Technology, Innovation and Development: why policy matters

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Outline

• Technology, innovation and economic growth and development
• Innovation and how it is created
• Why national policies are essential
• What national policies are relevant
• Conclusions
Technology and economic growth (1)

Standard neoclassical growth theory

\[ Y = f(K, L, T) \]

\[ Y = f(K_p, K_h, L, T) \]

\[ Y = T \cdot f(K_p, K_h, L) \]

Output or GDP (\(Y\)) depends on physical capital (\(K_p\)), human capital (\(K_h\)), labour (\(L\)), and technology (\(T\))

Technology (\(T\)) is exogenous (external) ie unexplained
Technology and economic growth (2)

- Economic growth is directly a function of Kp, Kh and improved technologies (factor productivity).
- Controversy over the relative importance of each.
- Additional growth determinants: Initial conditions; institutions and incentive structures; geography; national policies; perhaps culture.
Innovative Capabilities and Income

(from UNCTAD LDCR 2007)

Real per capita income and innovative capabilities, 2001
Wide innovation capability gaps exist among countries and regions
(from UNCTAD, WIR 2005)

<table>
<thead>
<tr>
<th>Region</th>
<th>1995</th>
<th>2001</th>
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<tbody>
<tr>
<td>Developed countries (excl. new</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU accession members)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004 accession EU members</td>
<td>0.655</td>
<td>0.707</td>
</tr>
<tr>
<td>South-East Europe and CIS</td>
<td>0.602</td>
<td>0.584</td>
</tr>
<tr>
<td>South-East and East Asia</td>
<td>0.492</td>
<td>0.518</td>
</tr>
<tr>
<td><strong>West Asia and North Africa</strong></td>
<td><strong>0.348</strong></td>
<td><strong>0.361</strong></td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>0.375</td>
<td>0.360</td>
</tr>
<tr>
<td>South Asia</td>
<td>0.223</td>
<td>0.215</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>0.157</td>
<td>0.160</td>
</tr>
</tbody>
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Factors reflected in the UNCTAD Index:
- R&D personnel/million population;
- U.S. patents granted per million population;
- Scientific publications/million population;
- Literacy rate as % of population;
- Secondary enrolment as % of age group
- Tertiary enrolment as % of age group
### UNCTAD – Innovation Capability Index components

<table>
<thead>
<tr>
<th>Human capital Index</th>
<th>Technological Activity index</th>
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</thead>
<tbody>
<tr>
<td>Literacy rate as % of population X 1</td>
<td>R&amp;D personnel per million population</td>
</tr>
<tr>
<td>Secondary school enrolment as % of age group X 2</td>
<td>US patents granted per million population</td>
</tr>
<tr>
<td>Tertiary enrolment as % of age group X 3</td>
<td>Scientific publications per million population</td>
</tr>
</tbody>
</table>
Why STI is important

• Building strong national STI (SeTI) capabilities, accessing foreign technologies and building strong national systems of innovation are important for:
  - economic growth
  - social welfare
  - environmental challenges
  - sustainable development
SeTI applications

- improving productivity - in agriculture, industry
- increasing value added - in agriculture, industry
- diversifying production (structural transformation)
- mitigating/adapting to climate change - affecting Africa strongly (especially agriculture)
- Adopting new energy sources - a huge problem across Africa
- Managing natural resource use (fish, oil and gas, minerals)
- conserving water in agriculture
- improving public services (health, education)
- addressing disease epidemics
- organizing mega-cities (smart urban planning, sustainable cities)
- slowing desertification etc.
What is technology?

• Technology - knowledge applied to the production of goods or services or solving practical problems. (Often tools to convert inputs into outputs).

• Different forms:
  - physical machinery (embedded Kn)
  - production processes (embedded Kn)
  - software (embedded Kn)
  - codified + tacit knowledge

• ToT is transfer of machinery + knowledge
What is innovation?

• Narrow definition: Frontier innovation: Introduction for first time by a firm or organization of a product, process or organizational method new to the world.

• Broad definition: The introduction of new or significantly improved products, processes or organizational methods in the design, production and distribution of goods and services.

