Producing Prosperity: Advanced Manufacturing and the Innovation Ecosystem

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AGENDA

• Some history on growth of the tradable sector and the “commons” problem

• The globalization of supply chains

• Rebuilding the industrial commons
Post World War II

The U.S. led the world in manufacturing …
Extraordinary investments in public goods

- Public faith – “science had won the war”
- Investments in basic science research, education
- Cold war investments in technology
Especially since the 1970s onwards:

Expansion of the Tradable Sector

That portion of industrial output that can be traded internationally

- Traditionally manufactured goods — anything that can be “put in a box”

Enabled by technological progress in transportation and communication
Labor Arbitrage

• Cost benefit has to exceed transport and coordination costs (inventory carrying costs, spoilage, contracting costs)
The story of the late 1990s and 2000’s

• Massive increase in the global supply of (low cost) labor
Vertically Integrated

Vertically Dis-integrated

- Specialization — Division of Labor, Outsourced
- Labor Arbitrage
- Localization of Offshore Supply Chains

Off-shored (More and more pieces over time)
Localizing the Supply Base

When production first moved to China

- Initially used “kitting” of components (Many unique, temporal circumstances)
- Many incentives to “localize”

China has now “captured” the supply chain in many, many sectors

- Localization takes time and money
Local suppliers were “good students” …

“I was working on the strategic sourcing, we wanted to develop suppliers as one of the major strategic partners in China … We wanted them to grow … So ESI — early supplier involvement, was actually also required. Suppliers had to not only be able to provide the manufacturing capability, but also the design-in capability. That's why this required a higher level of, you know, collaboration.”
Today … you can’t find a lot of these in the U.S.
First recognition of the “commons” problem

Setting: Rochester, NY, 1997

Why was it so hard to make things like digital cameras in the United States?

Paralleled Gareth Harding’s tragedy of the commons
A question with far more serious implications

Does it make economic sense to conduct advanced R&D in fields when the commons is gone?

*Examples:*

- Organic electronics
- Display materials
- Nanomaterials
Synthesized these ideas into a paper published in Harvard Business Review – July 2009

“Why America can’t make a Kindle”
Some Principles:
Linking Manufacturing and Innovation

What you can make

What you can design

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When must R&D and manufacturing be geographically proximate?

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<thead>
<tr>
<th>Process Maturity</th>
<th>High</th>
<th>Low</th>
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<tr>
<td>Process-Embedded Innovation</td>
<td>• Craft products, high-end wine, heat-treated metal fabrication, advanced materials, specialty chemicals</td>
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<tr>
<td>Pure Product Innovation</td>
<td>• Desktop computers, consumer electronics, active pharma ingredients, commodity semiconductors</td>
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<tr>
<td>Process-Driven Innovation</td>
<td>• Biotech drugs, nanomaterials, OLED and electro-phoretic displays, super miniaturized assembly</td>
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<tr>
<td>Pure Process Innovation</td>
<td>• Advanced semiconductors, high density flexible circuits</td>
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Harvard Business Review, March 2012
Example: Intel 22nm 3D Tri-Gate Transistors

- FinFET technology starting with Ivy Bridge processor family was directly tied to Intel’s continued investments in advanced semiconductor process technology and manufacturing.
Learning from production

- Learning curve is extremely valuable

- Recognize how much protection of differentiation can accrue here

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<th>Establish Operational Baseline</th>
<th>Production Ramp-Up</th>
<th>Steady State</th>
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<tr>
<td>Start up plant</td>
<td>Improve run-rate</td>
<td>Optimize production run rate</td>
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<tr>
<td>Establish process consistency</td>
<td>Establish supply chains</td>
<td>Optimize costs</td>
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<td>Gradually expand operations</td>
<td>Grow volume and mix</td>
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Practice   |   Driving down the learning curve
A “generational skills gap” in the United States

“Our operations management leadership program ended up becoming training of procurement agents”

Do the managers who are left really have the scientific breadth to evaluate choices?
Know-how diffusion

*IBM Copper Damascene Process*

- IBM’s experience in IC packaging and electroplating techniques developed for the thin-film heads of disk drives ultimately enabled it to develop a “damascene” process for plating copper wiring on ICs
- Copied by competitors within two years
Know-how diffusion
Assume innovations have half-lives that are constantly getting shorter

- Pace of knowledge diffusion is accelerating
- Know-how flows through people movement, tools, promulgation of standards (and open source)
- The *only* answer is to keep your innovation pipeline full

Why High-Tech Commoditization Is Accelerating

WILLY SHIH

Knowledge embedded within state-of-the-art production and design tools is a powerful force that is leveling the global technology playing field. It democratizes innovation and makes future competition ever more challenging.

For tech companies that rely on sophisticated engineering, staying ahead of international competition seems to get harder every day. It used to be an article of faith that technology-intensive product manufacturers, automakers, or white goods makers could capitalize on their longstanding engineering and design leadership to cement their position worldwide. But that’s no longer the case. Today, younger upstarts in many product segments, especially from China, can develop world-class design and production capabilities in a short period of time. In some cases, they are closing gaps with long-established incumbents and becoming market leaders within a decade.

