Geography & Innovation: Exploring the Drivers of National Innovative Capacity

SMG Breakfast Briefing
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* These slides build on research conducted with & presentations prepared by Michael Porter (HBS) & Scott Stern (Kellogg). The presentation also draws data from multiple projects and papers, so tables & figures may vary in their underlying datasets. All errors are my own.
Questions to start the morning

1. Why are some countries more innovative than other countries?

2. Why are some regions of the USA more innovative than other regions?

3. As telecommunications advance, location no longer seems to matter – individuals and firms can locate & thrive anywhere.
   - do you agree or disagree?
Two key motivating facts

- Historically, the club of the world’s most innovative countries has been relatively small
  - and leadership in the club has been stable over time

1. The club has expanded
   - as some previously industrializing countries have devoted increasing share of resources to innovation
     - e.g., S-Korea, Ireland, Israel, Taiwan, Singapore

2. The gap between the most innovative and the rest in the club has narrowed
   - less innovative members have improved their innovative capacity to a greater rate than the historically most innovative members
Who am I? (I)

- Grew up in **Philadelphia**
- Undergraduate studies
  - University of Pennsylvania (B.A., Psychology)
  - U. Penn - Wharton (B.S., Economics)
- Work experience
  - Health Care Consulting (DC)
  - Fulbright Scholarship – WZB (Berlin, Germany)
- Graduate School
  - MIT - Sloan School (PhD)
  - additional research experience at Wharton & HBS
Who am I? (II)

- **Boston University** *(since 2001)*
  - Assistant Professor - Strategy & Policy
  - **Teaching:**
    - Strategic Management
    - Technology Strategy

- **Research on innovation & strategy**
  - Why are some **countries** more innovative than others?
  - Why are some **pharmaceutical firms** are better at coming up with new drugs than others?
    - How do firms choices about where to put their laboratories affect their productivity?
  - How do **institutions** affect scientific progress?
  - What is the effect of the Bush Stem Cell Policy on regional scientific advantage?
  - [http://people.bu.edu/furman](http://people.bu.edu/furman)
Issues for the Morning (I):
Location, Innovation, & Strategy

- **Location Paradox:**
  - despite improvements in innovation technology that ease communication across great distances, location has not become irrelevant to economic activity
  - if anything, location has become more important
    - cities & regional clusters experienced resurgence since 1990s
    - e.g., life sciences in MA, wine in CA, oil in TX, med tech in MN
    - *local characteristics can aid firm competitiveness & innovation*

- **Location, Innovation, & Strategy lessons:**
  - firm-level
  - region-level
  - country-level
  - planning
  - implementation
Issues for the Morning (II):
Key questions about Location & Innovation

- Why are some regions (countries) more innovative than others?
  - What regional (national) characteristics lead to innovative leadership (stagnation)?

- Why does it matter?
  - for society / for the economy?
  - for specific firms?
Innovation, Competitiveness, & Prosperity

For *advanced economies*, the ability to innovate at the global frontier is crucial for maintaining competitiveness in the face of evolving regional and national challenges.

- **Innovative Capacity**
- **Competitiveness (Productivity)**
- **Prosperity**
Innovation, Competitiveness, & Prosperity

For **firms** in advanced economies, the ability to access knowledge at the global frontier & the need to compete with world-class rivals encourages continuous upgrading of firm capabilities and competitive position.

- Local Innovative Capacity
- Competitiveness among Rivals (Productivity)
- Competitive Position
Sources of Prosperity

- A nation’s or region’s standard of living (wealth) is determined by the productivity with which it uses its human, capital, and natural resources. The appropriate definition of competitiveness is productivity.
  - productivity depends both on the value of products and services (e.g. uniqueness, quality) as well as the efficiency with which they are produced.
  - it is not what industries a nation or region competes in that matters for prosperity, but how firms compete in those industries
  - productivity in a nation or region is a reflection of what both domestic and foreign firms choose to do in that location. The location of ownership is secondary for prosperity.
  - the productivity of “local” industries is of fundamental importance to competitiveness, not just the productivity of industries engaged in int’l trade

