Chapter 8

THE ROLE OF TECHNOLOGY IN GROWTH

Modified for EC 375 by Bob Murphy
Technology and Productivity Growth

• Productivity gains are an important source of growth and differences in productivity levels are an important determinant of differences in per capita income.

• Improved technology is a natural explanation for productivity improvements:
  – What explains technological progress itself?
  – Can differences in technology explain differences in the levels of productivity between rich and poor countries?
The Nature of Technological Progress

• Allows economy to transcend limitations of diminishing returns to physical and human capital.
• Captured by parameter “A” in production function.
• Research and development leads to technology creation:
  – Most spending on R&D is done by private firms
  – Governments spend also, but patents are key government role.
### Table 8.1 Researchers and Research Spending, 2009

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Researchers</th>
<th>Researchers as a Percentage of the Labor Force</th>
<th>Research Spending ($ billions)</th>
<th>Research Spending as a Percentage of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>1,412,639</td>
<td>0.89%</td>
<td>398.2</td>
<td>2.8%</td>
</tr>
<tr>
<td>Japan</td>
<td>655,530</td>
<td>1.00%</td>
<td>137.9</td>
<td>3.4%</td>
</tr>
<tr>
<td>Germany</td>
<td>311,519</td>
<td>0.74%</td>
<td>82.7</td>
<td>2.8%</td>
</tr>
<tr>
<td>France</td>
<td>229,130</td>
<td>0.80%</td>
<td>48</td>
<td>2.2%</td>
</tr>
<tr>
<td>Korea</td>
<td>236,137</td>
<td>0.96%</td>
<td>43.9</td>
<td>3.3%</td>
</tr>
<tr>
<td>OECD Total</td>
<td>4,199,512</td>
<td>0.70%</td>
<td>965.6</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

*Source: OECD Main Science and Technology Indicators database.*
The Nature of Technological Progress

• Transfer of technology:
  – Ideas are non-rival meaning that use by one person (country) doesn’t limit use by another.
  – Ideas are non-excludable meaning that the owner can not prevent use by others.
  – Non-rival aspect makes technology transfer among countries easier as inventing country doesn’t lose use of the technology.
  – Non-excludable aspect reduces the incentive for innovation.
The Nature of Technological Progress

• Determinants of R&D spending:
  – Profit Considerations:
    • How big an advantage over competitors--is it patentable?
    • Size of market.
    • How long is patent protection?
    • Uncertainty and risk in R&D--invention might not work.
  – Creative Destruction:
    • Schumpeter: New inventions are costly for those with stakes in old technologies.
    • So, economic system that encourages new technologies faces a delicate balance.
Patents and Other Forms of Intellectual Property Protection

• Features of Patents
  – Patents help to limit the problem of non-excludability.
  – Gives creator of an invention sole right to make, use and sell that invention for a period of time (20 years in U.S.).
  – Must be novel and nonobvious. Cannot patent laws of nature, physical phenomenon or abstract ideas.
  – Rules for what can be patented are clear, but can be complicated to apply:
    • What’s novel and nonobvious is subject to judgement.
    • Verification of underlying science is not always thorough.
    • Who deserves the patent: first to file vs. first to invent
Patents and Other Forms of Intellectual Property Protection

• Problems with Patents
  
  – Monopoly power given to inventor. Benefits of technology may be limited if too costly to use.
  
Patents and Other Forms of Intellectual Property Protection

• Problems with Patents

– Emergence of “Patent Trolls”--NTP vs. RIM over Blackberry. Portfolios of patents intended only for lawsuits. Might also patent technologies already in wide use that were thought to be too obvious.

– Patent trolls hold back technological progress as inventors fear they might lose their control of their ideas. Also leads to defensive patenting, wasting resources.

– Separately, computer and telecommunications firms may try to acquire patents for purpose of suing competitors or to dissuade other firms from suing them.
Patents and Other Forms of Intellectual Property Protection

• Alternatives to Patents

  – Secrecy: Twice as important as patent protection (survey of R&D lab managers).
  
