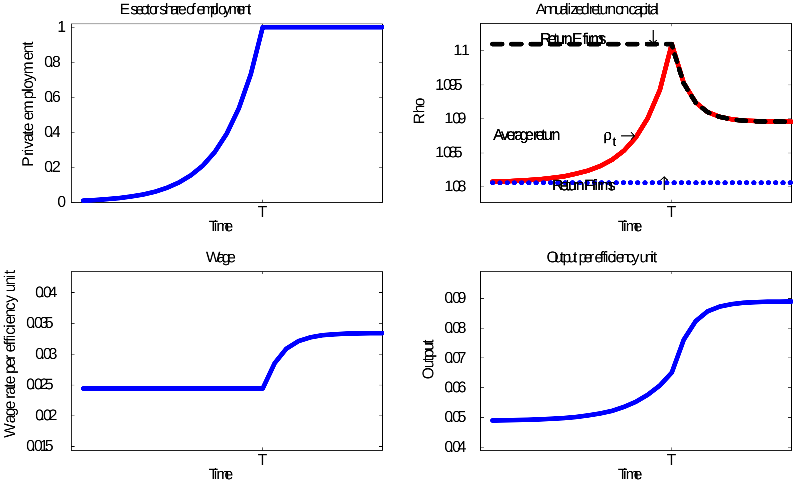
$$Y_{Et} = \left((1-\psi) \chi \right)^{\frac{1-\alpha}{\alpha}} \frac{R^l}{\alpha} \times K_{Et}$$

because it uses the "labor reserve" of the F sector, which keeps wages per efficiency units constant.

Comparative Statics

- Greater R (higher world interest rates) lead to faster growth.
- Greater ξ (higher iceberg intermediation costs), which make financing less efficient, leads to faster growth.
- Why? Do these results make sense?

Equilibrium Dynamics



Foreign Imbalance Implications: Extreme Scenario

- No borrowing.
- For entrepreneurs: $S = I$.
- The difference between worker's savings and the investments of F sector determines the foreign balance.
- From the balance sheets of the bank sector,

$$\underbrace{K_{Ft} + B_t}_{\text{ASSETS}} = \underbrace{\zeta \times w_{t-1} N_{t-1}}_{\text{DEPOSITS}}$$

$$\begin{aligned} B_t &= \zeta^W \times (w_{t-1} N_{t-1}) \uparrow - K_{Ft} \downarrow \\ &= \left(\zeta^W \frac{1-\alpha}{(1+z)(1+\nu)} \kappa_F^{\alpha-1} - 1 + \frac{N_{E,t}}{N_t} \right) \times \kappa_F A_t N_t \end{aligned}$$

- As the F sector shrinks, while wage income grows, B increases.
- The economy accumulates a surplus.

Foreign Imbalance Implications: with Borrowing

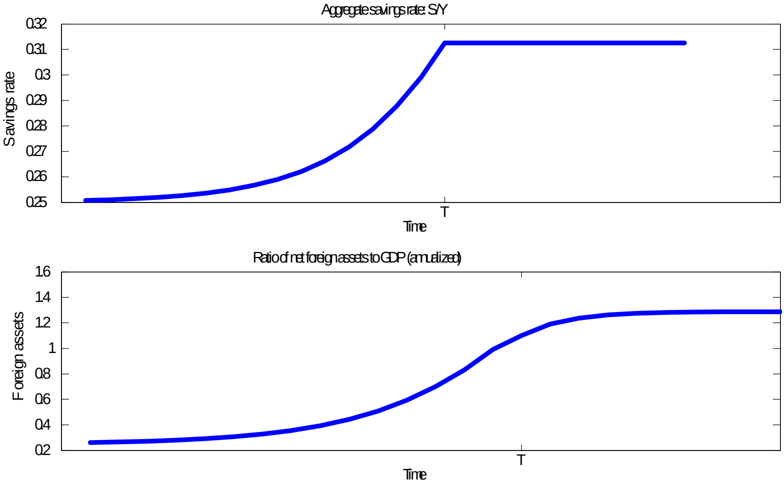
- The difference between worker's savings and the investments of F + gap of E sector determines the foreign balance.
- From the balance sheets of the bank sector,

$$\underbrace{K_{Ft} + B_t + \frac{\eta \rho_E}{R_l} K_{Et}}_{\text{ASSETS}} = \underbrace{\zeta \times w_{t-1} N_{t-1}}_{\text{DEPOSITS}}$$

$$\begin{aligned} B_t &= \zeta \times \left(w_{t-1} N_{t-1} \right) \uparrow - \left(K_{Ft} \downarrow + \frac{\eta \rho_E}{R_l} K_{Et} \uparrow \right) \\ &= \left(\zeta^W \frac{1-\alpha}{(1+z)(1+\nu)} \kappa_F^{\alpha-1} - 1 + (1-\eta) \frac{N_{E,t}}{N_t} \right) \times \kappa_F A_t N_t \end{aligned}$$