- Nations or regions compete in offering the most productive environment for business
- The public and private sectors play different but interrelated roles in creating a productive economy
Background:
Key facts about Location & Innovation

- Historically, new-to-the-world innovation has been concentrated in only a few locations
  - 1800s: UK → Germany
  - 1900s: USA & Switzerland

- Recently, sets of new countries have joined ‘club’ of world’s leading innovators
  - e.g., Japan & Germany in 1970s & 1980s
  - e.g., Sweden & Finland, in 1990s
  - e.g., some Asian economies, Israel, Ireland in 2000s
  - overall pattern of **convergence** (some catch-up)

- Nonetheless, vast differences remain across countries and across regions within countries
New-to-the-World Innovation is Concentrated in a Small Number of Regions Around the World

Data are Patents Per Million Population (2002).  Source: United States PTO
These differences have persisted historically, although a growing number of countries have joined the “innovator club”
Even with similar *initial* innovation rates, regions can diverge greatly in producing world-class technology...

<table>
<thead>
<tr>
<th>Country</th>
<th>United States Granted Patents</th>
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<tbody>
<tr>
<td><strong>Emerging Latin American Economies</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>115</td>
<td>228</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>136</td>
<td>492</td>
<td>2.62</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>12</td>
<td>60</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>Costa Rica</td>
<td>22</td>
<td>48</td>
<td>1.18</td>
<td></td>
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<tr>
<td>Mexico</td>
<td>124</td>
<td>431</td>
<td>2.48</td>
<td></td>
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<tr>
<td><strong>Emerging Asian Economies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>3</td>
<td>577</td>
<td>191.33</td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>176</td>
<td>1,694</td>
<td>8.63</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>17</td>
<td>725</td>
<td>41.65</td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>23</td>
<td>12,062</td>
<td>523.43</td>
<td></td>
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<tr>
<td>Taiwan</td>
<td>135</td>
<td>15,871</td>
<td>116.56</td>
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Even within US, there are substantial differences across regions in terms of the intensity of innovation.

Source: M-Porter, ISC, HBS
For a given industrial area, leadership is concentrated in a small number of regional locations within the United States.

- **Denver, CO**: Leather and Sporting Goods, Oil and Gas, Aerospace Vehicles and Defense
- **Chicago**: Communications Equipment, Processed Food, Heavy Machinery
- **Boston**: Analytical Instruments, Education and Knowledge Creation, Communications Equipment
- **San Francisco-Oakland-San Jose Bay Area**: Communications Equipment, Agricultural Products, Information Technology
- **San Diego**: Leather and Sporting Goods, Power Generation, Education and Knowledge Creation
- **Pittsburgh, PA**: Construction Materials, Metal Manufacturing, Education and Knowledge Creation
- **Seattle-Bellevue-Everett, WA**: Aerospace Vehicles and Defense, Fishing and Fishing Products, Analytical Instruments
- **Los Angeles Area**: Apparel, Building Fixtures, Equipment and Services, Entertainment
- **Raleigh-Durham, NC**: Communications Equipment, Information Technology, Education and Knowledge Creation
- **Atlanta, GA**: Construction Materials, Transportation and Logistics, Business Services

**Source:** M-Porter, ISC, HBS
What is Innovative Capacity?

- The potential for a region – as both a political and economic entity – to produce and commercialization a stream of innovation with potential global impact.

- Not simply the realized level of innovation, but the fundamental conditions, investments and policy choices that create the region’s environment for innovation.
Relevant literatures:
Standing on the shoulders of giants

- **Ideas-driven growth theory** *(Romer, 1990)*
  - endogenous growth theory *(macroeconomics)*
  - “production function for new ideas” depends on
    - stock of knowledge in economy and
    - level of R&D effort invested in production of new ideas

- **National Industrial Competitive Advantage** *(Porter, 1990)*
  - emphasizes microeconomic underpinnings of innovation
    in country-specific industrial clusters

- **National Innovation Systems** *(Nelson, 1993)*
  - rich descriptive accounts
  - emphasizes configuration of institutions and overall policy environment supporting innovation
The Drivers of Innovative Capacity

