Class Four: The New Advanced Manufacturing Challenge and Globalization

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Innovation Systems for Science, Technology, Mfg., Health and Energy

Paul Samuelson on Comparative Advantage

Paul A. Samuelson, late Prof. Of Economics, MIT (Nobel Prize 1972), "Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization"

Jour. of Economic Perspectives, Vol. 18, No. 3 (Summer 04)

- Mainstream economists (Alan Greenspan, Jagish Bhagwati, Gregory Mankiw, etc.) argue re Globalization:
- "Yes, good jobs may be lost in the short run, but still total US net national product must by economic laws of comparative advantage be raised in the long run (and in China, too)…. Never forget the real gains of consumers alongside admitted possible losses of some producers in this working out of what Schumpeter called 'creative capitalist destruction.
- Correct economic law recognizes that some American groups can be hurt by dynamic free trade. But correct economic law vindicates the word 'creative' destruction by its proof that the gains of the American winners are big enough to more than compensate the losers."
- But Samuelson says: "The last paragraph can only be an innunendo For it is dead wrong about the necessary suply of winnings over losings"

Samuelson: Capturing Comparative Advantage

- Q: How can the US be a loser in trade with a low cost, low wage competitor like China despite the Ricardo's theory of "comparative advantage"?
- A: Ex.: If China begins to make productivity enhancing gains in its production, and couples that with its low wages, it can capture some of the comparative advantage that belonged to the US through its productivity dominance [note: US still the most productive economy in the world]
- Then -- in a Ricardo analyis, there is never any unemployment that lasts forever from trade – "So it is not that US jobs are ever lost in the long run; it is that the new labor-market clearing real wages has been lowered by this version of dynamic fair trade."
- In other words, US wages can drop after a time to a point where China's productivity enhancement is offset. The US still has a benefit from lower prices for goods, but there are now "new net harmful US terms of trade"

Samuelson: Economic history is replete with the story of capturing comparative advantage:

- Example: Farming moves from east US to midwest two centuries ago
- Example: Textile and shoe mfg. moved from new England to the low-wage South early last century
- Example: English mfg. leaadership shifted to the US starting in the middle of the 19th century
- “Even where the leaders continued to progress in absolute growth, their rate of growth tended to be attenuated by an adverse headwind generated from low wage competitors and other technical imitators.”

Samuelson's conclusions:

- So: "a productivity gain in one country can benefit that country alone, while permanently hurting the other country by reducing the gains from trade possible between the two countries" – all this is "long run Schumpeterian [the creative destruction of capitalism] effects"

- There is a "roulette wheel of evolving comparative advantage" in a world of free trade
- "Comparative advantage cannot be counted on to create…net gains greater than the net losses from trade"
- But if you respond with tariffs and protectionism, you may be breeding "economic arteriosclerosis"

Gary Pisano and Willy Shih (Harv.Bus. Sch. 2009)

- The "Kindle 2" could not be made in the US:
  - Flex circuit connector – China
  - Electrophoretic display–Taiwan
  - Controller – China
  - Lithium polymer battery–China
  - Wireless card – China
  - Injected molded case – China

- Eroding US ability to create:
  - every brand of US notebook computer (except Apple) and mobile/handheld *designed* in Asia

Pisano and Shih, con't

- Advanced Technology at risk of shifting abroad:
  - Advanced materials:
    - Gone: advanced consumer composites, advanced ceramics, IC packaging
    - At Risk: carbon composite components for aerospace/wind
  - Computing and Communications:
    - Gone: desktop, notebook, netbook PC's, low end servers, hard disk drives, routers, home network tech
    - At Risk: midrange servers, blade servers, mobile handsets, optical comm. equipment, core network equipment

Eroding Capacity, Con't

- Green technology/Storage:
  - Gone: Lithium ion, lithium polymer batteries for consumer electronics, chrystalline and poly-crystalline silicon solar cells, bulk of wind turbines
  - At Risk: thin film solar
- Semiconductors:
  - Gone: fabless chips, bulk of SC mfg.
  - At Risk: flash memory chips
- Displays:
  - Gone: LCDs, electrophoretics
  - At Risk: next gen "electronic paper"

Jonas Nahm and Edward Steinfeld, Scale-Up Nation: Chinese Specialization in Innovative Manufacturing (MIT paper March 2012)

- **ISSUE:** China moves from 5.7% of global mfg. output in 2000 to 19.8% in 2011, has passed the U.S. in output
- What happened?

Nahm and Steinfeld, Con't

- Most assume this is low production costs due to cheap labor and cheap parts --
  - Assumption that mfg. naturally migrates to low cost producers *and* knowledge req'd for mfg.processes is trivial – neither is true
  - Assumption that production knowledge flowed via multinationals from outside into China
  - Assumption that IT revolution enables severing of mfg. from R&D, product definition, design, branding and marketing
  - None explains China's rise – instead new link between process innovation and manufacturing

Nahm & Steinfeld, con't

- China's form of innovative manufacturing specializes in rapid scale-up and cost reduction
- Joins unparalleled skills in simultaneous management of tempo, production volume, and cost.
- So production is able to scale up quickly and with major reductions in unit cost.
- This has enabled China to expand even in industries that are highly automated or not on governmental priority lists, despite limited labor cost advantage or government subsidies, respectively.
- So low costs and gov't support are not sufficient to explain China's success in manufacturing.

Nahm & Steinfeld, Con't

- China has developed production processes that were previously considered fully mature and impervious to further cost reductions or technological improvements.
- *Key: accumulation of firm-specific expertise in manufacturing via extensive, multidirectional inter-firm learning in an international dimension*
- Elements of China's model:
  - Backward design – take existing products and create cheaper models
  - Partnership of foreign design and Chinese mfg.= multidirectional learning
  - Technology absorption and collaborative development across networked production firms

Seven Stories – Findings of the MIT "Production in the Innovation Economy" Report

Co-Chair: Prof. Suzanne Berger

Seven Stories:

1) Manufacturing is not Agriculture

2) Our Manufacturing Firms are Increasingly: "*Home Alone"*

3) Small, mid-sized, and start-up firms – most of U.S. manufacturing - can't get financing to "Scale-Up" innovative production

4) Keeping our innovation strong means keeping production strong

- Close linkage between innovation/production

5) Workforce Training/Education – the issues

6) What Germany can teach us: strong ecosystem

7) Jobs - How our manufacturing sector affects our services sector

Story One; Manufacturing is not Agriculture

- For a long time we thought manufacturing *was* agriculture.
- In 1900 half our populations was farming; now less than 2% are farming
  - We are producing more than ever so have had enormous "Productivity gains' in agriculture
- But the MIT report tells us this manufacturing is *not* agriculture
- We lost 5.8 million manufacturing jobs from 2000 to 2010
  - We thought manufacturing output was holding firm, but it wasn't - on reexamination we're finding it was in decline
  - So we didn't the productivity gains we thought we got
- Our job loss tells us our manufacturing sector is hollowing out not getting more productive