New → new to a firm, market, country or the world (Oslo Manual)
Frontier vs local innovation

• At frontier vs. behind frontier.
• At frontier – new to the world (global inno) - innovation leaders
• Behind frontier – new to country (national inno), new to market or firm - innovation followers
• Two important questions:
  1. Who leads? Who follows?
  2. Can followers catch up? How to catch up?
Manufacturing firms introducing product innovations (as % of product innovating firms in manufacturing)

(source: InnovaLatino 2011)
Innovation vs invention: the science push model of innovation:
Types of innovation

- Across value chain: design, production, distribution, marketing.
- Technological (related to the introduction of new technologies) vs. non-technological (organizational, managerial or institutional).
- Based on formal training and R&D vs. based on informal learning, trial and error, use and experience.
- Direction: sustaining vs. disruptive.
- Nature of process: Open vs closed.
- Size of impact:
  - Incremental/marginal (small improvements)
  - Radical (major breakthroughs)
  - Revolutionary (fundamentally important new technology).
Some African examples

- Agriculture: goats milk production, Mauritania.
- Aeronautics: development of components subcontracting production in Morocco
- ICTs: mobile money (mPesa of safaricom in Kenya).
What drives innovation?

• Two basic conceptual approaches:
• Linear approaches
• The systems approach
Linear models of innovation
Policy implications of linear approaches

**Linear approaches**: Science/technology-push and market-pull models

1a: Science-push:
   - basic and applied science (R&D) → Innovation

1.b: Market-pull:
   - market needs → R&D → innovation

Key market failure is R&D under-investment
Policy implication: more R&D → more innovation
Sources of Technological innovation in LDCs and ODCs, 2000-2005 (source: UNCTAD, LDCR 2007)

The chart illustrates the percentage of firms in LDCs and ODCs that obtained technological innovation from various sources over the period 2000-2005. The sources include:

- New machinery or equipment
- Key personnel
- Internal R&D
- Collaboration with customers
- Trade fairs
- Collaboration with suppliers
- Consultants
- Business or industry associations
- Licensing from domestic sources
- Licensing from international sources
- Transferred from parent company
- Universities, public institutions

The chart shows the distribution of firms across different LDC and ODC categories, with each bar representing a different source of technological innovation.
Innovation systems: conceptual frameworks

- **Systems approach**: Innovation created within complex, dynamic system
- **IS**: networks that help actors within the network to access, create and diffuse knowledge, technologies and innovations (and to learn, understand and use them).
- Types of IS: Global; national; sub-national: regional, local; sectoral (by industry)
National systems of innovation
(source: Arnold and Bell (2001))

Framework conditions
- Financial environment
- Taxation and incentives
  - Propensity for innovation and entrepreneurship
- Trust
- Mobility
  - Education, Literacy

Demand
- Consumers (final demand)
- Producers (intermediate demand)

Business system
- Companies
- Farms
- Healthcare, etc

Intermediate Organizations
- Research institutes
  - Brokers, etc

Education and research system
- Professional education and training
  - Higher education and research
  - Public sector research

Infrastructure
- Banking, venture capital
- IPR and information system
- Innovation and business support system
- Standards and norms
A national innovation system

(source: UNCTAD, Framework for STI Policy Reviews)
National systems of innovation
(source: OECD (1999))
Policy implications of a systems approach

• Strong innovation systems improve innovation performance.
• Innovation systems may not develop spontaneously, or perhaps very slowly.
• Therefore policy action is critical.
Policy implications of a systems approach

**Systems approach:** Innovation created within complex, dynamic system

Implications?

Policy implications: policies for R&D + others - networks, linkages, institutions, knowledge system, capabilities, financing, infrastructure etc.
Can you build innovation systems?

- Strong innovation systems may develop only very slowly.
- Developing countries have emerging, incomplete, weak innovation systems.
- NSI are context specific, have historical roots.
- National policies can accelerate development.
- Problem: How to build them not well understood.
- Policy experimentation and policy learning needed.
China innovation policy and institutional reform

(source: OECD, National IP Systems, 2014)
Stages of technology development by innovation effort
(from UNCTAD, WIR 2005)

- **FRONTIER INNOVATION**
  - Improve products, processes, skills etc. to raise productivity and competitiveness

- **TECHNOLOGY IMPROVEMENT & MONITORING**
  - Change products and processes, plant layout, productivity management and quality systems, procurement methods and logistics to adapt technology to local or export market needs.

