Grand Challenges in U.S. Manufacturing and the Innovation Ecosystem

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Grand Challenges in U.S. Manufacturing

Grand Challenge: “Innovate here, Manufacture there” is reaching its logical conclusion: “Innovate there, Manufacture there”

Convened 7 roundtables across the nation with over 100 thought leaders, spent over 1200 hours discussing potential solutions.

Round Tables and Partners

- Boston, MA
- Washington D.C.
- Austin, TX
- San Jose, CA
- Raleigh, NC
- Indianapolis, IN
- Detroit, MI

Issues discussed at the roundtables
1. Regaining America’s industrial commons
2. Creating wealth from national R&D investments
3. Ensuring financing for “hardware” start-ups and scale-ups
Overview

• After decades of offshoring, the U.S. has lost its manufacturing and innovation capacity to scale emerging technologies such as flexible displays, next-generation batteries, and a range of nanotechnology products, to name a few.

• ”Invent here, manufacture there” paradigm of the past two decades has reached its logical conclusion, “Invent there, manufacture there” – a dangerous trend for a developed country.

• We need a bold national strategy to create national wealth and security – the first step is to establish a National Manufacturing Foundation
Over 66,000 U.S. manufacturing facilities were shut down and nearly 5 million mfg. jobs lost in the last decade due to offshoring.

17 out of 19 manufacturing sectors saw decline in production; productivity has declined an average of 0.3% per year from 2004 through 2016.

Robots and Automation did not cause job loses

Countries with higher robot density (#robots per 10,000 employees) than the U.S. have stronger manufacturing sectors and trade surplus in goods.

(2016) S. Korea: 631; Germany: 309; Japan 303; U.S. 188

In 2016, Mercedes Benz and Toyota have begun replacing robots with humans to increase efficiency and reduce waste.
Manufacturers contributed $2.33 trillion to the U.S. economy

12.75 million manufacturing workers = for 8.6 percent of the workforce. Additional 17 million indirect jobs for a total of ~30 million.

In 2017, the average manufacturing worker in the United States earned $84,832 annually, including pay and benefits. The average worker in all nonfarm industries earned $66,847

92 percent of manufacturing employees were eligible for health insurance benefits provided by their employer in 2015

Foreign direct investment in manufacturing exceeded $1.6 trillion in 2017 employing more than 2 million manufacturing workers.

Trade deficit in goods is ~4X the trade surplus in services
GDP by sector – Q2 2018

Service sector = 4.5X Manufacturing

3 ways to create real national wealth

• Manufacturing
• Mining
• Agriculture
A Different Perspective on Manufacturing v. Service Sector

“What’s with the political fetish for manufacturing? Are factories really so awesome?”- Brookings Inst. economist Justin Wolfers,

A policy that promotes the production of “real things” is misguided because “American consumers value health care and haircuts as much as washing machines and dryers.” - Christina Romer, White House Economic Advisor, NYT -Feb 2012

Speaking about re-industrialization of the U.S....

“no going back to the past”... the new economy is built on “health care, retail, services, recreation, education, haircuts and insurance polices, hotels and houses.” – Larry Summers, Head of the White House National Economic Council, 2010

Factory Jobs are Gone. Get Over it – Charles Kenny, Jan 2014

“The Upside of Down: Why the Rise of the Rest is Great for the West” Charles Kenney
Defense Manufacturing Vulnerabilities

“If any particular manufacture was necessary, indeed, for the defense of the society it might not always be prudent to depend upon our neighbors for the supply.”

• May 2012: SASC report revealed a “flood of counterfeit electronic parts coming into the Defense Department’s supply system. ..Found 1,880 cases of suspected counterfeits involving more than 1 million parts in the most important military systems”

• 2012 DoD report, Assuring the U.S. Dept of Defense on Strong STEM Workforce: “for many technologies, the most advanced work is no longer being conducted in the United States.”
Positive trade balance in only two advanced industries: aerospace and (barely) engines and turbines.
Real value added is no higher than in mid-90s

- The U.S. lost 8 percentage points since 2000
- Germany lost only 2 points

Much of advanced manufacturing can’t return easily because skills, suppliers aren’t here anymore.

