Sectoral systems, economic development and catching up

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THIS LECTURE

- Do sectoral differences matter in economic development and catching up?
- A first step. The learning and knowledge environment for innovation: technological regimes
- Sectoral systems
- The process of catching up in different sectoral systems across countries
Catching up, lagging behind and forging ahead

The meso and micro view: the growth of local knowledge and the changing productive and innovative structure of the economy. Catching up does not mean imitation or cloning. Catching up means a process through which emerging countries learn and accumulate knowledge, and develop products, processes and technologies that may differ more or less from the ones of advanced countries.

The focus on learning and knowledge implies the possibility of different trajectories of knowledge accumulation, innovation and production specialization with respect to the leading countries.
FOCUS ON MESO AND MICRO

The focus on meso and micro implies that development and catching up:

- may take place in industries that can be different from country to country and that may change in importance over time

- means that the learning processes and the factors that affect the catching up may greatly differ from one industry to another
Why sectoral innovation systems?

1. Innovation in sectors is the result of different learning processes, the use of different knowledge and the interaction of different actors.

2. Major differences across sectors exist. Think for example of ICT, pharmaceuticals or textiles.

What do we know about these issues?
Various traditions have emphasised sectoral differences

- Case studies
- Innovation studies – Keith Pavitt
- Industrial economics
- Management literature and Porter’s five forces
WE WILL MOVE FORWARD

- In two steps.
  - First, we will consider the learning and knowledge environment of firms in sectors. These learning environments may differ across sectors.
  - Second, we will consider not only the learning and knowledge environment, but also industries as systems.
Do sectoral differences matter?

The learning and knowledge environment that affects innovation

This environment may greatly differ across sectors
FROM CONCEPTS AND THEORIZING TO MEASUREMENTS AND ECONOMETRICS

F. Malerba L. Orsenigo  Industrial and corporate change 1997

S. Breschi F. Malerba L. Orsenigo  Economic Journal  2000

Castellacci F.  Technological regimes and sectoral differences in productivity growth  Industrial and Corporate Change 2007
TECHNOLOGICAL REGIMES

- Opportunities (scientific and technological)
  - Level
  - Sources (R&D, universities, research institutes,...)
- Appropriability of innovations
  - Level
  - Instruments (patents, secrecy, ...)
- Cumulativeness of technical advance
- Cognitive base underpinning innovative activity in a sector
  *Nature of knowledge: some simple distinction*
  - Complex / Simple
  - Tacit / Codified
  - Independent / Part of a system

*Malerba and Orsenigo, ICC 1997*
*Breschi, Malerba and Orsenigo, EJ 2000*
THE RELATIONSHIP BETWEEN TECHNOLOGICAL REGIMES AND SCHUMPETERIAN PATTERNS

BASIC RELATIONS from Malerba and Orsenigo (1997) and from Breschi, Malerba and Orsenigo (2000)

\( \text{CONC} = f (\text{OPP}, \text{APP}, \text{CUM}, K_{\text{basic}}, K_{\text{applied}}) \)

\( \text{STAB} = f (\text{APP}_+, \text{CUM}_+) \)

\( \text{ENTRY} = f (\text{OPP}_+, \text{CUM}_-, K_{\text{BA}}_-, K_{\text{AP}}_+) \)
### The Effects of Technological Regime and Market Structure on SCHUMP

