Science, Technology and Innovation for Sustainable Development

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Background

- ECOSC: theme of 2013 AMR
  = STI for promoting sustainable development and achieving the MDGs
- CDP to examine and make recommendations on this theme at its 15th plenary session

- 3 dimensions of sustainable development:
  1) Economic; how to sustain economic growth
     > poverty trap; middle income trap
  2) Environmental: ecological and climate crisis
  3) Social: inequality; exclusion; inclusive development
2 Simple Goals

- How to use STI
  -> to make economic growth sustained, rather than short-lived
  (assuming it also helps social dimension of SD; b/c growth collapse is one reason for inequality)

- How to use STI
  -> to change the current ‘environment-unfriendly’ growth trajectory into more environment-friendly growth

• But gradual shift to new growth;
  -- not to scrap old industries in the South right away
  but first to make them more STI intensive
Specifically,

1) Policies to advance STI capabilities of the latecomers to sustain economic growth
2) Application of STI in transformation of industrial structures in developing countries,
   - while meeting environmental objectives.
3) Latecomers in a position to leapfrog into environment-saving technologies to take a different path of development than the old path of the current North.
4) What can be done to achieve these
Several Challenges

1) *Middle income trap, poverty trap, and the adding-up problem*

2) *Environment-friendly development;*
   -- level of human activity: threatening to surpass the limits of the Earth’s capacity;
   -- the South to bear 75% of costs and more vulnerable

3) *Intellectual Property Rights: incentive or barrier for Catch-up Development?*
Middle- and Low-income Traps: connected

Middle income Trap and Adding up problem

**MIT** = middle-income countries face a slowdown of growth;
-- caught between low-wage manufacturers and high-wage innovators.

**Adding-up problem:**
- developing countries flood the market with the same goods that they produce well,
-- resulting in a decrease in the prices of these goods and less profits (Spence, 2011)
Why the Middle Income Trap important?

1) 70% of World Poor in MICs
2) It is future of the LICs
3) MIT linked with the adding-up problem.
   (Eg; adding up in flower industries in E Africa)
   Eg) China needs to go quickly beyond the low-end goods based growth, so that it may leave rooms for other low income countries

⇒ To be free from adding-up, you got to differentiate your products
   → need to have innovation capabilities
Weak STI (weak R&D) as Source of the MIT (flat R&D/GDP ratio for MICs)
Different Factors at different Stages  
(Lee and Kim 2009 WD)

1) For lower income & lower middle income countries:

   Secondary education & institutions mattered;  
   + basic infrastructure (SOC)

2) For upper middle and higher:

   a) college education and innovation  
   b) big business (Lee et al ; JCE) mattered
Theoretical Framework for Catching-up and Leapfrogging Development
Latecomers’ Advantage (Leapfrogging) vs. Forerunners’ Trap

• Leapfrogging: Perez and Soete (1988)

-> Emerging technological paradigms
   = a window of opportunity
-> not being locked into the old technological system and thus being able to grab new opportunities in the emerging industries. for the catching up country,

• Cf) Forerunners’ Trap: locked into exiting technologies due to the sunk costs of their investment.
2 Kinds of Latecomers’ Advantage

1) Advantage in Mature Industries (Gerschekron)
   -> possibility of low cost-based entries without bothering to bear the burden of R&D costs
   -> you can adopt most up-to-date facility or products

2) Advantages in Emerging Industries
   -> entry at an earlier stage with the same entry costs but without the sunk costs or being locked into old technologies.
   -> Leapfrogging
3 Patterns of Technological Catch-up (Lee & Lim 2001)

Path of the Forerunner: stage A --> stage B --> stage C --> stage D

Path-Following Catch-up: stage A --> stage B --> stage C --> stage D
   eg. PC, some consumer goods, and Machine Tools

Stage-skipping Catch-up (leap-frogging I):
   stage A -------------> stage C --> stage D
   eg. Hyundai's fuel-injection engine (cf. carburetor engine)
   Samsung' 64 K D-Ram production technology; 256 K D-ram design technology
   Telephone switch in in China

Path-Creating Catch-up (leap-frogging II)
   stage A --> stage B --> stage C' --> stage D'
   eg. CDMA development, digital TV
   (Notes: C and C', represent competing technologies.)
3 strategies in Graphs

- Path-following = start from generation 1
- Stage-skipping = from generation 3 (most productive and stable)
- Path-creating = from generation 4 (emerging technology)
Solar power cost; now reduced $1 per watt, cheaper than diesel; affordable to the South