Story Two: Home Alone

- The MIT report tells us for the past three decades we have been thinning out our manufacturing sector
  - We used to have firms and supply chains that were very vertically integrated
  - We hit on a financial model of emphasizing quarterly returns, which led us to reduce risk by making our firms "core competency" and "asset light"
  - So the shared assets of training, bringing best practices to suppliers, thinned out
  - **The companies in our system are now much more "home alone"**

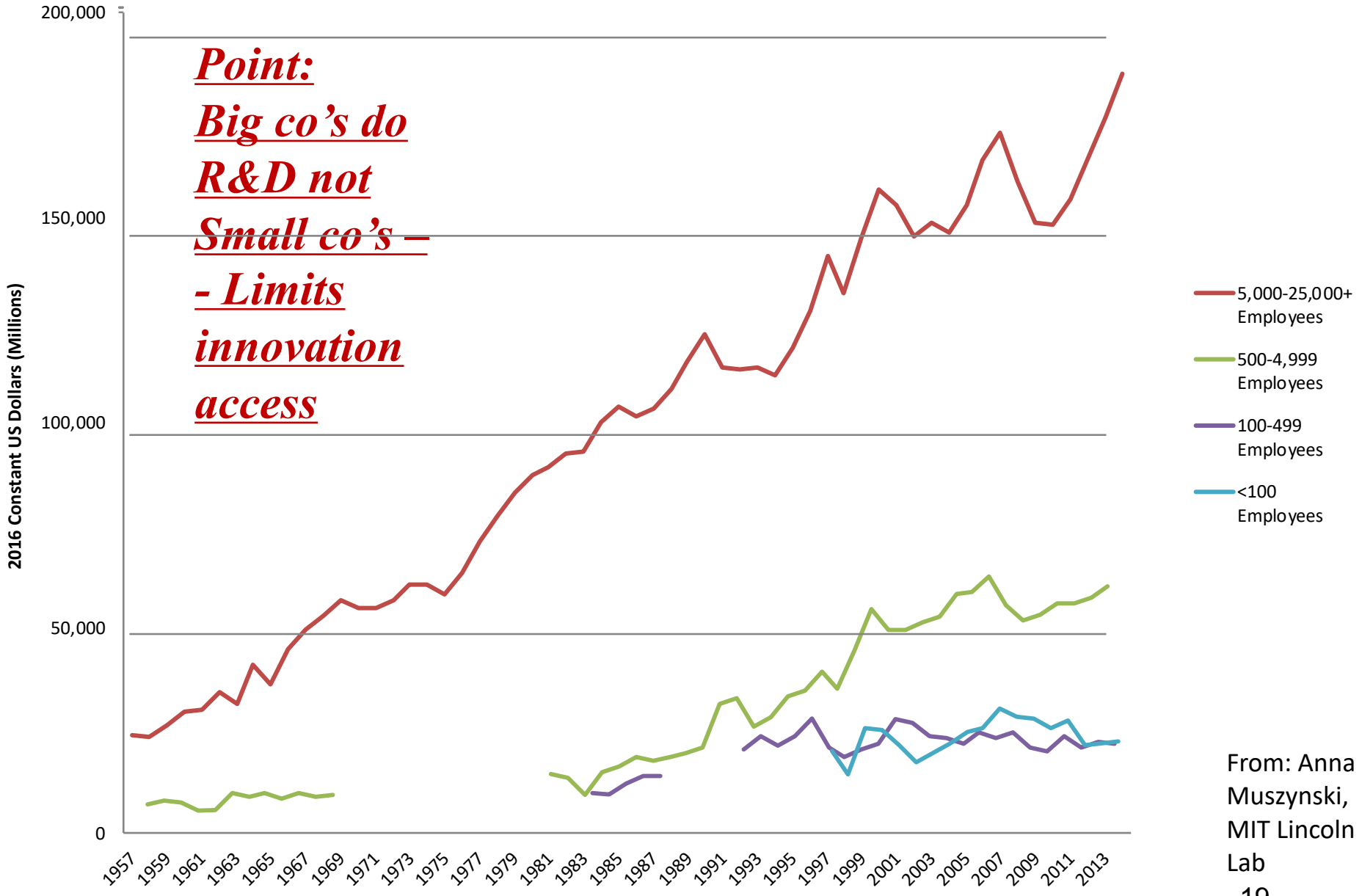
Story Three: The Scale Up Problem

- We have three manufacturing sectors
  - **Big multinationals** – they are global, they can get production efficiencies by producing in lower cost countries and they must be in all the global markets
    - **They're OK, although they are increasingly producing abroad**

  + Two More Vulnerable Sectors:

  - **Main Street firms** – they do most of our manufacturing, there are 300,000 small and mid-size firms
  - **–**They have trouble getting production scale up funding, they're thinly capitalized, must be risk adverse to survive, and don't do R&D (although they can be very innovative about process)
  - **Our entrepreneurial startups that make something** –
    - they do well until they have to **scale up for production** of their product – they lack financing for scale- up here – Venture firms don''t fund this – send startups to contract mfgs. In Asia
    - So they turn to contract manufacturers abroad

Private Industrial R&D Funding in the US by Company Size (1957 - 2014)



From: Anna Muszynski, MIT Lincoln Lab

Sources: "Domestic R&D Funded by Companies Doing Business in the US" 2014 - The NSF Business R&D and Innovation Survey (BRDIS), *in press*; 2008 to 2013 - The NSF Business R&D and Innovation Survey (BRDIS), https://www.nsf.gov/statistics/srvyindustry/; 1980 to 2007 - The NSF Survey of Industry R&D (SIRD), https://www.nsf.gov/statistics/iris/

Story Four: The Tie between Innovation and Production

- So what if they scale up abroad? What's the problem?
- Because for most products you need to tie innovation very closely to initial production
  - You need dense feedback loops as you do product design- initial production requires very creative engineering and design – it's part of innovation
  - So if you shift production capability, in many cases innovation capability has to follow it
- Innovation is the U.S. strong suit – it's what we do best
- But the MIT report finds that if many of our important innovations have to follow production, then we are endangering our innovation strength
- And Innovation is the key factor in growth

Story Five: Workforce

- MIT study surveyed 3000+ manufacturing firms
  - 75%: filled job vacancies in less than a month
  - There is no emergency on workforce talent
  - After all, we laid off 5.8m workers in last decade
- But the 25% is interesting
  - Innovative firms requiring higher job skills in this group
  - If we want to move to advanced mfg., increasing skills key
  - And: Big demographics problem – aging workforce