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>(1) OLS†</th>
<th>(2)</th>
<th>(3)</th>
<th>(4) Logit†</th>
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<td>Intercept</td>
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<td>0.509***</td>
<td>0.725</td>
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<td>(0.768)</td>
<td>(2.813)</td>
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<td>APPSCIENCE</td>
<td>-0.035***</td>
<td>-0.034***</td>
<td>-0.058**</td>
<td>-0.050**</td>
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<tr>
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<td>(-4.510)</td>
<td>(-4.367)</td>
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<td>BASSCIENCE</td>
<td>0.040***</td>
<td>0.055***</td>
<td>0.080**</td>
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<td></td>
<td>(3.215)</td>
<td>(4.432)</td>
<td>(1.995)</td>
<td>(2.891)</td>
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<td>APPROPRIABILITY</td>
<td>0.058***</td>
<td></td>
<td>0.153***</td>
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<tr>
<td></td>
<td>(5.703)</td>
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<td>(4.899)</td>
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<td>CUMULAT</td>
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<td>0.095***</td>
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<td>0.181**</td>
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<td></td>
<td></td>
<td>(3.243)</td>
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<td>(2.183)</td>
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<tr>
<td>OPPORTUNITY</td>
<td>-0.091***</td>
<td>-0.027**</td>
<td>-0.119***</td>
<td>-0.099**</td>
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<tr>
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<td>(-2.648)</td>
<td>(-2.229)</td>
<td>(-2.824)</td>
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<tr>
<td>DItaly</td>
<td>-0.017</td>
<td>-0.049</td>
<td>-0.346</td>
<td>-0.420</td>
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<td></td>
<td>(-0.195)</td>
<td>(-0.519)</td>
<td>(-1.112)</td>
<td>(-1.377)</td>
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<tr>
<td>DUKingdom</td>
<td>0.093</td>
<td>0.074</td>
<td>-0.090</td>
<td>-0.139</td>
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<td>(1.106)</td>
<td>(0.860)</td>
<td>(-0.346)</td>
<td>(-0.555)</td>
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<td>Adj. R²</td>
<td>0.120</td>
<td>0.072</td>
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<td>F(6,430)</td>
<td>F(6,430)</td>
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<td></td>
<td>10.88***</td>
<td>6.69***</td>
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<tr>
<td>n</td>
<td>437</td>
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</tbody>
</table>

**Notes:** † Heteroskedasticity-robust t values in parentheses; ‡ Heteroskedasticity-robust asymptotic t values in parentheses. * Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level.
TECHNOLOGICAL REGIMES AND DIFFERENCES IN PRODUCTIVITY GROWTH

- Technological regimes (APP, OPP, CUM)
- External sources of opportunities (cooperation, users, science and suppliers)
- Industry specific characteristics
  - Skills and training
  - Openess
  - Market size
- Country specific factors

Castellacci, ICC 2007
Table 3 Results of econometric estimation

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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPROPRI</td>
<td>0.089 (2.11)**</td>
<td>0.074 (1.90)*</td>
<td>0.075 (1.95)*</td>
<td>0.077 (2.04)**</td>
<td>0.067 (2.04)**</td>
</tr>
<tr>
<td>CUMUL</td>
<td>0.048 (1.90)*</td>
<td>0.025 (0.77)</td>
<td>0.001 (0.04)</td>
<td>-0.002 (0.07)</td>
<td>0.010 (0.30)</td>
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<tr>
<td>OPPORT</td>
<td>0.290 (1.71)*</td>
<td>0.660 (1.52)</td>
<td>0.963 (1.95)*</td>
<td>0.901 (1.96)*</td>
<td>-0.013 (0.02)</td>
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<tr>
<td>COOP</td>
<td>0.034 (0.83)</td>
<td>0.014 (0.31)</td>
<td>0.008 (0.20)</td>
<td>0.016 (0.47)</td>
<td>-0.041 (0.93)</td>
</tr>
<tr>
<td>COOP-OPPORT</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.013 (1.43)</td>
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<tr>
<td>SKILLS</td>
<td>–</td>
<td>0.083 (3.28)***</td>
<td>0.084 (3.70)***</td>
<td>0.082 (3.65)***</td>
<td>0.079 (3.64)***</td>
</tr>
<tr>
<td>TRAIN</td>
<td>–</td>
<td>0.057 (1.98)**</td>
<td>0.047 (1.68)*</td>
<td>0.058 (2.15)**</td>
<td>0.058 (2.23)**</td>
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<tr>
<td>TRAIN-OPPORT</td>
<td>–</td>
<td>-0.011 (1.31)</td>
<td>-0.010 (1.37)</td>
<td>0.013 (1.70)***</td>
<td>-0.010 (1.28)</td>
</tr>
<tr>
<td>EXP</td>
<td>–</td>
<td>0.636 (2.18)**</td>
<td>0.634 (2.33)**</td>
<td>0.071 (1.94)*</td>
<td>-0.084 (1.01)</td>
</tr>
<tr>
<td>EXP-OPPORT</td>
<td>–</td>
<td>–</td>
<td>0.219 (1.65)*</td>
<td>0.209 (1.78)*</td>
<td>-0.084 (1.01)</td>
</tr>
<tr>
<td>MARKET SIZE</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.253 (2.11)**</td>
<td>0.239 (2.14)**</td>
</tr>
<tr>
<td>MARKET SIZE-OPPORT</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.047 (1.42)</td>
</tr>
</tbody>
</table>