1st G: amorphous silicon cells

2nd G: thin-film solar cell

Cost of solar PV cells, falling 45% per year

Source: BNEF Bazilian et al (2012), Fig. 1
Now
Another Paradigm Shift

1) New Energy Revolution (Renewable Energies) to replace fossil-fuel

2) Fusion of Technologies (IT, BT, NT,) in search for new solutions

-> Best Time for Leapfrogging and already happening;
   former latecomers are no more latecomers
Stage-skipping and Leapfrogging in the Environmental Kuznets Curve

Source: adapted from Assefa (2011)
Examples of Leapfrogging 1
Wind-Turbines, Solar power, Solar Thermal Heating in China

- Wind Turbines
  - By early 2000s, China relied heavily on European suppliers for most of the production and parts
  - but localized much of the production process and required inputs owing to national procurement policy and local content requirements.
  - China became the leader by 2010.

- Solar thermal heating in China (developed by Tsinghua Univ)
  - Rural area bypassed the stage of gas or electricity based heating but leapfrogged into solar thermal based heating.
  - Solar water heater = huge disruption on the existing residence style of urban dwellers,
    whereas rural areas: no such lock-in.
  - Leapfrogging driven not by supply-side (technology)
    but by mismatch with the demand side
Examples of Leapfrogging 2
Bio-Ethanol and Bio-Diesel in Brazil

- Brazil: green industrial restructuring
- Technology for ethanol production was initially imported and rapidly localized with subsidies on alcohol and ethanol
  - and then diffused rapidly through the R&D efforts of Brazilian Agricultural Research Corporation, EMBRAPA.

- This public entity maintained a technological watch on global developments and utilized advanced technological methods for researching Brazil’s sources of comparative advantage,
  - e.g. soils suitable for sugar cane cultivation as revealed by satellite surveillance.
Mozambique: from Black to Green Development

- Mozambique: state oil company Petromoc (modelled on Petrobras) has partnered with the Portuguese oil company Galp and local company (Ecomoz) in a $19 million investment to produce biodiesel from jatropha.

- Up to 50,000 hectares of land will be dedicated to the project. Endowed with land, sunshine and adequate rainfall.

- Good prospects to become a bio-fuels powerhouse, which could reduce the country’s dependence on imported fossil fuel, contribute to diversify exports

- These projects financed by its Coal Exports
  - (Turning Black into Green)

- Also, South-South Cooperation: help from India & Korea
Nigeria: Solar power

In desert grasslands rural area

- Jigawa State in Nigeria:
- No water supply in this semi-desert area

- Traditional options:
  -- Open wells with rope and bucket; hand pumps;
  or Government supplied diesel-powered pumps that work only until they break down or until villagers run out of money to buy the expensive diesel.

- Now, solar-powered pumps designed to run maintenance free for eight to ten years or more
- Solved the problem
Need incentives/promotion
For early adopters/developers

- Market-based approach:
  - Often not adequate to bring in necessary new technologies and replace unsustainable old ones in the remaining time frame before irreversible environmental damage occurs

- Policy intervention: justified to correct market failures and make green technologies more profitable than less sustainable ones.

- India’s Solar power
  - Jawaharlal Nehru National Solar Mission (NSM)
  -- used competitive reverse bidding for tariffs (rents).
STI Policy for National Development
### The 3 Failures as Justification for Gov’t Activism

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<th>Market failure</th>
<th>System failure</th>
<th>Capability failure</th>
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<td>Knowledge as public good</td>
<td>Cognition failure</td>
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<td>Example problem</td>
<td>Sub-optimal R&amp;D</td>
<td>R&amp;D impact: low</td>
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<td>Solutions</td>
<td>R&amp;D subsidies</td>
<td>Reducing cognitive distance</td>
<td>Access to knowledge and help in learning</td>
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<td>School Analogy</td>
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<td>Making more friends</td>
<td>Targeting student learning</td>
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<td>Relevance</td>
<td>Developing and advanced countries</td>
<td>Developing and advanced countries</td>
<td>More unique to developing countries</td>
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From Keun Lee, a coming chapter in Stiglitz & Lin eds,
Policy to cultivate directly capabilities of private firms

- To raise “capability failure” as a justification for gov’t activism,
- To suggests ways to cultivate capabilities of firms.
  -- In developing countries where firms have a low R&D capability, a safer way of doing business is to buy or borrow external technologies or production facilities, as well as to specialize in less technical methods or assembly manufacturing.
- To move beyond such states (middle income trap),
  -> effective policy to include not the simple provision of R&D funds but various ways to cultivate R&D capability itself.
## Stages of Knowledge Learning/Creation and Catch-up

