Project on Innovation and Access to Technologies for Sustainable Development

Sustainability Science Program, Harvard Kennedy School Fellows’ Orientation
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Overview

1. Motivation
2. Key concepts
3. Project research questions & approach
4. 3 Main Contributions
   – Scalable model of innovation system
   – Sociotechnical conditions (STCs) for comparative analysis of technologies and system barriers across sectors
   – Typology of transnational functions
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Sustainable Development Objectives

Among others:

• **Food** security
• Access to sustainable **energy** for all
• **Health** as component and indicator of sustainable development
• Access to safe drinking **water** and sanitation
• Cleaner industrial production of **goods**

For present and future generations

What technologies might help to secure these goals?
Motivation for the Research

• **Insufficient research**: Neglected diseases, neglected crops
• Indoor cookstoves not suited for local foods
• Water desalination and purification technology requires infrastructure that doesn’t exist
• Vaccines to prevent cervical cancer that are **too expensive**
• A system to improve rice yield largely **ignored by experts**
• **Few firms adopt** less toxic methods to manufacture chemicals

→ Underperforming global innovation systems
→ How? Why? What to do (at transnational level)?
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Global innovation system: Why?

• Empirical:
  – Innovation processes increasingly transnational: intensified cross-border flows of knowledge and ideas, capital, goods, services, people, with globalization
  – Threats to sustainable development increasingly transnational: cross-border flows of pollutants, pathogens, scarcity, volatility
  – Knowledge at the heart of technological innovation – major externalities, potential to be a global public good

• Normative: Sustainable development as global goal

• Practical:
  – Realizing benefits and reducing harms of technological innovation for sustainable development likely to require transnational arrangements
Global innovation system: Why?

• Scholarship & Policy:
  – Innovation policies: primarily national in motivation & scope
  – Conceptual frameworks to understand, design and evaluate policies primarily national
  – Unlikely to capture the complex dynamics of increasingly globalized innovation systems,
  – Unlikely to provide adequate understanding of how to make such systems work better for sustainable development.
  – Need frameworks and research to enhance understanding of complex transnational innovation processes
Global innovation system: What?

- **Definition**: the actors and institutions whose interactions shape the innovation process beyond national borders.

- **Actors**: individuals and/or organizations with agency in the system
  - Individuals: farmers, scientists or entrepreneurs, and
  - Organizations: governmental bodies; intergovernmental organizations; private firms; not-for-profit entities; research organizations; community-based organizations; collaborative entities that link multiple organizations, such as public-private partnerships.
  - Public, private, academic, non-profit, or hybrid, operating local to global level.

- **Institutions**: sets of formal and informal rules, norms, decision-making procedures, beliefs, and expectations that govern the interaction of actors.
  - Formal binding intergovernmental agreements
  - Non-binding normative texts (e.g. post-2015 Sustainable Development Goals);
  - Less formally codified norms (e.g. voluntary codes of conduct among firms)
  - Emerging discourses around rights to energy, a clean environment, or sanitation.

- Sector/Technology specific: e.g. “global innovation system for seeds”
Definition of Technology

- **Technology**: “knowledge of how to fulfill certain human purposes in a specifiable and reproducible way (Brooks)” including devices and methods or processes, as well as “assemblages of practices and components” and the “collection of devices and engineering practices available to a culture (Arthur).”
Global innovation system failures

Innovation system inadequate...
• ...for problems affecting populations with relatively weak political or economic power (1,2,3)
• ...for problems with large positive externalities across borders or generations (1,2,3)
Sectors & Technologies

Global Innovation System

- Agriculture
- Energy
- Water
- Health
- Manufacturing
Sectors & Technologies & Institutions

Global Innovation System

- Agriculture
- Energy
- Water
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- Health

Institutions
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Key Research Questions

1. How and why does the global innovation system fail to maximize the potential of science and technology to contribute to sustainable development?

2. How can the system be strengthened to do so?
<table>
<thead>
<tr>
<th>Building on prior work</th>
<th>Project Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>National innovation systems</td>
<td>Global innovation “system”</td>
</tr>
<tr>
<td>Focus on one stage, e.g., invention</td>
<td>Incorporate all stages into a complex system</td>
</tr>
<tr>
<td>Meet present needs, without compromising future generations’ needs</td>
<td>Yes...with special attention to equity</td>
</tr>
<tr>
<td>Focus on actors, or institutions, or technologies</td>
<td>Focus on actors + institutions + technologies (and on transnational interventions)</td>
</tr>
<tr>
<td>Focus on one sector / need / field or type of technology</td>
<td>Cross-sectoral comparison &amp; learning, technologies broadly defined</td>
</tr>
</tbody>
</table>
Project to Date