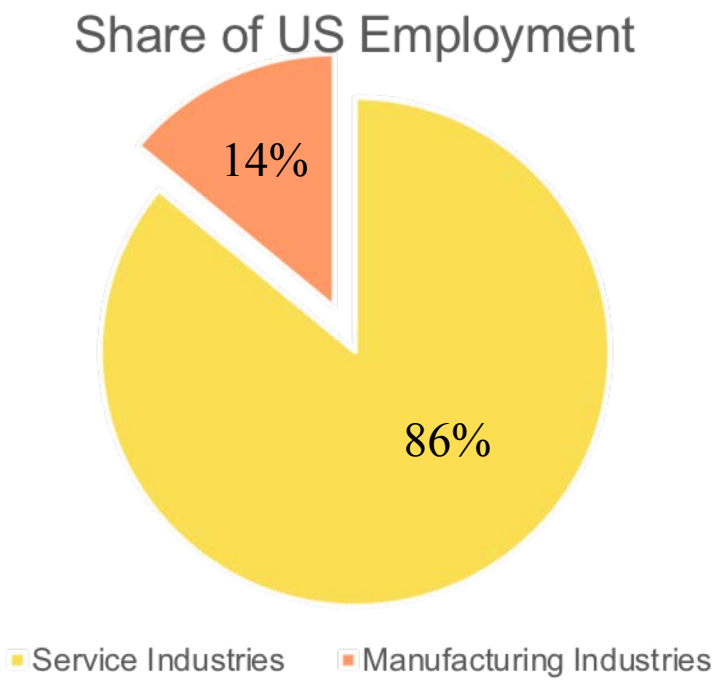
Story Six: What Germany can teach us

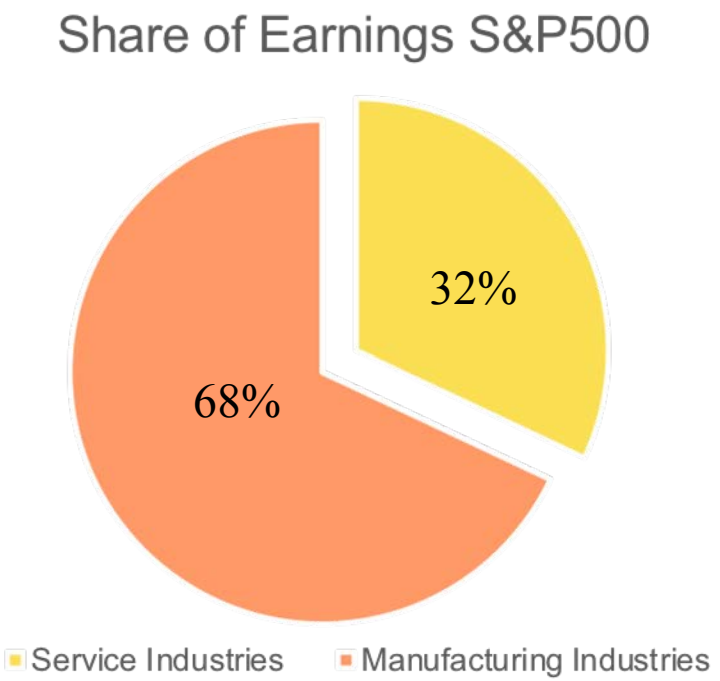
- We thought that we had to lose manufacturing jobs to low cost producers in Asia because we are high wage.
- But Germany is high wage and high cost – German wages and benefits are 66% higher than the U.S.
- They run a major manufacturing surplus, including a manufacturing surplus with China
- The MIT team went to Germany and interviewed a wide range of their firms to try to understand their system
- They have a deep ecosystem for their manufacturers, small and large – they aren't "home alone"
- Extensive collaborative R&D shared by industry- gov't-universities around manufacturing technologies and processes
- Shared training system for their workforce
- Ways to link their supply chains for rapid scale up
- Some German practices won't apply here, but some do

Story Seven: Jobs – the manufacturing sector affects our services sector

- U.S.: 80% "services" economy
- But increasingly – the 21st century firm ties complex products to services – to offer "solutions"
  - Tradeable goods are tied to services, which makes the service tradeable
  - Personal services are face to face, don't scale
  - But with the tradeable good, you can scale both the good and the service
  - So: success in production increasingly tied to success in services, & vice versa
  - Scaling is how an economy grows
  - Lose the product, can't scale the service either

Services vs. Manufacturing – employment/economic roles:





Deutsche Bank Research 2015

Summary: The Seven Stories --

- Manufacturing is not Agriculture
- Our Manufacturing Firms are Increasingly "Home Alone"
- The Scale-Up problem for small, mid-sized, and start-up firms – most of U.S. manufacturing production strong
- Close linkage between innovation/production
- Workforce: to move to adv'd mfg., need skills training
- Germany's lesson on strong mfg. ecosystem
- Jobs – tie tradeable goods to tradeable services for scaleable growth
- (How our manufacturing sector affects our services sector)

W.B. Bonvillian and Charles Weiss, *Technological Innovation in Legacy Sectors* (Oxford 2015) (manufacturing chapter) ***and*** Bonvillian, Donald Trump Voters and the Decline of US Mfg. (*Issues in S&T* 2016)

Hollowing Out?

- Employment:
  - Down almost 1/3 in decade of 2000s, still only 12.3m
- Investment:
  - Manufacturing fixed capital investment declined (accounting for costs) in the 2000s for the first time since the data has been collected
- Output:
    - Adjusting gov't data (for foreign component origin and inflationary assumptions in IT and energy sectors), U.S. manufacturing output value declined in the 2000s
    - Decline in 16 of 19 manufacturing sectors
- Productivity:
    - If output lower than assumed, productivity is lower