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<th>Stages of Catch-up</th>
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<th>Stage II</th>
<th>(crisis) Stage III</th>
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<td>Overseas R&amp;D</td>
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<td>P&amp;P R&amp;D consortium</td>
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## Learning Mechanism

- Learning by doing
- by producing/organizing following foreign designs
- crisis->
- in-house R&D
- Overseas R&D
- P&P R&D consortium

## Co-development

- strategic alliance
Learning how to Design
By Gov’t-Private-Gov’t (GPG1):
eg) Telephone switch development in Korea & China

Government:
R&D by Public labs
(ETRI in Korea)

Government:
Market protection
or Procurement
( local telephone authorities)

Private:
Manufacturing
(private Co’s:
Samsung, LG in Korea)

India & Brazil had the same development but not sustained
without initial protection;
=> Infant protection still matters, together with joint PP R&D
Leapfrogging into Emerging Technologies By GPG2

eg) Korea: Digital TV, mobile phones (CDMA);
China: 3G TD-SCDMA, Photovoltaic; electric vehicles

Policy tools: Standards policy matter,
eg), exclusive standards in wireless.
GPG0 (GG) in Steel (POSCO: a SOE)
Production & R&D by SOEs

Government:
R&D by a SOE and GRI (KIST)

Government:
Tariffs & demand industries (autos, sheeps)

No Private Sector:
But later privatization
From GPG model to FLG (Foreign actor-local firm-Government) Model

<table>
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<tr>
<th>1st Stage</th>
<th>GPG0</th>
<th>F-L-G0</th>
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<tr>
<td>Tech Transfer/R&amp;D</td>
<td>PRO/Foreign Actor</td>
<td>Foreign Cooperation partner</td>
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<tr>
<td>production</td>
<td>SOEs/Private firms</td>
<td>Local firm (private, SOEs)</td>
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<tr>
<td>market</td>
<td>Gov't</td>
<td>Gov't</td>
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<tr>
<td>promotion/protection</td>
<td>Gov't</td>
<td>Gov't</td>
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<tr>
<th>2nd Stage</th>
<th>GPG1</th>
<th>FL-P-G (FLG1)</th>
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<tbody>
<tr>
<td>R&amp;D</td>
<td>PROs/Univ.s</td>
<td>Joint R&amp;D by foreign &amp; Local PROs/firms</td>
</tr>
<tr>
<td>production</td>
<td>private firms</td>
<td>Local Private Firms</td>
</tr>
<tr>
<td>market</td>
<td>Gov't</td>
<td>Gov't</td>
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<tr>
<td>promotion/protection</td>
<td>Gov't</td>
<td>Gov't</td>
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<tr>
<th>3rd Stage</th>
<th>GPG2</th>
<th>G-P-G2 (FLG2)</th>
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<tr>
<td>R&amp;D</td>
<td>public &amp; Private Joint R&amp;D</td>
<td>Local public &amp; Private Joint R&amp;D</td>
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<tr>
<td>production</td>
<td>private firms</td>
<td>Local Private Firms</td>
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<tr>
<td>market</td>
<td>Gov't</td>
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<td>promotion/protection</td>
<td>Gov't</td>
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<th>4th Stage</th>
<th>GPG3 (PG)</th>
<th>G-P-G3 (FLG3)</th>
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<td>R&amp;D</td>
<td>private firms</td>
<td>Local Private Firms</td>
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<tr>
<td>production</td>
<td>private firms</td>
<td>Local Private Firms</td>
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<tr>
<td>market</td>
<td>None</td>
<td>None</td>
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Examples of F-L-G Model:
Green Revolution & SRI

1) Green Revolution:
   → saved over a billion from starvation.
   • In response, Governments/regions expanded roads, irrigation systems and electrical power supply to support farmers to adopt the new technology.
   • International lending: also prioritized for this

2) System of Rice Intensification (SRI): in 40 countries
   SRI first assembled in Madagascar in 1983;
   - but spread to the world with Cornell Univ. participation
   -- India one of the biggest beneficiaries
Two kinds of upgrading via capability building

1) Upgrading in the same Industry  
   (moving into higher value segments)  
   = intra-industry diversification

2) Upgrading by entry into new (higher VA) industries  
   which results in inter-industry diversification