- The economy accumulates a surplus as long as η is not too large

Equilibrium Dynamics of Savings Rate and Foreign Assets



Appropriate and Inappropriate Technologies and Productivity Differences

- Why does rapid diffusion of ideas not remove all, or at least most, cross-country technology differences?
- "Technology" differences and income gaps can remain substantial even with free flow of ideas because technologies of the world technology frontier may be *inappropriate* to the needs of specific countries.
- Technologies and skills consist of bundles of complementary attributes that vary across countries
- Three versions of this story. Appropriateness stemming from differences in:
  1. exogenous (e.g., geographic) conditions,
  2. capital intensity,
  3. skill intensity.

Inappropriate Technologies. Example: Health Innovations

- Productivity in country j at time t, $A_j(t)$, is a function of whether there are effective cures against certain diseases affecting their populations.
- Two different diseases, heart attack and malaria.
- $j = 1, ..., J'$ are affected by malaria and not by heart attacks.
- $j = J' + 1, ..., J$ are affected by heart attacks, not malaria.
- If the disease affecting country j has no cure, $A_j(t) = \underline{A}$.
- When a cure is introduced, $A_j(t) = \overline{A}$.
- A new cure against heart attacks is discovered and becomes freely available to all countries.
- Productivity in countries $j = J' + 1, ..., J$ increases from $\underline{A}$ to $\overline{A}$, but productivity in countries $j = 1, ..., J'$ remains at $\underline{A}$.

Inappropriate Technologies

- Technologies of the world frontier may be "inappropriate" to the needs of some of the countries (the J' countries).
- A technological advance that is freely available to all increases productivity in a subset of the countries and creates cross-country income differences.
- Could issues of the sort be important? Yes and no:
  - Over 90% of the world R&D is carried out in OECD economies; technologies should be optimized for the conditions in OECD countries.
  - But, other than the issue of disease, there are not many obvious *fixed* country characteristics that will create this type of "inappropriateness".
  - The issue is much more likely to be important in the context of whether new technologies will function well at different *factor intensities.*

Capital-Labor Ratios and Inappropriate Technologies I

- Atkinson and Stiglitz (1969): technological change shifts isoquants (increasing productivity) at a given capital-labor ratio.
- Technological changes are localized for specific capital-labor ratios:
  - e.g, discovery that favors firm that is using a type of tractor with a single worker can be used by any other firm employing the same tractor with a single worker, but not by firms using oxen or less (or even more) advanced tractors.
- Implications for cross-country income differences: technologies developed for high capital-intensive production processes in OECD countries may be of little use to labor-abundant less-developed economies (Basu and Weil, 1998).

Capital-Labor Ratios and Inappropriate Technologies II

- Production technology for all countries in the world:

$$Y = A\left(k \mid k'\right) K^{1-\alpha} L^{\alpha},$$

- Output per worker:

$$y \equiv \frac{Y}{L} = A\left(k \mid k'\right) k^{1-\alpha},$$

  where $k = K/L$.

- $A\left(k \mid k'\right)$ is the (total factor) productivity of technology designed to be used with k' when used instead with k.
- Suppose that

$$A\left(k \mid k'\right) = A \min\left\{1, \left(\frac{k}{k'}\right)^{\gamma}\right\}$$

  for some $\gamma \in (0, 1)$.

Capital-Labor Ratios and Inappropriate Technologies III

- New technologies developed in richer economies, with greater k.
- Productivity in country with capital-labor ratio $k < k'$ will be

$$y = A\left(k \mid k'\right) k^{1-\alpha} = Ak^{1-\alpha+\gamma}\left(k'\right)^{-\gamma}. \tag{1}$$

- (1) implies less-developed countries will be less productive even when producing with the same techniques.
- Moreover this productivity disadvantage will be larger when the gap between k and k' is greater.
- Important for understanding cross-country income differences?
  - With $\alpha \approx 2/3$, an economy with $k' = 8k$ would only be twice as rich, when there is no issue of inappropriate technologies. But if $\gamma = 2/3$, the difference would be eight fold.
  - But does the structure make sense at all?