  – Example: Formula for Coca Cola was never patented.
  
  – Terminator gene: Patents help to limit the problem of non-excludability but not perfectly--need for built-in way to prevent product from being copied. Monsanto’s terminator gene for seeds.
The Relationship between Technology Creation and Growth

One-Country Model

Labor force is divided between technology sector (A) and rest of economy (Y):

\[ L = L_Y + L_A \]
\[ \gamma_A = \frac{L_A}{L} \]
\[ L_Y = \left[ 1 - \gamma_A \right] L \]

Production function:

\[ Y = AL_Y \]
\[ y = A \left[ 1 - \gamma_A \right] \]

so

\[ Y = A \left[ 1 - \gamma_A \right] L \]

or in per worker terms,
The Relationship between Technology Creation and Growth

Creation of new technologies:

\[ \hat{A} = \frac{L_A}{\mu} \]

where \( \mu \) is the "price" of new inventions measured in labor units, and can rewrite growth of technology as:

\[ \hat{A} = \frac{\gamma A L}{\mu} \]

If \( \gamma_A \) is constant, then from production function:

\[ \hat{y} = \hat{A} \] implying that:

\[ \hat{y} = \frac{\gamma A L}{\mu} \]
Figure 8.1 Effect of Shifting Labor into R&D
The Relationship between Technology Creation and Growth

• Similar to raising investment share for physical capital in Solow model, except here effect is on growth rate of y rather than only on steady-state level of y.

• The effect of increased investment in the Solow model had only a transitory effect on output growth, while here it has a permanent effect.
The Relationship between Technology Creation and Growth

• Model predicts a rise in L will lead to faster growth.
• But no evidence that countries with more people grow faster or are richer.
• Reason for model’s failure is that the level of technology depends not only on R&D done in one’s own country but also R&D done elsewhere: *technology transfer* is important.
The Relationship between Technology Creation and Growth

2-Country Model: Innovation and Imitation

Assume equal labor forces, \( L_1 = L_2 = L \), but allow \( A \) to differ:

\[
\begin{align*}
    y_1 &= A_1 \left[ 1 - \gamma_{A,1} \right] \\
    y_2 &= A_2 \left[ 1 - \gamma_{A,2} \right]
\end{align*}
\]

Assume \( \gamma_{A,1} > \gamma_{A,2} \), so that country 1 is the leader and country 2 is the follower in steady state.

Leader: \( \hat{A}_1 = \frac{\gamma_{A,1}}{\mu_i} L_1 \)

Follower: \( \hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L_2, \quad \mu_c = c \left( \frac{A_1}{A_2} \right) \)

where \( \mu_i \) is the cost of invention and \( \mu_c \) is the cost of copying.
The Relationship between Technology Creation and Growth

Leader: \( \hat{A}_1 = \frac{\gamma_{A,1}}{\mu_i} L \),

Follower: \( \hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L \) where \( \mu_c = c \left( \frac{A_1}{A_2} \right) \)

Assume:

1. \( c' < 0 \)
2. As \( \frac{A_1}{A_2} \to \infty, c \to 0 \)
3. As \( \frac{A_1}{A_2} \to 1, c \to \mu_i \) (the cost of invention).