Country dummies

R²          | 0.474          | 0.550          | 0.600          | 0.615          | 0.631          |
N            | 175            | 156            | 146            | 146            | 146            |

Base results
Heteroskedasticity-robust t-values in parentheses.
***Significance at 1% level; **Significance at 5% level; *Significance at 10% level.
The differences in the innovation and production systems across sectors: sectoral systems
F. Malerba Sectoral systems of innovation and production
Research Policy 2002


F. Malerba and P. Adams Sectoral systems of innovation management in Oxford Handbook of Innovation Management Oxford University Press 2013
The foundations

- Change and transformation in industries
- Industry life cycle
- Innovation systems
  Lundvall, Edquist
- Evolutionary theory
  Nelson and Winter, Dosi
SECTORAL SYSTEMS OF INNOVATION AND PRODUCTION

Innovation and production take place in sectoral systems that are characterized by:

- a knowledge base
- firms
- other actors relevant for generating or supporting learning and innovation in a sector such as suppliers, users, universities, public research organizations, the government, financial organizations;
- links and networks among the different actors;
- institutions;
- processes of interaction, cooperation, and selection

Major differences exist among sectoral systems.
The central role of knowledge

- The specific knowledge base of sectors
- The content of knowledge
- The sources of knowledge
- Specificity, tacitness, complexity, complementarity, independence
- Knowledge and the boundaries of sectors
Dynamics and evolution: key aspects of sectoral systems

- Sectoral systems: dynamics first!

- Dynamics and the role of:
  - knowledge, learning and capabilities
  - various actors
  - demand

- The redefinition of the boundaries of sectors
A sectoral system approach for the study of innovation in sectors:

- Is not a straight jacket, but broad, flexible and adaptable: it points to a system view of sectors, to key variables and to fundamental relationships

- It leads to analyses done at different levels of aggregation, depending on the purpose of the research

- It has a strong link with theory

- It allows modeling

- It enables quantitative analyses

- It allows for comparative analysis across industries and across countries

- It provides a framework for policy
WE KNOW A LOT OF SECTORAL SYSTEMS OF INNOVATION IN THE UNITED STATES AND EUROPE

F. Malerba  Sectoral systems of innovation Cambridge University Press 2004

Wide variety of papers on specific sectors
WE START TO UNDERSTAND THE RELATIONSHIP BETWEEN SECTORAL SYSTEMS AND ECONOMIC DEVELOPMENT

- F. Malerba and S. Mani “The structure and evolution of sectoral systems in developing countries” Elgar 2009

Pharmaceuticals, telecommunications, ICT, software, aeronautics, motorcycle, salmon farming, machine tools, bio-fuels

Various countries examined.
Major insights from Malerba and Mani (2009)

Understanding the specificities of the relevant sectoral system is fundamental in order to identify the source of innovation in development.

The so-called traditional sectors may have a process of major transformation and be highly innovative.

The separation of research from development and production capability can be very harmful for innovation and development.

The type of network that emerge in a sector is strongly associated with the specific knowledge base of that sector.