1. Development of common framework of actors, institutions, and innovation stages
2. Background papers on each sector building on existing literature
   - Evolution of international norms
   - Description of the key actors & institutions in each sector
   - Summary of major gaps in information needed to understand the system
3. 18 case studies
4. Synthesis Paper
5. Spring ‘14 Major academic workshop with workshop report
18 cases across 5 sectors
Spanning different technology development phases, technology types, and novel strategies

**Energy**
- Rural PV - Bangladesh
- Cookstoves - Sudan & Ethiopia
- Carbon capture and storage - USA
- Geothermal - Kenya

**Health**
- Heat stable vaccines – USA, global
- Ready to use therapeutic foods – France, global
- AMF Malaria - SSA, etc
- Cancer treatment - India

**Agriculture/Food**
- Biopesticides - Kenya
- Cassava bread - Nigeria
- Cocoa genome - USA
- Drip irrigation – India, Africa
- System of rice intensification - India

**Water**
- Wastewater reuse – Australia, Middle East
- Ceramic pot filters – Ghana
- Apps for water sanitation - global

**Manufacturing**
- Industrial symbiosis – Denmark, S Korea
- Higg Index
Overview

1. Motivation

2. Key concepts

3. Project research questions & approach

4. 3 Main Contributions
   – Scalable model of innovation system *(description)*
   – Sociotechnical conditions (STCs) for comparative analysis of technologies and system barriers across sectors *(diagnosis)*
   – Typology of transnational functions *(recommendation)*
Scalable model of innovation systems

Knowledge Stock
- Risk-adjusted cost of invention
- Murriniveness

Invention Mechanisms
- Accidental discovery
- Goal-oriented search
- Repurposing

Selection Mechanisms
- Selection by agents at social distance
- Selection by policy (regulations and national objectives)
- Agents who select on behalf of users

Initial Adoption Mechanisms
- Marketing
- Relative prices
- Benefits to early adopters
- Behavior and culture
- Information

Feasible Technology Stock
- Relative production and adoption cost
- Size of manufacturing or adopting organization
- Infrastructure needs
- Intellectual property protection
- Standards or guidelines for manufacturing or adoption

Production Mechanisms
- Manufacturing, codification, and dissemination

Technologies in Limited Production / Use Stock
- Relative costs to users
- Infrastructure needs
- Standards or guidelines for use
- Social distance between users
- Revealed disadvantages
- Network externalities

Widespread Use Mechanisms
- Marketing
- Relative prices
- Benefits to adopters
- Behavior and culture
- Information

Network Effects

Retirement Mechanisms
- Risk assessment

Obsolete Inventions and Retired Technology Stock
- Available of substitute technologies
- Knowledge about performance of technologies at scale
- Knowledge about harms of current technology
- Presence of entrenched incumbents

Adaptation Mechanisms
- Intentional re-design by non-users
- Re-design by end-users, learning by doing, learning by using

Basic research, experiential knowledge advancement
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Process for identifying commonalities across cases

1. Tried to compare cases across the whole innovation process
2. We then hypothesized that cases may share features at different points in the innovation system

Splitting cases according to bottlenecks to identify shared characteristics

Socio-Technical Conditions (STCs)

Splitting cases according to characteristics to identify shared bottlenecks
What are socio-technical conditions (STCs)?

- Properties relevant for explaining the extent to which different technologies were able to flow and evolve between stocks

- “Socio-technical” encompasses both technological aspects, and the social practices and context that relate to the technology

- Certain STCs can inhibit the flow of technology between stocks
Sets of socio-technical conditions by flow

From Knowledge to Invention Stock (invention)
- Risk-adjusted cost of invention
- Mundaneness

From Invention to Feasible Technology Stock (selection)
- Selection by agents, selection by laws
- Mundaneness
- IP
- Modularity

From Feasible Tech. to Tech. in Limited Use Stock (production/initial adoption)
- Relative prod. & adopt. cost
- Size of adopting entity
- Infrastructure needs
- IP
- Standards and guidelines

From Tech in Limited Use to Widespread Use Stock (production/adoption)
- Relative prod. & adopt. costs
- Infrastructure needs
- Standards and guidelines
- Revealed disadvantages
- Network externalities

From Widespread Use to Other Stocks (adaptation)
- Social distance between users
- Capability of users
- Modularity of technology

Flow into Obsolete Stock (obsolescence)
- Availability of substitute technologies
- Knowledge about performance and harms at scale
- Presence of incumbents
- Standards and guidelines
Identified sets of conditions that inhibit flows
e.g., ceramic water filters and cookstove cases

- **Invention**
  - Both: high risk-adjusted cost of invention and mundane
  - Developed in an ad-hoc fashion by researchers in the US in their “free time” due to funding scarcity and lack of incentives
  - Generally they do not get invented through ‘goal-oriented search’

- **Selection**
  - Ceramic filters selected by agents, cookstoves by agents working with users
  - Cookstoves seem to have resulted in greater and more long-lasting demand
Uses of the innovation framework and the concept of socio-technical conditions

- STCs allow us to identify what successful strategies in some of our cases may be applicable to others within our set of cases.