Inappropriate Technologies and the Dual Economy

- Technology is Leontief type: requires a certain number of skilled and unskilled (L) workers.
- Technology A_h will produce $A_h L$ units of final good, but requires a ratio of skilled to unskilled *exactly* equal to h.
- A_h is increasing in h.
- Less-developed economy has access to all technologies A_h for $h \in [0, \bar{h}]$ for some $\bar{h} < \infty$.
- Population of this economy consists of H skilled L unskilled, such that $H/L < \bar{h}$.
- Hence not all workers can be employed with the most skill-intensive technology.
- All markets are competitive, so allocation of workers to tasks will maximize output.

The Dual Economy (continued)

- Thus problem can be written as

$$\max_{[L(h)]_{h\in[0,\bar{h}]}} \int_0^{\bar{h}} A_h L(h)\,dh \tag{2}$$

subject to

$$\begin{aligned} \int_0^{\bar{h}} L(h)\,dh &= L, \text{ and} \\ \int_0^{\bar{h}} hL(h)\,dh &= H, \end{aligned}$$

where $L(h)$=number of unskilled workers assigned to technology A_h.

- First-order conditions:

$$A_h \leq \lambda_L + h\lambda_H \text{ for all } h \in [0, \bar{h}], \tag{3}$$

where λ_L=multiplier of first constraint and λ_H=multiplier of second constraint.

Equilibrium

- First-order conditions. If $A_{\bar{h}}$ is sufficiently high and if $A_0 > 0$:
  - all skilled workers will be employed at technology $\bar{h}$ with $L(\bar{h}) = H/\bar{h}$ unskilled workers, and
  - the remaining $L - L(\bar{h})$ workers will be employed with the technology $h = 0$.
- Equilibrium feature of a dual economy: two very different technologies, one more advanced (modern) and one least advanced that is feasible.

Equilibrium (continued)

- The dual economy emerges because of a non-convexity:
  - To maximize output, necessary to operate the most advanced technology.
  - But this exhausts skilled workers, so unskilled have to be employed in technologies that do not require skilled inputs.
- This suggests dual economy might be outcome of technology transfer from more advanced, especially if these technologies are inappropriate, and can be generalized by assuming more advanced technology will be operated in urban areas and with contractual arrangements enforced by modern institutions.

Endogenous Technological Change and Appropriate Technology I

- The evidence discussed before suggests differences in human capital may be particularly important in the adoption of technology.
- Moreover, the past 30 years have witnessed the introduction of skill-biased technologies.
- A mismatch between the skill requirements of frontier technologies and skills of workers in less-developed countries may be more important than differences in capital intensity.
- Model here emphasizes implications of this mismatch, uses ideas of directed technical change, and provides tractable multi-sector growth model (Acemoglu and Zilibotti, 2001).

Endogenous Technological Change and Appropriate Technology II

- Two groups of countries, North and South.
- Two types of workers, skilled and unskilled.
- Two differences between North and South:
  1. All R&D and new innovations take place in the North; the South copies. Because of lack of intellectual property rights in the South, the main market of new technologies will be Northern firms.
  2. The North is more skill-abundant:

$$H^n / L^n > H^s / L^s,$$

- Many Northern and many Southern countries.
- Technological change in the North directed, and similar to what we have seen in the course of our.

Main Result

- The steady-state equilibrium technology ratio N_H^* / N_L^* turns out to be such that, given a constant level of for given $N_H + N_L$, it achieves the unique maximum of net output in the North, NY^n, as a function of relative technology N_H / N_L.
- Moreover, at the steady-state equilibrium technology ratio N_H^* / N_L^*, we have $y_n > y_s$ and $y_n^{eff} > y_s^{eff}$.

Implications

1. The steady-state equilibrium technology is appropriate for the needs of the North; research firms are targeting Northern markets. Moreover, since there is a unique maximum of NY_n (given $N_H + N_L$), NY_s will *not* be maximized by N_H^* / N_L^*.
2. Technologies are inappropriate for the needs of the South. Hence, income per capita and income per effective units of labor in the North will be higher than in the South.
3. The process of directed technical change, combined with import of frontier technologies to less-developed economies, creates an advantage for the more advanced economies and acts as a force towards greater cross-country inequality.
4. This source of cross-country income differences can be quite substantial in practice (Acemoglu and Zilibotti, 2001)