-> Examples from East Asia
3 Stages: OEM – ODM – OBM:
Upgrading in a given sector into higher value segments

<table>
<thead>
<tr>
<th></th>
<th>Assembly/Production</th>
<th>Design (R&amp;D)</th>
<th>Marketing</th>
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<tbody>
<tr>
<td>OEM</td>
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<td>ODM</td>
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<tr>
<td>OBM</td>
<td>0</td>
<td>0</td>
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→ Often not easy or quite difficult;
   Many stuck in OEM Trap (low end good production)
Trends of Sales by Aurora World
with 1992 the year of own brand marketing
showing “U” shaped OEM trap over 1991–97
(unit: million Won)
Upgrading in the same industry: Value Chain in Semiconductor Sector

IC Design → IC Mask → IC Wafers → IC Fabrication → Equipment → IC Testing → IC Packaging → Materials

Value-added chain

High value-added
Low value-added
Korea’s Entries into New Industries:
Composition of Major Export Items, (% Share)
3 Steps along the Catch-up Process

1) Acquiring Design Capability
   (to move beyond OEM/assembly)

2) Targeting/Entering
   the mature/medium short-cycle sectors
   or low-end segment of short cycle Sectors

3) Leapfrogging into New/Emerging
   Technologies
   in the Short-cycle Sectors
Cycle Time of Technology

- High Income countries
- Middle Income countries
- Korea and Taiwan
- Brazil and Argentina
Diversification by moving into shorter cycle technology sectors

Tech. turning point

Steel & Automobiles
Memory chip
Cell Phone
Digit TV

<table>
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<tr>
<th>Dynamics of industrial policy</th>
<th>from low- to middle-income and beyond the middle-income trap</th>
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<tr>
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<td>Low or lower-middle income</td>
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<td>Policy tools</td>
<td>Industrial policy:</td>
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<td>(tariffs, undervaluation of currency, entry control)</td>
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<tr>
<td>Access to External/Foreign knowledge</td>
<td>FDI, OEM/ Assembly work/ Licensing</td>
</tr>
<tr>
<td>Type of specialization</td>
<td>Trade specialization</td>
</tr>
<tr>
<td>Criterion of Specialization</td>
<td>Labor or resource-intensive industries</td>
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<tr>
<td>End goal</td>
<td>Competitive export industries</td>
</tr>
<tr>
<td>Background theory</td>
<td>Product life cycle (inheriting)</td>
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Suggested Examples of Upgrading in Africa

Upgrading in the same Industry
Make Flower/Coffee Higher value-added using STI (entry into more & higher value segments)

eg) Make flower insects/disease free; last longer with specific flavour/smells

Coffee: from crude coffee to processed coffee promote your own brand: “Kaffa” “Kaffa Inside” like “Intel inside”

In both: enter into R&D & distribution/marketing segments rather than just production
Second Kind upgrading in Africa

**Upgrading by entry into new industries related/unrelated diversification

a) entries into seed/plant variety industries to save or generate royalty incomes;

b) into IT services (eg: India as benchmark)

Lower entry barriers

(->English speaking IT manpower)

c) into manufacturing from mining:

eg Nigeria: oil refineries; Botswana: Diamond polishing

d) at later stages: entries into genetic engineering; biotechnologies (fusion of IT and biology)
Concluding Remarks
Overall Message

Now = paradigm shift in energy and climate change
-> offering potential for leapfrogging by the South.
However, to realize this potential,
   need to build up technological capabilities and have
   enhanced access to global knowledge.

Reviewed the experience of selected developing countries in
   capability building and policy options

   To find: while private firms emerge to play critical roles,
    Governments provided strategic framework to nurture the
   growth of the both old and new industries.

   -> From G-P-G to F-L-G Model of Stages of Capa. Building
Recommendations

1) Environment-friendly technologies as global public goods; to be promoted by shared incentives for early adoption.

2) From protection of IT to more use of IP:
   - Broad research exemption for experimental users;
   - Judicial power to require nonexclusive licensing in the spirit of anti-blocking or public interest;
   - petite patents (utility model) as alternative IPRs

3) Latecomers: Policy space to nurture their local firms (need to reform of global rules and governance)

4) New forms of cooperation and technical assistance: such as LFPs, STI doctors; UNIDO programs

5) Potential for South-South cooperation in the area of technology transfer and leapfrogging.
References (www.keunlee.com)

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- Lee, Keun, & BY Kim,”Both Institutions & Policies matter but differently at different income levels: long run economic growth,: World Development (2009)