- **SIGNIFICANT ADAPTATION**
  - Train workers in essential production and technical skills; reach plant design capacity and rated equipment performance levels; configure products and processes; set up essential quality management systems; institute supervisory; procurement and inventory management systems; establish in and out-bound logistics.
Building STI capabilities

• Accessing knowledge/technology + learning
• **Learning** is key to building capabilities.
• Learning requires effort + investment.
• Learning is gradual, cumulative.
• **Technological learning** by enterprises (firms and farmers).
• **Policy learning** by policy makers.
Building innovation capabilities in Indian auto firms (source: Kale, 2012)
Common STI challenges in developing countries

1. Excessive focus on S&T, R&D (not STI/innovation)
2. Low familiarity with and priority on STI/innovation
3. Enduring linear thinking on innovation
4. Inadequate coordination at policy level
5. Lack of STI policy/strategy or weak implementation
6. Inadequate government support for STI
7. Weak human capital (STEM assets)
8. Weak innovation systems (collaboration, linkages)
9. Difficult "framework conditions"
10. Physical infrastructure challenges
11. Limited innovation financing
12. Weak private sector, little investment in T&I
13. Low private sector R&D; limited public sector R&D
14. R&D not linked to industry, weak commercialization
Some key STI policy goals:

- build STI capacity - including policy capacity
- Find effective, coordinated policy frameworks
- mainstream STI in national development plans
  - build strong firm/industry STI capabilities
- develop effective innovation systems, linkages
- build "absorptive capacity" - education, skills and R&D capacity
- increase and improve PROs R&D
- access knowledge/technologies (ToT)
- promote research-industry collaboration
- increase firm investment in STI, learning, skills
Relevant policy areas for STI development (1)

1. STI policy (S&T, R&D, innovation policy)
2. Institutional/organizational framework (MOST, NRC etc.) (national/regional levels)
3. Education and training (HE, TVET, skills)
4. Trade policies (export promotion, machinery imports)
5. Foreign direct investment (FDI) and TNC policies (domestic linkages)
6. Industrial policies (IP)
7. Intellectual property rights (IPR) policies
8. Technology transfer policies (ToT)
9. Strategic technology intelligence/foresight
Policy areas for STI development (2)

9. S&T infrastructure (R&D labs, equipment, ICTs)
10. Basic infrastructure (electricity, transport, water)
11. Financing policy (financing innovation – direct financing (grants, seed finance) and incentives (R&D, training tax credits))
12. Macroeconomic policies (stability, r, er)
13. Migration policies (skilled migrants and brain circulation)
14. Cluster policies (S&T parks (STPs), industrial parks/districts, SEZs, FTZs)
Policy areas for STI development (3)

15. MSME (micro-enterprise, SME) policies
16. Supporting innovative firms (incubators, inno centers, accelerators)
17. Entrepreneurship policies
18. Competition policies
19. Metrology, standards, testing and quality (MSTQ) policies - enforce standards, force upgrading
20. Demand side policies - public procurement
21. Developing STI indicators (tool for PM’s - monitoring)
Institutional framework for STI

Issues: (1) resolving conflicting interests of government ministries/departments; (2) coordinating STI across government ministries/depts.

- Key ministries and interests:
  1. Ministry of S&T – often focused narrowly on R&D
  2. Ministry of Trade and Industry - relevant education and skills, manufacturing sector, exports, trade agreements (possibly technology & innovation)
  3. Ministry of Labour – relevant education, skills (matching skills to industry – supply to demand)
  4. Ministry of Education – access to/quality of education
  5. Ministry of Finance – budget (revenue & exp., public debt), balance of payments
  6. Ministry of Agriculture – farming, rural development
Thailand STI system governance

Source: (Durongkaveroj, 2014a)
Singapore STI governance structure
Germany research and innovation governance
(source: erawatch Germany country report 2012)

[Diagram showing the governance structure of Germany's research and innovation system, including federal and state institutions, funding organizations, and key acronyms.]