- Checklist of things to think about when deciding to promote a particular technology (at all scales) ➔ diagnosis.

- Common terminology to enable discussions across practitioners and scholars in various sectors.

- Applied at the global level, we have tentatively identified system gaps for technologies with specific STCs.
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3 types of transnational functions

1. **Core functions**: cannot be performed by any one nation-state alone (e.g. cross-border externalities)

2. **Facilitating functions**: can make the system work more efficiently or effectively (e.g. economies of scale)

3. **Supportive functions**: to support countries with shortage of necessary resources (e.g. information, expertise, skills, financing, normative authority, or convening power).
<table>
<thead>
<tr>
<th>Type</th>
<th>Sub-function</th>
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<tbody>
<tr>
<td>Core</td>
<td>1. Negotiating norms, rules, standards</td>
</tr>
<tr>
<td></td>
<td>2. Managing transnational externalities</td>
</tr>
<tr>
<td>Facilitating</td>
<td>3. Setting transnational/global goals, priorities and agendas</td>
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<td></td>
<td>4. Reducing information asymmetries</td>
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<tr>
<td>Supportive</td>
<td>5. Reducing social distance between local populations and transnational actors</td>
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<td></td>
<td>6. Building capacity</td>
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<tr>
<td></td>
<td>7. Reducing (financial) costs</td>
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<td></td>
<td>8. Reducing risk</td>
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</tbody>
</table>
**Using STCs to prescribe functions**

<table>
<thead>
<tr>
<th>Sociotechnical condition</th>
<th>Transnational function</th>
<th>Case study examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>High relative costs to users (impeding flow from limited to widespread use)</td>
<td>Reduce costs</td>
<td>- Global subsidy on malaria medicines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Drip irrigation</td>
</tr>
<tr>
<td>Absence of standards and guidelines (impeding flow from feasible technology to limited use)</td>
<td>Negotiate norms, rules, standards</td>
<td>- Higgs Index for “cleaner” clothing manufacturing</td>
</tr>
</tbody>
</table>

- Global subsidy on malaria medicines
- Drip irrigation
- Higgs Index for “cleaner” clothing manufacturing
<table>
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<th>Resource needed to perform function</th>
<th>Transnational Functions</th>
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<tbody>
<tr>
<td>a) Normative authority</td>
<td>Set goals, priorities &amp; agendas</td>
</tr>
<tr>
<td></td>
<td>Reduce transaction costs</td>
</tr>
<tr>
<td></td>
<td>Internalize externalities</td>
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<tr>
<td>b) Convening power</td>
<td>Reduce transaction costs</td>
</tr>
<tr>
<td></td>
<td>Reduce social distance</td>
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<tr>
<td></td>
<td>Build capacity</td>
</tr>
<tr>
<td></td>
<td>Internalize externalities</td>
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<tr>
<td>c) Information</td>
<td>Reduce transaction costs</td>
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<tr>
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<td>Reduce information asymmetries</td>
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<td></td>
<td>Reduce social distance</td>
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<tr>
<td></td>
<td>Reduce risks</td>
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<tr>
<td>d) Expertise/skills</td>
<td>Build capacity</td>
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<tr>
<td>e) Finance</td>
<td>Internalize externalities</td>
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<td>Reduce (net) costs</td>
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Some proposals for consideration:

When invention involves high costs or risks (eg medicines, cookstoves)
→ internationally-pooled funds to reduce R&D costs and risks.

When end-user is a small organization or entity (eg farming household)
→ international support for training and information provision, eg extension services.

When high relative prices to end-users for highly beneficial technologies
→ international subsidization in the short- or longer-run.

When high social distance between inventors and selectors
→ transnational convening or information provision
Summary & Conclusions

1. Common framework (across sectors, stages, technologies) for describing, diagnosing and recommending policies to strengthen the global innovation system for sustainable development

2. Not a blueprint for monolithic global system → recommendations specific to technology, & context

3. Emerging global innovation system → more robust transnational institutional arrangements needed
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THANK YOU