In steady state the two countries grow at the same rate. Steady state is stable.
Figure 8.2 Cost of Copying for the Follower Country

Cost of copying, $\mu_c$

$\mu_i$

$c(A_1/A_2)$

1

$A_1/A_2$
Figure 8.3 Steady State in the Two-Country Model
The Relationship between Technology Creation and Growth

Solve for relative levels of technology in the steady state defined as when the two countries grow at the same rate:

$$\frac{\gamma_{A,1}}{\mu_i} L = \hat{A}_1 = \hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L \quad \text{where} \quad \mu_c = c \left( \frac{A_1}{A_2} \right)$$

Thus, $\mu_c = \frac{\gamma_{A,2}}{\gamma_{A,1}} \mu_i$ and can use $\mu_c = c \left( \frac{A_1}{A_2} \right)$ to obtain $\frac{A_1}{A_2}$ in the steady state.
The Relationship between Technology Creation and Growth

• Leader is not necessarily better off:
  – More productive but devotes more labor to R&D so has lower y.
  – Follower could be better off depending on cost of copying versus cost of invention:
    • If copying (imitation) is very cheap, then follower will have productivity close to leader’s level while devoting less labor to R&D (and more to production of output).
    • If copying is expensive, then follower will have to devote almost as much L to R&D as the leader to have productivity close to leader’s level or have productivity much lower if devote only small share of L.
The Relationship between Technology Creation and Growth

• Consider a policy change:
  – Increase in the share of labor used for R&D in the follower country.
  – Follower gets transitory boost in growth--similar to Solow model.
  – If instead increase share of labor used for R&D in the leader, get a permanent increase in growth
The Relationship between Technology Creation and Growth

• Does this fit real world experience?
  – Maybe for UK in early 19th century or US after WWII.
  – Not today, as have many leaders. Different countries leading in different industries.
  – Model still useful as increased R&D in a given country will:
    • Lead to change in relative position in world technological hierarchy, generating transitory growth in both technology and income.
    • Lead to faster growth in technology for world as a whole.
Figure 8.4 Effect of an Increase in R&D in the Follower Country on the Steady State
Figure 8.5 Effect of an Increase in $\gamma_{A,2}$ on Productivity and Output
The Relationship between Technology Creation and Growth

• International Technology Transfer:
  – Various means, both legal and illegal.
  – Historically countries tried to limit transfer.
  – Nations today rarely restrict transfer outside their borders for economic reasons (but do so for national security reasons).
  – Reason is that you might have subsidiaries abroad and competitors at home.
Barriers to Technology Transfer

• Appropriate Technologies:
  – Most R&D is done in rich countries, tailored to factor mix in those countries rather than poor countries.
  – Property rights enforcement is weak in poor countries, so little incentive to design innovations for use in poor countries.
  – End up with technology that is available but not appropriate for use in poor countries.
  – Alternatively, might be the case that it is appropriate for poor countries but they are unable to use it.
Figure 8.6 Neutral Technological Change
Figure 8.7 Capital-Biased Technological Change
Barriers to Technology Transfer

• Tacit Knowledge:
  – Knowledge that engineers gain from experience.
    • Not just blueprints alone. Example of lightbulb machine in Hungary versus Germany in 1950s and example of truck engines in the Japan versus India in the 1960s.

  – Specific to a type of technology not a given technology.
    • Makes it easier for technology to move among developed countries as opposed to developing countries.
    • Implies potential for large externalities from transfer of technology—which possibly explains why S. Korea and Taiwan were able to catch up to the cutting edge in a few decades.
Barriers to Technology Transfer

• Embodied Technological Progress:
  – Technology is very often tied up with physical and human capital.
  – Rate of investment can thus influence technology adoption as can age structure of population.
  – Example: Oxygen steel furnace invented in early 1950s was adopted quickly in Japan where steel industry expanded rapidly but slowly in U.S. where the industry grew more gradually.
    • Japan had 75% of steel production using this process by 1968 whereas the U.S. had only 40%.
Barriers to Technology Transfer

• Leapfrogging:
  – Continue using technology until capital good is worn-out or until technology is too old.
  – Then adopt newest technology by investing in new capital.
  – Example: Computers and software.
  – Example: Cell phones in Africa.
    • By 2001, Africa has more cell phones than land lines. From 2001 to 2010, cell phone subscriptions rise by 1300%.
    • Africa leads the world in using cell phones for informal banking and small transactions--For example, using “minutes” as a form of payment.