Vertical interdependencies and local demand may foster in some cases or impair the full development of a sector.
The dynamics and evolution of sectoral systems

- Incremental changes in the system
- Radical change
CHALLENGE FOR RESEARCH - 1

CONTINUE TO ENLARGE THE SECTORS EXAMINED IN NEW LEADING AND DEVELOPING COUNTRIES

In particular:

Services

Traditional or low tech sectors

CHALLENGE 2

DEVELOP TAXONOMIES OF SECTORAL SYSTEMS
CHALLENGE 3

UNDERSTAND THE DYNAMICS AND EVOLUTION OF SECTORAL SYSTEMS IN THE PROCESS OF ECONOMIC DEVELOPMENT

For a sectoral system: is there a unique structure, path, trajectories across countries? Or not?

Key themes: understanding the emergence of new sectors, the transformation of existing sectors, the possible trajectories of a sector, the lock-ins, competence destruction within sectors, self reinforcing mechanisms in sectors

Examine the specific co-evolutionary processes at the base of change and growth in sectors

CHALLENGE 4

PROGRESS ALONG COMPLEMENTARY METHODOLOGICAL TRAJECTORIES THAT FEED ONE WITH THE OTHER

1. Case studies on actors, structure and evolution of sectoral systems
2. Appreciative theorizing
3. Quantitative-econometric analyses
4. Modelling

Link 1-2-3-4 together!
Catching up and sectoral systems

- Malerba and Nelson: Catching up in different sectoral systems  Industrial and corporate change, 2011
- Malerba and Nelson: Economic development as a learning process  Elgar 2012
**Pharmaceuticals**: India and Brazil  
*S.Ramani* and *S.Guennif*

**Agro-food**: China, Brazil, Nigeria and Costa Rica  
*S.Gu*, *J.Adeoti*, *A.Castro*, *J.Orozco*

**Software**: India, Brazil, Russia, Philippines...  
*G.Niosi*, *S.Athreye*, *T.Tschang*

**Telecommunications**: Korea, China, Brazil  
*K.Lee*, *S.Mani*, *Q.Mu*

**Auto**: Korea, China, Brazil  
*R. Quadros*, *Y. Huyn*, *Y. Wang*

**Semiconductors**: Korea, China, Malaysia  
*R. Rasiah*, *X. Kong*, *Y.Lin*
COMMON FACTORS ACROSS SECTORS
AFFECTING POSITIVELY CATCH UP

1. Accumulation of domestic capabilities

2. Access to foreign knowledge and international links

3. Development of advanced human capital

4. Active government policy

In successful countries, these factors work together in a dynamic complementary way: learning and capability building, knowledge access, advanced human capital
SECTOR-SPECIFIC FACTORS (1)

a) INDUSTRIAL STRUCTURE

- Scale and large size vs entry of new small firms
- Presence of local clusters
- Role of multinational corporations (global value chains vs licences to local firms vs competent local branches)

These differences are the result of the working of:
- different technological regimes, of different scale, scope and modularity of production and of different demand
- dynamic elements such as industry life cycle and the time of catch-up
b) DEMAND CONDITIONS:
- Different role of exports, domestic demand, demand segmentation and user-producer links.
- Often a dynamic relationship between demand and economic performance has been present.

c) OTHER SECTORAL SYSTEM ELEMENTS
- Universities and public research organizations (pharma and telecom)
- Finance: venture capital vs internal finance (software vs telecom and auto)
- Diversity in the types of government policy (relevant in telecom vs software vs pharma), with different dynamic effects over the short run and the long run.
AGAIN, THESE FACTORS ACT TOGETHER IN COMPLEMENTARY WAYS

SOFTWARE: entrepreneurship, local clusters, links with customers

TELECOM: large firms, active government support for domestic firms R&D

SEMICOND: entrepreneurship, specialization

PHARMA: university research, relaxation of IPR

AGRO-FOOD: development of market institutions, diffusion policies, development of a knowledge infrastructure
A KEY ISSUE:  
THE ROLE OF THE NATIONAL INNOVATION SYSTEMS

The role of national systems in terms of national institutions and government policy has been significant across sectors.