The popular narrative is that three main factors are driving this: (1) blatant copying of intellectual property (IP), (2) governments pressuring companies to share technology in exchange for rights to do business, and (3) normal knowledge spillover as workers move from multinationals to local companies. But other, less recognized forces are at play, and they are accelerating commoditization and making product differentiation increasingly difficult to sustain.

Knowledge, particularly the tacit know-how that takes years to develop, now flows through pathways that we take for granted. It is embedded into the tools used to design and manufacture products, and it is incorporated into the building blocks that are used to build more complex systems. The implications are profound. Perhaps the biggest implication is that, armed with this knowledge, young competitors can skip years of practice and experience building, and become competitive threats almost instantly.
What Can We Do?

Revisit assumptions … Run faster …
WE can localize supply chains

Revisit assumptions …
Source: SEMI China, April 2015
Maps to where the technology is heading …

3D packaging

• This is how the industry is going to keep Moore’s Law going

• We should catch this wave in the U.S.
The global sourcing paradigm
Global sourcing …

The job of today’s global manager is to match market demands in different regions with products and production sourced advantageously

- Does this mean loss of local advantage?

Separate topic: supply chain complexity and visibility into 3rd, 4th tier and beyond
Some firms think …

that localization of supply chains make sense

**Toyota Georgetown**
- 350 U.S. suppliers
- 100 in Kentucky
- Among highest domestic content of U.S. produced vehicles

Report recommends focus on Small and Medium-sized Manufacturers
More Ideas:

**Government Sponsorship of Early-Stage Research**

Senate Aeronautical and Space Sciences Committee Hearing (Fall 1975) → Energy Efficient Aircraft Program

- Six projects including Engine Component Improvement, Energy Efficient Engine, Advanced Turboprop, Energy Efficient Transport, Composite Primary Aircraft Structures, Laminar Flow Control

- Contracts to Pratt & Whitney and GE for early-stage research on advanced propulsion systems
Experimental Clean Combustor Program

- Sponsored early development of Dual Annular Combustor at GE

NASA Advanced Subsonic Technology and Ultra Efficient Engine Technology programs

- Ten-year development of TAPS combustor design

All this from Aircraft Energy Efficiency Program …

Winglets

Supercritical Wing

Laminar Flow

“NASA’s work on managing the sound barrier provided the fundamental understanding of transonic and supersonic aerodynamics, which allowed the development of the aircraft we fly around in today.”

PCAST Report on “Ensuring Long Term Leadership in Semiconductors” urges the same thing

— Robert Gregg, Boeing Commercial Airplanes

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MORE Funding for Basic Science

Like it or not, we are in a race and everybody else has figured that out.

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Federal R&D as a Percent of GDP

*Note: Beginning in FY 2017, a new official definition of R&D has been adopted by federal agencies. Late-stage development, testing, and evaluation programs, primarily within the Defense Department, are no longer counted as R&D. Based on historical AAAS data estimates and figures from the FY 2018 omnibus legislation. © 2018 AAAS*
Support more translational research

Basic Science → Translation to Humans → Translation to Patients → Translation to Practice

- Preclinical & Animal Studies
- Proof of Concept Phase I Trial
- Controlled Studies Phase II, III Trials
- Phase IV Outcomes Research

Too often …

Great Technology → Foreign Commercialization

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Invest in Manufacturing Innovation

It's NEVER been a cooler time to be an industrial engineer.
Pre-Competitive Collaborations

- Knowledge sharing
- Development of standard tools
- Generation and aggregation of data

- Generation of proprietary IP

Technology Readiness

Exploratory Research  Pre-competitive R&D  Competitive R&D  Go-to-Market
Why?

- Declining supply-side competitiveness
- Market failure to support longer-term R&D
- Capture scale and scope economies from R&D coordination

A direct way of addressing the commons problem
BioPro - Denmark

Matching platform for biologics manufacturing process development

- Fermentation – from recipe-driven to real-time measure/adjust
- Strengthen the fermentation cluster

*In 2013, fermentation contributed ~4-5% of all economic value creation in Denmark*
Stable Funding – Defense Industrial Base

Impact of sequestrations and continuing resolutions
- Challenge the viability of suppliers
- Make it difficult to hire and retain a skilled workforce
- Make multi-year investment decisions very challenging
Leverage Government Procurement

Government as a customer for lead markets
Value creation: Hard-to-replicate capabilities

Complex systems dynamics

“Know why”, e.g. noise, vibration, and harshness in automotive

Industrial design

Supply chain – component manufacture

Parts assembly

“The water level is rising …”
All this is predicated on a capable workforce

On multiple dimensions

Pipeline

• STEM training
• Mentorship
• Shop floor leadership

Flexibility

• Retraining/reskilling
No easy answers …

- R&D Leadership
- Workforce Skills
- Early Production
- Production Learning
Thank You

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