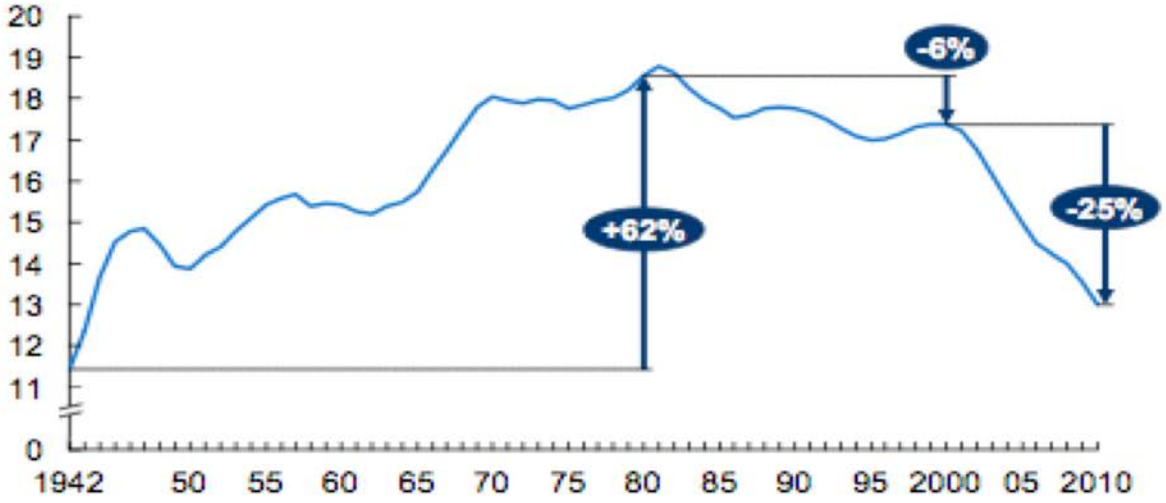
Sharp Decline in Mfg. Employment, 2000-2010 -- drop so steep that productivity gain can't explain

Exhibit 16

US manufacturing employment has been shrinking since 1980, but the pace dramatically accelerated after 2000

Manufacturing employment, 1942–2010, 5-year moving average

Millions of jobs

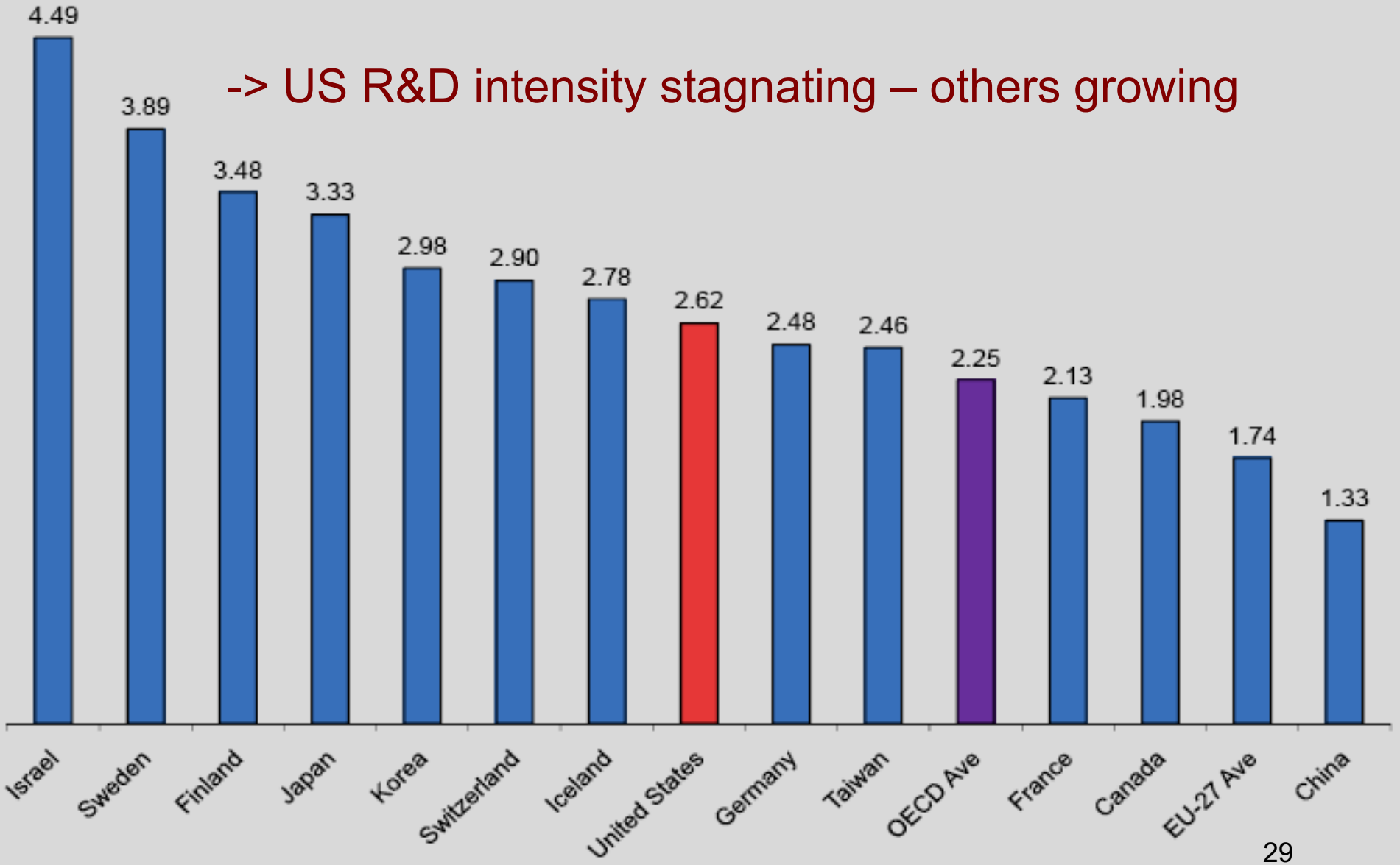


Manufacturing share of US employment %	36	36	34	31	25	19	16	11

SOURCE: US Bureau of Labor Statistics; National Bureau of Economic Research; McKinsey Global Institute analysis