Global Value Add in Manufacturing
Foundational manufacturing capabilities have been significantly reduced or lost entirely as production in multiple industries has moved abroad.

(Pisano & Shih) The **Industrial Commons** is the set of knowledge and practical skills, supply chains and production capacity, materials and equipment, and overall industrial ecosystems that enable manufacturing across multiple industries.

The loss of Industrial Commons means that not only are an increasing number of advanced technologies manufactured abroad but also that the United States cannot manufacture many of them.

- Between 1998 and 2012 over a third of U.S. tool, die, and mold makers closed and employment halved.
- 10% generic drugs are manufactured domestically
- Shortage of medical supplies
Imported Content of U.S. Manufactured Goods

<table>
<thead>
<tr>
<th>Product Category</th>
<th>2000 Sales</th>
<th>2015 Sales</th>
<th>Change from 2000 - 2015 in % points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic consumer goods</td>
<td>38</td>
<td>208</td>
<td>-15</td>
</tr>
<tr>
<td>Technology-driven innovative products</td>
<td>55</td>
<td>410</td>
<td>-13</td>
</tr>
<tr>
<td>Vehicles and heavy machinery</td>
<td>55</td>
<td>623</td>
<td>-4</td>
</tr>
<tr>
<td>Locally processed goods</td>
<td>81</td>
<td>460</td>
<td>-8</td>
</tr>
<tr>
<td>Resource-intensive commodities</td>
<td>57</td>
<td>125</td>
<td>10</td>
</tr>
<tr>
<td>All manufacturing</td>
<td>59</td>
<td>1,922</td>
<td>-6</td>
</tr>
</tbody>
</table>

Source: MGI, 2015

Import Penetration in Advanced Technology and Erosion of Foundational Capabilities

Most manufacturing segments use less domestic and more imported content today than they did in 2000.
Manufacturers (excluding electronics and biotech/pharma) driven by short-term financial incentives, primarily invest in applied R&D (product development) rather than translational R&D to mature basic research results to capture the “next big thing”

Intel spent ~$13 billion on R&D was the only computer/electronics firm on the list that actually manufactures in the U.S.
Federal government invests in R&D
Private sector invests in R&D

There is very little connection between federal R and industrial D

Electronics and biotech/pharma do invest in translational R&D to create “next big thing”

Most other manufacturing firms invest primarily in current product development (incremental innovation to remain competitive)
Invent Here, Make There: Creating Knowledge, Not Wealth

- Federal S&T investment ~ $140 billion annually
- Mfg. deficit ~ $810 billion
- Adv. Tech. Products deficit ~ $111 billion

Leading the world in R&D is little comfort if we are simply subsidizing it for other countries.
Creating Knowledge but not Wealth

- Prof. John Goodenough (UT-Austin) widely credited for its original identification and development.
- Duracell and Energizer “opted out” of volume manufacturing
- Sony commercialized the technology in 90s

- Bell labs- first silicon solar cell 1953; DoD’s use in satellites; 1970 -Exxon’s research reduced $100/watt to $20/watt; NREL - GalliumArsenide; CA, Japan, and Germany promoted solar fields;
- South Korea’s firm is developing flexible solar
Invent Here, Manufacture There – And Losing faster

By not completing the cycle of innovation within our nation’s borders, we are losing our ability to innovate

**Dominant countries** have both high Nanotech Activity (NA) and the Technology Development Strength (TDS) needed to commercialize it.

**Ivory Tower countries** have high NA, but are less likely to develop their economies based on it because of relatively poor TDS.

**Niche countries** are technology development powerhouses, scoring high on TDS, but they do not have the scale to support internationally competitive levels of NA.
Flexible Electronics “Asian firms have acquired most of the critical intellectual property associated with OLED displays from Western sources.”