Common Innovation Infrastructure

Cluster-Specific Environment for Innovation

Innovation Resources
- National “Knowledge” Stock
- Innovation Policy

Quality of Linkages

Context for Firm Strategy and Rivalry

Demand Conditions

Related & Supporting Industries

Factor (Input) Conditions
The Common Innovation Infrastructure

**Innovation Resources**
- Science & Engineering Workforce
- Access to Higher and Postgraduate Education
- Availability of Risk Capital
- High Quality of Information Infrastructure

**Innovation Policy**
- Subsidy and Grant Programs
- R&D Tax Policy
- Education Policy & Funding
- Intellectual Property Protection Policy
- Openness to International Trade and Investment

**National “Knowledge” Stock**
- “Basic” Research Investments
- Cumulative Innovation Record
- Overall Technological Sophistication
Climate for Innovation-Based Local Rivalry

- A local context that encourages investment in innovation-related activity
- Open and vigorous local competition

Factor (Input) Conditions

- High quality human resources, especially scientific, technical, and managerial personnel
- Strong basic research infrastructure
- An ample supply of risk capital
- High quality information infrastructure

Demand Conditions

- Sophisticated and demanding local customers
- Customer needs that anticipate those elsewhere

Clusters of Related and Supporting Industries

- A critical mass of capable local suppliers
- Clusters of related and supporting industries and institutions to harness linkages

The Environment for Innovation in Industrial Clusters

- Economic development is a process of successive upgrading, in which the business environment evolves to support and encourage increasingly sophisticated and productive ways of competing

Avoid “picking winners” and “playing catch-up”
Innovative Capacity Depends on Strong Linkages Between Solid Infrastructure & Dynamic Clusters

Common Innovation Infrastructure

Cluster-Specific Environment for Innovation

Quality of Linkages
- Universities
- Venture Capital

Factor (Input) Conditions
- Related & Supporting Industries

Demand Conditions
- Context for Firm Strategy and Rivalry
Finally, global innovation leadership results from leveraging local innovative capacity though effective and sophisticated firm operations and strategy.

- Regional innovative capacity may be squandered through ineffective innovation management.
- Innovation leadership within a region results from integrating external resources with internal capabilities.
- R&D productivity depends on the locations at which a company’s business units are based.
- Cluster participation is an important contributor to innovative success.
Innovation, Competitiveness & Geographic Levels

World Economy

Broad Economic Areas

Groups of Neighboring Nations

Nations

States, Provinces

Cities, Metropolitan Areas

APEC

North America

United States

Texas

Houston
Assessing National Innovative Capacity

An objective, quantitative international benchmark of the *national* capacity for innovation
Quantitative measures of National Innovative Capacity

Common Innovation Infrastructure
- Personnel employed in R&D
- Share of GDP spend on secondary and tertiary education
- Expenditures on R&D
- Strength of Intellectual Property Protection
- Openness to International Trade & Investment
- GDP per capita as a proxy for demand conditions and overall productivity

Cluster-Specific Conditions
- Percentage of R&D expenditures funded by Private Industry
- Specialization

Quality of Linkages
- Percentage of R&D performed by universities
- Venture Financing
Empirical Framework

- We estimate a modified “ideas production function”

\[ \dot{A}_{j,t} = \delta_{j,t} (X_{j,t}^{\text{INF}}, Y_{j,t}^{\text{CLUST}}, Z_{j,t}^{\text{LINK}}) H_{j,t}^A \lambda \phi \]

where in country \( j \), at time \( t \)

\( \dot{A}_{j,t} \) = flow of new-to-the-world technologies

\( H_{j,t}^A \) = aggregate capital and labor devoted to R&D

\( X^{\text{INF}}, Y^{\text{CLUST}}, Z^{\text{LINK}} \) represent qualities of common infrastructure, clusters, and linkages, respectively