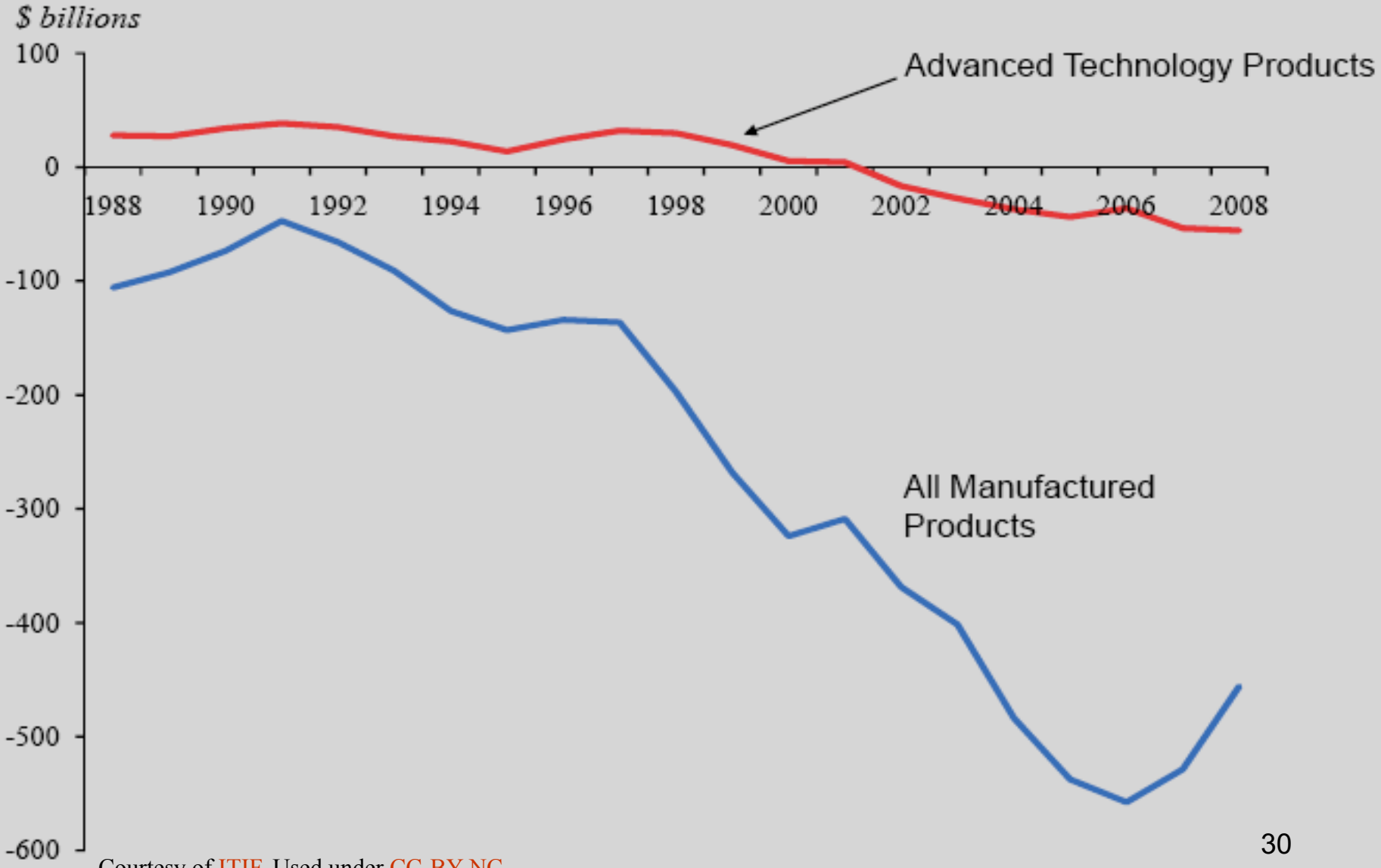
National R&D Intensities, 2005

Gross R&D Expenditures as a Percentage of GDP

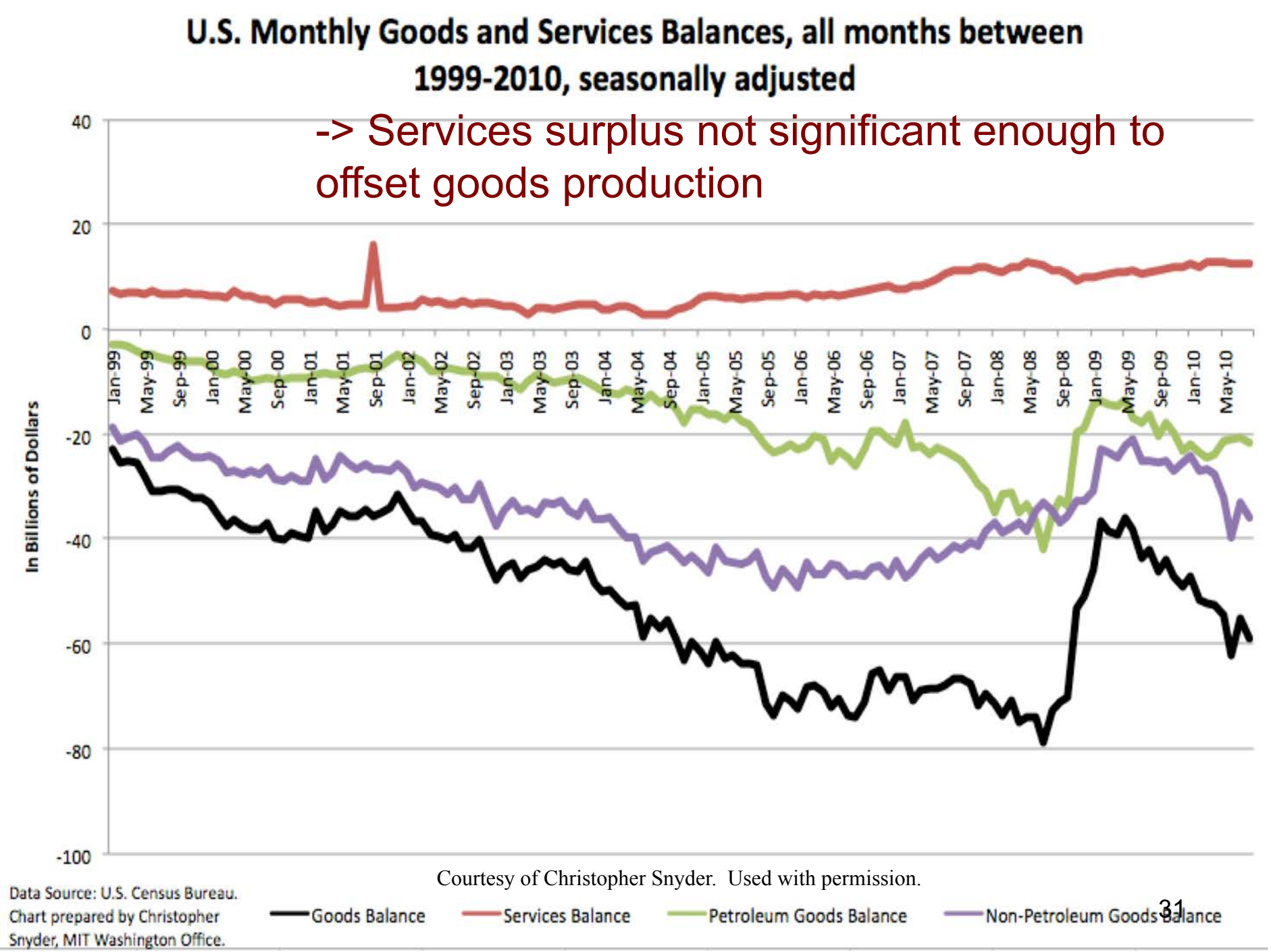


Source: OECD, *Main Science and Technology Indicators*, May 2007

U.S. Trade Balances for High-Tech vs. All Manufactured Products, 1988-2008



Source: Census Bureau, Foreign Trade Division

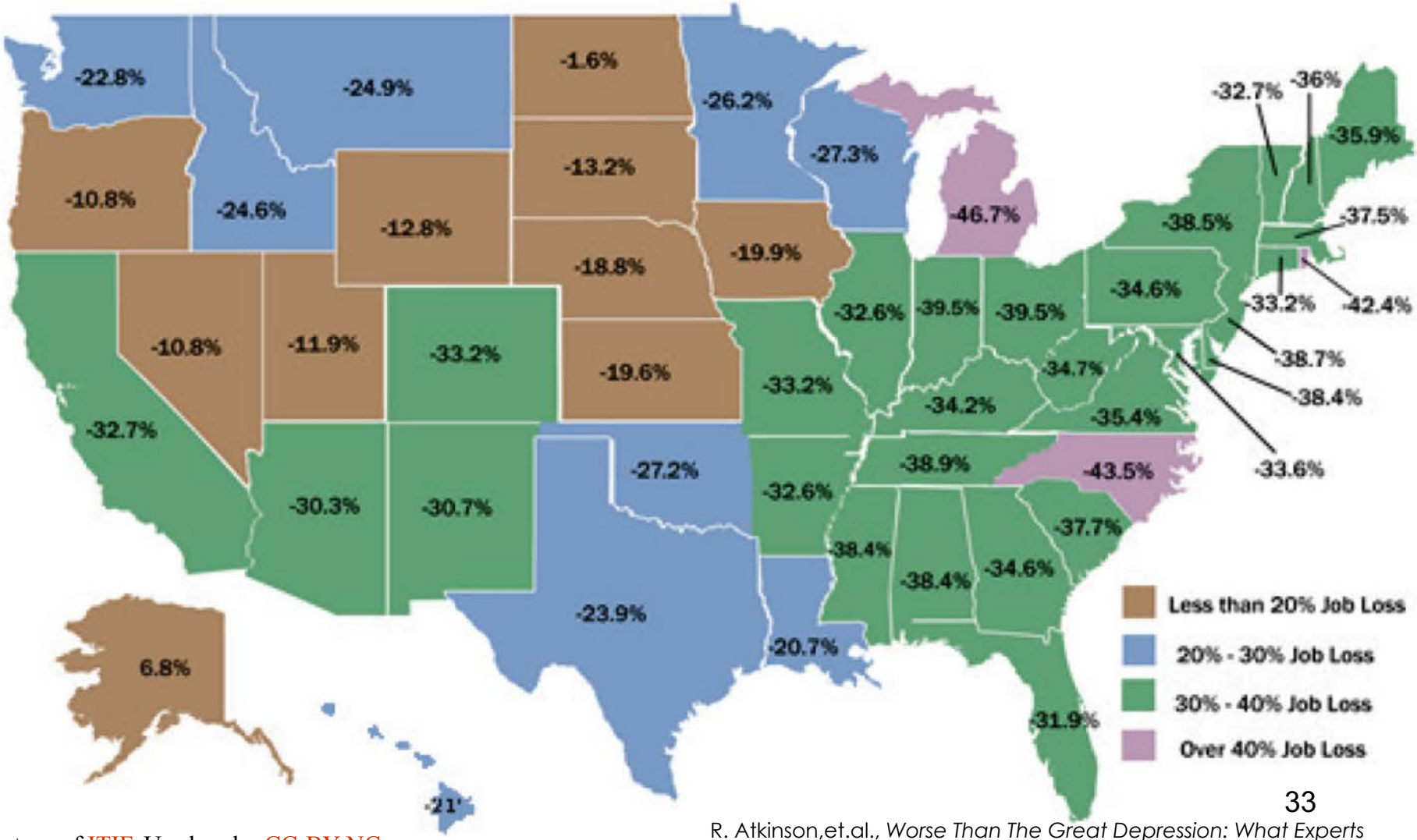


Courtesy of Christopher Snyder. Used with permission.

We have been assuming we have been losing manufacturing jobs because of productivity gains

- Many thought **productivity gains were explanation for declining manufacturing jobs** – mfg is ag – but analysis shows **lower output**
- Historically - most recently, tech boom of the 90's - **productivity gains**, although disruptive initially, **grow <u>more</u> jobs**
- If lower output, we may need to **search for our profound national job losses in the manufacturing sector.**
- That means "The Great Recession" is **structural, not business cycle,** so the Keynesian macro-economic **stimulus tools we have been applying won't work well with structural problems.**
- The **Manufacturing Hollowing Out is why these aren't working – requires a *<u>Structural</u>* strategy not just a maco-economic strategy**

Percentage Loss in Manufacturing Jobs: 2000-2010



R. Atkinson,et.al., *Worse Than The Great Depression: What Experts Are Missing About American Manufacturing Decline*, ITIF, March 2012

An American Brexit: Manufacturing Decline = Social Disruption

- Between 2000 and 2010, U.S. manufacturing employment fell by 5.8 million jobs:
  - from 17.3 million to 11.5 million;
  - 2015: only recovered to 12.3 million
- Manufacturing – historically important middle class pathway for high school educated males –
  - full year employment - men with high school but not college degrees:
    - went from 76% in 1990
    - to 68% in 2013.
  - Share of these men who did not work at all
    - went from 11% in 1990 to 18% in 2013.

Social Disruption, Continued