For example: government policy in Korea has supported learning and capability accumulation by large firms, in Taiwan new small firms and in Brazil has been favorable to multinationals.

This has affected also the sectors of a country catching up.

There has been a two-way dynamic relationship between national and sectoral variables: national policies have affected specific sectors that in turn have pushed for specific national policies.
Radical changes in the evolution of sectoral systems and windows of opportunity for catch-up from Lee and Malerba 2013

1) Radical change in the knowledge base and technologies
New Techno-Economic Paradigms (Perez and Soete 1988)
Generations of new technological trajectories, disruptive innovations
Analogue → Digital: Korean Digital TV (Lee, Lim and Song, 2005)

2) Changes in Demand
a. Changes in demand conditions or market regimes
Emergence of Chinese market with specific demand
b. Business Cycle Downturns
   TFT-LCD Industry (Mathews, 2005)

3) Changes in government intervention/regulation
   - Indian pharmaceutical industry (Guennif and Ramani, 2010)
   - Telecom in China, India, Brazil and Korea (Lee, Mani and Mu, 2011)
Successive changes in industrial leadership in sectoral systems: some examples from Lee and Malerba 2013

- **Steel industry**: Keun Lee and Jeehoon Ki
  Technological windows (basic oxygen furnace and continuous casting) allowed a leadership change from US to Japan and a demand window (global steel industry downturn) plus a government window generated a leadership change from Japan to Korea

- **Camera industry**: Jaeyong Song and Hoyseok Kang
  A technological window (rangefinder/portable camera) allowed a leadership change from Germany to Japan, and a new technological window in terms of a radically new trajectory (compact system camera) generated a change from Japan to Korea

- **Semiconductors (memory chips)**: Shin Jang-sup
  In the various generations of DRAM chips, demand windows (business cycles) plus stage skipping strategies allowed a first leadership change from US to Japan, and then a second change from Japan to Korea
☐ **IT services**  Sunil Mani,
Aborted catch up from US to Ireland and then sustained catch-up from US/Ireland to India

☐ **Mobile phones**  Claudio Giachetti and Gianluca Marchi
A technological window (digital phones/GSM) and a regulation window allowed the shift from US(Motorola) to Europe (Nokia). A new technological window (smart phones) allowed the shift from Europe to US (Apple) and Korea (Samsung)

☐ **Regional jets**  Daniel Vertesy
Government windows allowed a change in leadership from UK to Netherlands (Fokker), then to Canada (Bombardier) and then to Brazil (Embraer)
**Wine**  Roberta Rabellotti and Andrea Morrison  
Demand windows and technology windows allowed first the catching up of US and Australia and later on the change in leadership from France to Italy

**Games**  Yuko Ahoyama and Hiro Izushi  
A demand window (market crash) allowed a change in leadership from US to Japan (Nintendo and Sony). Later on a technology window (new ICT and software) and a demand window allowed a leadership change from Japan to US again
IN CONCLUSION

For catch up “One size does not fit all”.

The same “learning/knowledge/industrial structure/ interaction/ innovation/ institutions/ dynamics” link does not fit all sectors in the same way

Diversity is relevant across SECTORS.

Major DIFFERENCES exist across sectors in the learning processes, knowledge accumulation, structure, dynamics and transformation.
The sectoral dimension mediates between the MICRO analysis of learning and knowledge within firms and by firms and the MACRO relationship between knowledge and economic growth.

Sectors affect the MICRO dimension of firms learning and capability accumulation because of sectors’ specific knowledge base, structure and institutional context and the MACRO analysis of knowledge and economic growth in terms of the changing structural base of knowledge accumulation.
THE WAY AHEAD

This is just the beginning of a more systematic analysis of the dynamics of sectoral systems, catch up and industry evolution.

Future work has to systematically develop empirical evidence, build taxonomies, do quantitative analyses and develop empirically-grounded models in a complementary and interactive way.