Research Organisations by Institutional Funding:
- Federal: FGL
- Federal and Industry: AiF/IfG
- Federal and States: DFG, FhG, HGF, MPG, WGL, AoS
- States: HEIs, LGL

Key Acronyms:
- BMWi: Federal Ministry of Economics and Technology
- BMBF: Federal Ministry of Education and Research
- FhG: Fraunhofer Society
- MPG: Max Planck Society
- WGL: Leibniz Association
- AoS: Academies of Sciences
- HEIs: Higher Education Institutions
- FGL: Federal Government Research Organisations (Federal Agencies)
- DFG: German Research Foundation
- AiF: Association of Industrial Research Institutes
- IfG: Institutes of Co-operative Industrial Research
- KfW: KfW Banking Group - State-owned bank (80% Federal Government, 20% States)
- GWK: Joint Science Conference of the Federal Government and the Federal States
- LGL: Länder Government Research Organisations (State Agencies, other research institutions funded through State governments)
- EFI: Expert Commission on Research and Innovation
Policy tool 2: National STI policy framework

• The focus of policy framework important.
• Evolution: Science policy $\rightarrow$ technology policy $\rightarrow$ STI/innovation policy

Science policy – focus on science education, scientific research (basic), scientific infrastructure and human resources

Technology policy – focus on accessing, creating technologies, technology infrastructure, specific technologies, IPRs

STI/Inno policy – focus on building technological/inno capabilities, mainly firms and farmers, broader innovation system, innovation incentives/disincentives & support
Thailand country strategy 2014

Getting out of the middle-income trap

Growth & Competitiveness

Improving internal process

Improved infrastructure, R&D, and productivity

Better governance and public management

Inclusive Growth

Reducing social disparity

Human security, human development and quality of life

Green Growth

Increasing environmental friendliness

Improved infrastructure, R&D, and productivity

Regulations

Improved infrastructure, R&D, and productivity

Human security, human development and quality of life

Improved infrastructure, R&D, and productivity

Increasing environmental friendliness

Improved infrastructure, R&D, and productivity

Human security, human development and quality of life

Improved infrastructure, R&D, and productivity

Increasing environmental friendliness

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Better governance and public management

Improved infrastructure, R&D, and productivity

Reducing social disparity

Inclusive Growth

Improved infrastructure, R&D, and productivity

Human security, human development and quality of life

Increased social equality

Increased social equality
Financing of innovation

Issue: Investment in innovation is low in most developing countries

Problem: Investment in T and innovation is risky/undertain. Financing is often scarce.

• Investment in R&D a rough proxy for investment in innovation
• GERD to GDP low in most developing countries - especially LDCs.
• GERD performed by business enterprises is especially low in much of Africa.
• African financial systems often not serving micro and small firms, innovative firms, new startups.
### Policy tool eg. Financing innovation: instruments

<table>
<thead>
<tr>
<th>Direct financing: Private</th>
<th>Direct financing: public</th>
<th>Indirect financing</th>
</tr>
</thead>
</table>
| - Personal savings, family, friends and partners  
- Retained earnings  
- Business Angel finance  
- Venture capital  
- Commercial bank loans  
- Stock exchange  
- Bonds  
- Value chain financing  
- Microloans  
- Crowdfunding  
- Innovation prizes | - Seed finance schemes  
- Co-investment funds  
- Innovation or technology funds  
- Development banks  
- Innovation prizes  
- International development assistance | - Tax incentives (tax credits, allowances, deductions)  
- Public loan guarantees  
- Public R&D spending, business-academic-government R&D partnerships |
Successful examples of innovation financing

- R&D grants: USA, Small Business Innovation Research (SBIR) program (1982).
- Seed finance: Chile, Start-Up programme (2010).
- Seed finance, angels and VC: Brazil, INOVAR programme (2000)
- Seed finance & VC: Finland, PreSeed Finance Program (2001).
- Start-up funds: Germany, High-Tech Start-up Fund (2005).
- VC: Israel, Yozma Program (1992)
Innovation financing mixes in Asian NIEs

• Singapore: grants for POC, technology incubation scheme, early stage VC, innovation vouchers for SMEs; R&D tax credits; building clusters.

• Republic of Korea: VC financing, credit guarantees; payroll tax on large firms to finance training; R&D tax credits.

• Taiwan POC: Low interest loans (banks); SME financing; technology financing; Building STPs with financing schemes (HSIP).
Conclusions

• STI important for: growth, social welfare, environment, sustainable development.
• Strong innovation systems, STI capabilities improve innovation performance.
• Innovation systems and capabilities may not develop spontaneously.
• National policy action is critical.
Some issues for the Middle East

- How is the Middle East's (West Asia's) performance on STI?
- How can the region’s countries improve their STI performance?
- Are countries in region taking enough policy action?
- What can they learn from recent cases of successful technological and economic catch-up?
- What should policy makers do?