- Importantly, *median income of men with no high school diploma fell 20%, men with h.s. diploma or some college fell 13%, between 1990 & 2013.*
- *Growing income split between college and non-college educated*
  - *Major rise in U.S. income inequality*
- Restoring manufacturing was a frequently cited subject in the divisive 2016 Presidential election.
- This was clear a signal of:
  - a loss to middle income ranks and of
  - growing social inequality
  - Post Industrial Backlast
- *Can Advanced Manufacturing speak to this?*

Manufacturing Remains a Major Sector

- Manufacturing = $**1.7 Trillion** of $15T U.S. economy
- Employs **12 million** in workforce of 150m
- **Mfg. dominates the U.S. innovation system** – 70% of of industrial R&D, 80% of patents, employs 64% of scientists and engineers
- The **currency of international trade is complex high value goods** –
  - **80% of U.S. exports are high value goods** (capital goods, industrial supplies, transport goods, medicines)
  - 2012 - **$700B deficit in goods**
  - Services surplus ($160B) growing gradually but will not offset manufacturing deficit in foreseeable future
  - Services don't scale; don't get economies of scale

Underlying Issue: Our "Innovate here/Produce Here" Assumption

- Since WWII - **U.S. economy organized around leading the world in technology advance**.
  - US led all but one of the innovation waves of the 20th century – and growth economics tell us that **technological & related innovation = 60%+ of growth**
  - Led - from aviation to electronics, to nuclear power, to computing, to the internet, to biotech
  - Missing an innovation wave is serious: Japan led quality mfg.; 1973-1991 –>GDP and productivity 1% below historical averages - tough for U.S.
    - Response: '90s IT innovation wave and record growth
- **Our operating assumption - *we* would innovate *here* and *WE* would translate those innovations into products**
  - **Would realize the full range of economic gains from innovation at all stages**
  - It worked – world's richest economy

"Innovate here/Produce here" Bonds Breaking?