Quantum dot display: DIC Corporation and Nanosys

Nissha Co., Ltd., acquired the printed electronics business of GSI Technologies, LLC.

[July 2018] “Royole Corp. (Fremont, Calif.), a startup that has raised more than a billion dollars to fund its electronic manufacturing ambitions, has announced that its 1.1 million square foot production campus in Shenzhen, China, has started producing fully flexible displays.”

Plans to produce 50 million flexible display units per year in Shenzen. Royole was founded by Stanford engineering graduates in 2012

ASU’s The Flexible Display Center and AUO Enter Strategic Partnership to Accelerate Flexible Active Matrix OLED Development

“Combine AU Optronics Corp. AUO's manufacturing strength with the Flexible Display Center FDC's superior approach to handling plastic materials in a conventional flat panel manufacturing environment”
MIT 150 Study

- Studied growth trajectories of 150 manufacturing startup firms based on MIT technology and founded between 1997 and 2008

- None of these companies were able to scale in the U.S due to lack of funding, and know-how. All scaled in foreign countries; 70% of them scaled in China

".. when these firms were ready to take a giant step up to large-scale processes, the search for additional capital as well as scalable production capabilities drove many firms to relocate their production abroad."

Foreign MNCs along with foreign governments offered scale-up funds plus land, training, facilities, know-how, and other important resources.

- More than half (82 companies) received venture capital, and raised a total of $4.7 billion. On average they raised $74 million, with 33 firms raising over $50 million each, and 14 more than $100 million.

- After seven years, close to 40 percent of the firms were still raising funds. Only nine firms (eight biomedical companies and a battery maker,) raised funds through an initial public offering (IPOs)
Innovate There, Manufacture There

• 45% of foreign R&D centers in China are from U.S. companies
• The amount may not be worrisome, but the trend should be.

Most U.S. Multi National Corporations

Derive over 50 - 65% of the revenue from foreign sales
– Apple (65%), HP (61.5%), GE (55%), IBM (53%), Caterpillar (54%).

Employ over 50% of the total work force outside the US (J&J -73%, P&G - 73%) and

Have more than 50% of their corporate assets outside the U.S.
Factors driving manufacturing R&D to China

“Innovation happens faster here” – a former Google exec referring to China

Source: ConsultancyUK, 2015
Patents and Licenses

**Universities:** For every $1B of R&D activity, 168 patents issued; $52 million in license revenue

In 2015, $37 billion spent on R&D in S&E by fed gov. 6200 patents; $1.9 billion license revenue

**Federal labs:** For every $1B of R&D activity, 45 patents issued; $4 million in license revenue

In 2015, $46 billion total spent on R&D by fed gov. 2200 patents; $193 million license revenue

VCs rarely invest in hardware

- Biotechnology 10.9%
- Medical devices and equipment 7.9%
- IT Services 5.4%
- Industrial/energy 1.5%
- Media and entertainment 1.8%
- Consumer products and services 2.1%
- Software 57.4%
- Other 13.0%
Market Failures

Private Sector MNCs:
Driven by short-term financial incentives, most manufacturing MNCs focus primarily on the current product development through incremental innovation and do very little long-term translational R&D needed to mature basic research results into the “next big thing.”

Public Sector: Only government can overcome this market failure and enable the United States to remain globally competitive.

All federal S&T agencies are designed to successfully advance technology readiness to varying degrees but do not invest in engineering & manufacturing research needed to mature emerging technologies and process technologies.
Not just how much but what we invest in matters

2016 OECD data

**U.S federal R&D budget:** $149 billion

**Industrial Production and Technology:** $773 million (0.52%)

OCED definition: R&D on industrial products and their manufacturing processes.