- The resulting econometric specification becomes

\[ L \dot{A}_{j,t} = \delta_{\text{YEAR}} Y_t + \delta_{\text{COUNTRY}} C_j + \delta_{\text{INF}} L X_{j,t}^{\text{INF}} + \delta_{\text{CLUST}} L Y_{j,t}^{\text{CLUST}} + \delta_{\text{LINK}} L Z_{j,t}^{\text{LINK}} + \lambda L H_{j,t}^A + \phi L A_{j,t} + \epsilon_{j,t} \]
Data and Measures

- Panel dataset, 1978-1999
  - Core dataset = 23 countries; *expanded dataset = 29*
  - *Sources:* CHI Research, OECD, NSF, World Economic Forum, Penn World Tables

- Measuring national innovative output
  - *“International Patents”* = number of patents granted by United States Patent & Trademark Office to a county’s inventors
  - while no measure is ideal, “international patents”…
    - reflect important fraction of overall innovation
    - measure economically significant innovations at the world’s technological frontier
  - to reflect lag, analysis uses patents in time $t+2$
Measuring the drivers of national innovative capacity

- Quality of the Common Innovation Infrastructure
  - GDP per Capita
  - Number of R&D Personnel
  - R&D Expenditures
  - Share of GDP Spent on Higher Education
  - Strength of Intellectual Property Protection
  - Openness to International Competition and Trade

- Environment for Innovation in Industrial Clusters
  - % of R&D Funded by Private Firms
  - Specialization

- Strength of Linkages
  - % of R&D Performed by Universities
  - Availability of Financing for New Ventures
Result 1: A parsimonious number of factors predict new-to-the-world innovation precisely

- Small # of factors explain nearly all of variation in national innovative output
  - i.e., the factors in our empirical model

- The innovative capacity index is closely tied to important economic measures
  - productivity (TPF)
  - economic growth (GDP)

<table>
<thead>
<tr>
<th>COMMON INNOVATION INFRASTRUCTURE</th>
<th>Dep. Var. = ln(PATENTS)_{j,t+2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>A L GDP PER CAPITA</td>
<td>0.836</td>
</tr>
<tr>
<td>A L GDP78</td>
<td>-0.289</td>
</tr>
<tr>
<td>H\textsuperscript{A} L FT R&amp;D PERS</td>
<td>0.850</td>
</tr>
<tr>
<td>H\textsuperscript{A} L R&amp;D $</td>
<td>0.556</td>
</tr>
<tr>
<td>X\textsuperscript{INF} ED SHARE</td>
<td>0.089</td>
</tr>
<tr>
<td>X\textsuperscript{INF} OPENNESS</td>
<td>0.0018</td>
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<table>
<thead>
<tr>
<th>CLUSTER-SPECIFIC INNOVATION ENVIRONMENT</th>
<th></th>
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<tbody>
<tr>
<td>Y\textsuperscript{CLUS} PRIVATE R&amp;D FUNDING</td>
<td>0.012</td>
</tr>
<tr>
<td>QUALITY OF THE LINKAGES</td>
<td></td>
</tr>
<tr>
<td>Z\textsuperscript{LINK} UNIV R&amp;D PERFORMANCE</td>
<td>0.011</td>
</tr>
</tbody>
</table>

CONTROLS: Year Fixed Effects, US dummy

R-Squared: 0.9973
Observations: 473
The Innovation Index for selected countries

(Index computed as expected patents per capita based on regression analysis)
Result II: Innovator countries can be usefully categorized into four groups

- **Leading innovators**
  - consistently high level of innovative capacity; increasing commitments to R&D inputs and policies

- **Middle tier**
  - relatively stable or slightly improving levels of innovative capacity

- **Third tier**
  - consistently low absolute levels of innovative capacity; potentially high relative catch-up

- **Emergent innovators**
  - initially lower levels of innovative capacity, increased dramatically by investments drivers of innovation
Categorizing Innovator Countries