- With global economy, **assumption of "innovate here/produce here" no longer holds.**
  - **In some industrial sectors, can now sever R&D and design from production**
    RISK –> innovate Here/Produce There
  - That brings the **economic foundation of our innovation-based economy into question. Why invest in innovation here if gains elsewhere?**
- Last 25 years – **IT/electronics** allowed severing of R&D/design from production via **IT-based specs**; commodity goods, too
  - **Distributed Manufacturing** – Apple iPod example
- But **other sectors** still require **deep connection between R&D and production** – constant reengineering and improvements to cut costs

Mind the Connection between R&D/Design and Production in Different Sectors

- **IT goods can sever R&D/design & production**
- **Electro-mechanical-aero-pharma-capital goods– tie R&D/production**– variables too complex

- **RISK → "Innovate There/Produce There"**
  - **If Distributed Mfg.: risk losing production;**
  - **But the rest: offshore production, will design/innovation follow?**
- **Underlying all this: Competing with low cost/wage high tech competitors: must have productivity gains**
  - **That means new innovation required: technology and processes**

Suppose US decided it wanted to go back to Production Leadership…

- Need a strategy
- Need to understand key factors we do not understand now

- What do we need to understand?

Step 1: New Manufacturing Paradigms

- **Historically, shifts in manufacturing advantage have stemmed from introduction of:**
  1. **technology advances**
  2. **with accompanying process advances**
  3. **and new business and organizational models**

1) Historical Examples of Shifts with Tech-Process-Business Model Sequence:

1. US takes leadership of Industrial Revolution mid- 19th century through development of the "American system" of interchangeable machine-made parts
   - Result of 20-year DOD technology development of precision machine tools at Harper's Ferry Arsenal
2. Japan 1970's-80's – new quality price tradeoff, just in time inventory, making labor fixed price for labor flexibility
3. US recaptures Semiconductor manufacturing lead in 80's – focus on mfg process – advances in SC equip suppliers, roadmap

1) What technology advances = new manufacturing paradigms?

- "**Network centric**"
  – mix of advanced IT, RFID, sensors in every stage and element, datamining and recall; **advanced robotics, supercomputing modeling**
- **Advanced materials**
  - "materials genome" – ability with supercomputing to design all possible materials with designer features
  - Biomaterials, and bio assembly
  - Lightweighting everything
- **Nanomanufacturing**
  - fabrication at the nano-scale
- **Mass Customization**
  - Production of one at cost of mass production
- **Distribution efficiency**
  - IT advances that yield distribution efficiencies (incl. in supply chain)
- **Energy Efficiency** – energy is "waste"

Step 2 - Sectoral Evaluation

- Manufacturing is sectoral, but with increasing sectoral overlap for complex, high value goods
  - An airplane is aero design, electronics, IT, materials, etc.
- Technology paradigms have to make sense in the sectors
- Run a matrix – technology options against sectors they apply to – pick technologies with payoff across sectors
- Include emerging sectors

2) MATRIX: Tech Sectors/Mfg. Paradigms

Sector and Mfg. Pardigm	Bio/pharma	Aero-space	IT/electronics	Heavy Equipment	Digital search, network	New energy	Transport
Network - centric	x	x	x	x	x	x	x
Advanced materials	x	x	x	x		x	x
Nano Mfg.	x	x	x	x	x	x	x
Mass Customi-zation	x	x	x	x	x	x	x
Distribution Efficiency	x	x	x	x		x	x
Energy Efficiency	x	x	x	x	x	x	x

Step 3: It's no longer Manufacturing *OR* Services

- **Emerging:**
  - **new kind of firm that mixes services, production, supply chain management and innovation** (the "21st century" firm)
    - Need to look at this emerging firm model:
      - is it vertical or horizontal?
      - is it integrated or the result of flexible leveraging other firms' specialty capabilities?
      - Strengths and weaknesses of distributed mfg. model
      - are there examples of both forms? – look at firms attempting this model and their issues they face in pursuing it
  - **Business model stage will need to look at optimal combined model**

Step 4: Better look over the shoulder…

- **Need to look a competitor nation strategies**
  - **Hard to understanding the future of U.S. manufacturing without evaluating the context of global manufacturer competitors and their strategies**
  - **Look at:**
    - China/India/Brazil – **large emerging**
    - Germany/Japan – **large established**
    - Korea/Taiwan – **smaller scale, key niches**
  - We will learn from ***them***
    - ***Germany, China, Britain, etc. doing advanced mfg strategies***

Step 5: Workforce Issues-

- STEM Ed leadership req'd
- But innovation also requires "mind and hand"
  - Skilled artisans key to past innovation; it's a mix of skills, experimentalists and theorists
  - It's not just design as a stand-alone stage, design is over time also the ability to make, as well
  - Very hard, still, despite distributed IT manufacturing, to sever design from production – mutually informative
- Workforce lessons from Germany?

Step 6: The Pipeline and the Seams

- **US pipeline innovation** model organized with heavy federal basic research investment,
  - some applied (from DOD),
  - very little investment in manufacturing R&D (including tech, process, business model)
- We institutionalize the "Valley of Death" in our R&D model
- Other countries don't do it that way
- And profound **problems at the seams** of the innovation pipeline – big disconnects between actors
  - Research – basic research agencies, univ's
  - Applied – industry, some DOD support
  - Predominantly small firm supplier/production but limited dissemination
- Need new networked organizational models

Step 7 – New Financing - The "5-Year Yardstick" doesn't work in Manufacturing

- **2 Parallel US Innovation Systems:**
  - The **Induced/Incremental system** – led by established firms – focused on development and engineering for incremental advances
  - The **Breakthrough system** – the pipeline: federal R&D, univ. research, startups/entrpreneurs, VC's angel, IPO's
    - **5-year yardstick** based on **IT model**: VC's fund technologies no more than 2 years from commercialization, that they can flip to an IPO within 3 more years
    - Big policy issue: Valley of Death between research and late stage development: the handoff between researchers and scalers
  - **New manufacturing technology paradigms** probably require the **breakthrough innovation system** – won't evolve through induced system
    - But it doesn't fit the 5 year model --