**Germany:** $36 Billion

**Industrial Production and Technology:** $4.34 billion (12%)

6X the amount U.S spends

**Japan** – 7% of its budget; 3X U.S

**S. Korea** – 30% of its budget; 8X US

Trade balance in Goods (2017)

<table>
<thead>
<tr>
<th>Country</th>
<th>Balance</th>
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<tbody>
<tr>
<td>U.S</td>
<td>$796 billion deficit</td>
</tr>
<tr>
<td>Germany</td>
<td>$290 billion surplus</td>
</tr>
<tr>
<td>Japan</td>
<td>$25 billion surplus</td>
</tr>
<tr>
<td>S. Korea</td>
<td>$95 billion surplus</td>
</tr>
</tbody>
</table>

Isn’t 5% of total federal R&D a reasonable amount for the U.S to invest in this category?
Creating Demand, not just Supply

• Nascent technologies: technical risk and market uncertainty, requires long-term investment.
• Private sector does not invest in nascent, broadly applicable technologies – market failure.
• Government procurement has accelerated innovation and pilot production in the past.

The U.S led the world in these technologies.

Is the U.S poised to lead the world in these technologies?
Gaps in the U.S. Innovation Pipeline
Meeting the Grand Challenge: Manufacturing Prosperity

Establish a **National Manufacturing Foundation** – *a central focal point for manufacturing R&D in the federal government.*

Invest 5% of the federal annual S&T budget. (i.e., ~ $7billion annual investment)

1. Invest in translational R&D and manufacturing innovation
2. Invest in maturing Manufacturing Readiness Levels; Leverage govt. procurement.
3. Empower Small and Medium-Sized Manufacturers
4. Grow Domestic Engineering Talent
Closing the Gaps in the U.S. Innovation Pipeline

- Establish Translational Research Centers (TRCs) at Universities
- 3-4X domestic graduate fellowships in engineering
- Fund R&D in Engineering and Manufacturing (MRLs)
- Create public-private investment fund to support scale-ups
- Fund pilot production and Leverage Defense Procurement
- Empower small & Med sized companies
Recommendations

1. Invest in Translational R&D and Manufacturing Innovation:
   a. Invest in Translational Research Centers (university-affiliated but privately run) to translate the results of federally funded academic research into viable products. Licensing of resulting products should be restricted to U.S. production facilities only.
   b. Invest in manufacturing research, process technologies, and systems engineering, to mature MRLs and to overcome market failures
   c. Establish additional Manufacturing USA institutes targeting foundational capabilities.
2. Invest in Manufacturing R&D and promote scale-ups

a. Leverage government procurement:

Promote early adoption by leveraging government (defense) procurement to create lead markets for new products and technologies. Government purchase orders are an effective tool to incentivize private investment.

b. Form investment fund for scale-ups:

Form a number of geographically dispersed manufacturing investment funds, organized as public-private partnerships, that would combine public and private funding to invest in hardware start-ups and domestic scaled production.
Recommendations

3. Empower Small and Medium Sized Manufacturers (SMMs)

a. Institutionalize simple technology **licensing agreements** to facilitate and encourage technology transfer and joint technology development between universities and industry, especially SMMs.

b. Provide loan guarantees to incentivize SMMs to **modernize their capital equipment** and to implement smart manufacturing technologies.

c. Establish **industry fellowships** for engineering and management **retirees** to work with manufacturing start-ups and SMMs.
4. Grow Domestic Engineering and Technical Talent

a. Encourage enrollment of domestic students in engineering graduate programs through fellowships.

b. Create a national registry of apprenticeship and industrial training programs with the ability to match available programs at SMMs with high school and college students along with funding support for trainees.

c. Educate engineering technicians with emphasis on applied engineering skills.
Summary

• “Innovate there and Manufacture there” – a dangerous trend for a developed country

• Being the world’s best in basic research is critical but not sufficient to compete in the global economy.

• Addressing taxes, trade, and regulations may be necessary but not sufficient to create industries of the future.

• Recapturing global leadership in manufacturing and innovation requires long-term strategic investment in the industries of the future.

• Future of Manufacturing will be increasingly digital, distributed and democratized.

• The new parameters play to American strengths: flexibility and adaptability, a large capital market, superior higher education, and the world’s best R&D.