<table>
<thead>
<tr>
<th>Leading Innovator</th>
<th>Middle Tier</th>
<th>Third Tier</th>
<th>Emerging Innovator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Austria</td>
<td>Greece</td>
<td>Denmark</td>
</tr>
<tr>
<td>Japan</td>
<td>Australia</td>
<td>Italy</td>
<td>Finland</td>
</tr>
<tr>
<td>Sweden</td>
<td>Belgium</td>
<td>New Zealand</td>
<td>Iceland</td>
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<tr>
<td>Switzerland</td>
<td>Canada</td>
<td>Portugal</td>
<td>Ireland</td>
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<tr>
<td>USA</td>
<td>France</td>
<td>Spain</td>
<td>South Korea</td>
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<tr>
<td></td>
<td>Netherlands</td>
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<td>Israel*</td>
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<tr>
<td></td>
<td>Norway</td>
<td></td>
<td>Singapore*</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td></td>
<td>Taiwan*</td>
</tr>
</tbody>
</table>

* Countries in grey not included in full data analysis because of data availability.
PATENTS per million persons: Emerging Innovator Countries (& Japan)
PATENTS per million persons: Third Tier Countries + S. Korea

Year: 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97
International Patents per Million Pop

Austria
France
Italy
Spain
South Korea
UK
R&D workers per million people – South Korea (1978-2000)
Change in Percentage of R&D Financed by Industry (1978-1999)
Disentangling sources of national innovative productivity

- Use determinants of actual patenting to construct **indices**
  - weights in index determined by coefficients in preferred innovation production function model

- **Policy/Innovation System Index** \( (X, Y, Z) \)
  - \( = \text{actual policy/levels of policies} \times \text{coefficients} \)
    - (1) % R&D Expenditures Financed by Industry
    - (2) % R&D Expenditures Performed by Universities
    - (3) % of GDP devoted to Higher Education
    - (4) Openness of economy to international competition

- **Investment Index** \( (A & H) \)
  - \( = \text{levels of investment in innovation} \times \text{coefficients (corrected for POP)} \)
    - (1) GDP
    - (2) GDP PER CAPITA
    - (3) R&D Expenditure
    - (4) Scientist & Engineer Employment
Policy/System Index

- Leading Innovators
- Middle Tier Innovators
- Third Tier Innovators
- Emerging Innovators
Result III: Emerging innovators raise their level of innovative productivity

- By *continuously* increasing investments in innovation
  - differences across groups substantial
  - emerging innovator countries overtake middle tier
  - middle & bottom tiers do not substantially increase commitments to innovation over period; leading innovators *relative position* declines if investments lag

- As well as by improvements in policies and innovation system characteristics
  - differences across groups not as pronounced
  - initial levels substantially below those of continuous innovator, middle tier & bottom tier
  - final levels equal to continuous innovators & middle tier
Implications of country-level analysis

- The ability to innovate at the world technological frontier can be explained \((\text{precisely!})\) by a parsimonious set of factors.

- Catch-up is real: Emerging innovator countries are improving innovative output per capita, as a result of both:
  - continuously upgrading investments in innovative capacity
  - adopting innovation-oriented policies
  - as a consequence, the generation & exploitation of new-to-the-world innovation is becoming less geographically concentrated

- **There is, however, no one magic bullet, either to achieve or maintain innovative leadership**
  - continuous upgrading is essential for maintaining leadership
  - those countries that ‘rest on laurels’ are being overtaken
  - sound public policy appears capable of playing a positive role in shaping national innovative capacity
Implications for firms & industries

- Supporting investments in innovation and pro-innovation policies may have both specific and general positive effects
  - specific benefits may accrue from supporting sustained investment in drivers of industry/sector-level innovation
    - e.g., research consortia, R&D/technical training, …
  - general benefits from common innovation infrastructure
    - e.g., availability of highly-talented employees; overall innovation policy
  - mix of benefits from linkages between them
    - e.g., access to application-oriented university research

- Choice of location is important!
  - locations that support innovation and where spillovers are potentially available from own sector or relevant other industrial clusters are particularly desirable
  - low cost environments not necessarily conducive to innovation
  - that said, the # of attractive locations is increasing!
Thank you!!!

- Thank you again for your time & consideration
- I hope you enjoyed the Breakfast
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  - furman@bu.edu
  - http://people.bu.edu/furman