7) 5-Year vs. 10-year Yardstick:

- Manufacturing doesn't fit the 5-year yardstick:
  - New mfg. tech's face the **Valley of Death** –
  - **Then** they face the "**Mountain of Death**" – getting to market launch at scale: major financing and price competitive at the outset of launch

Valley of Death – 5 year scale up - creating connections and funding to move from research to late stage development

+

Mountain of Death: 10+ year scale up; major financing needed to scale, price competitive from moment of market launch

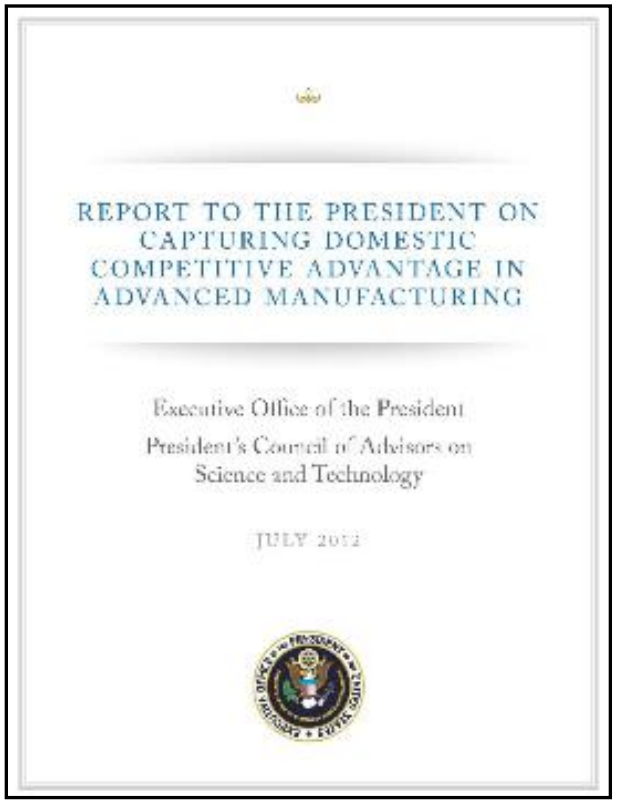
7) The "Mountain of Death" and Manufacturing…

- Manufacturing – the 10+year yardstick
  - Requires deeper, longer term, patient capitalization than IT
  - Longer time to stage entry and to scale – 10+ years not 5
  - It's a complex, established "legacy" sector
    - US better at bringing innovation into new areas, not at introducing innovation into legacy areas
  - Different mindset – can't create a company to sell it, as in IT, biotech

Production is to employment - like an hourglass:

- ←Input employment – resources, suppliers, etc.
- ←The production moment – limited employment, but key to other stages - 12M
- ←Output employment – distribution, services, sales, repair, etc.

Advanced Manufacturing Partnership 2012&14: Industry-University-Gov't Collaboration: Developed Innovation Model, Basis for the Advanced Manufacturing Institutes – Reports:



PCAST 2012

Recommends Manufacturing Innovation Institutes to address key market failure

PCAST 2014

Recommends strong, collaborative network of Manufacturing Innovation Institutes

Source: Office of the President. These images are in the public domain.

The 2012 & 2014 Advanced Mfg. Partnership Reports – 4 Basic Recommendations:

- *Transformative Technologies – Technology Strategies Linked to R&D*
- *Implementing Manufacturing Institutes and networking them*
- *Demand-Driven Workforce Solutions*
- *Technology Scale-Up/Policy*

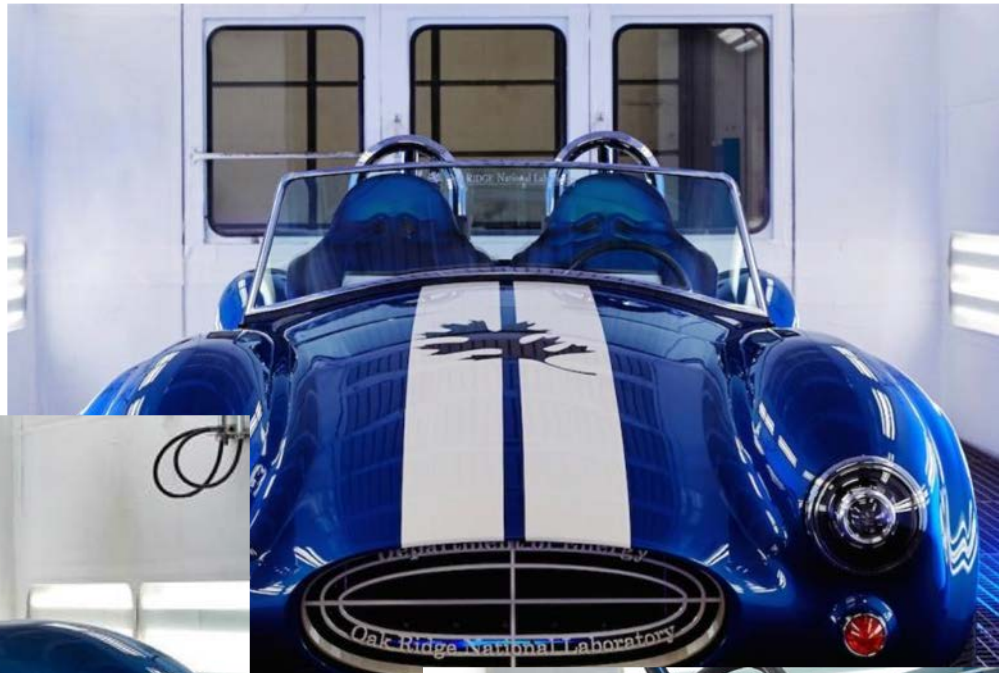
New Model - Advanced Manufacturing

- **Advanced Manufacturing Partnership (AMP) -** idea:
  - need innovation-based efficiency gains to compete with low cost/low wage nations
  - So: Apply innovation capabilities to manufacturing
  - So: New Technologies/Processes/Business Models
- **"Advanced Manufacturing Institutes"**- 14 now
  - Collaborative–industry/univ/gov't –in a way, Sematech model
  - Testbed role / Workforce education role
  - Around potential new technology paradigms
  - Cost shared between: federal gov't/industry/ state gov't

Example: 3D Printed Shelby Cobra at Oakridge w/Techmer PM composites -

concept to printed, 6 weeks; 500 parts/24 hours to print

- Used - BAAM ("Big Area Additive Manufacturing") machine -- can print parts 500 to 1,000 times faster than current industrial 3D printers

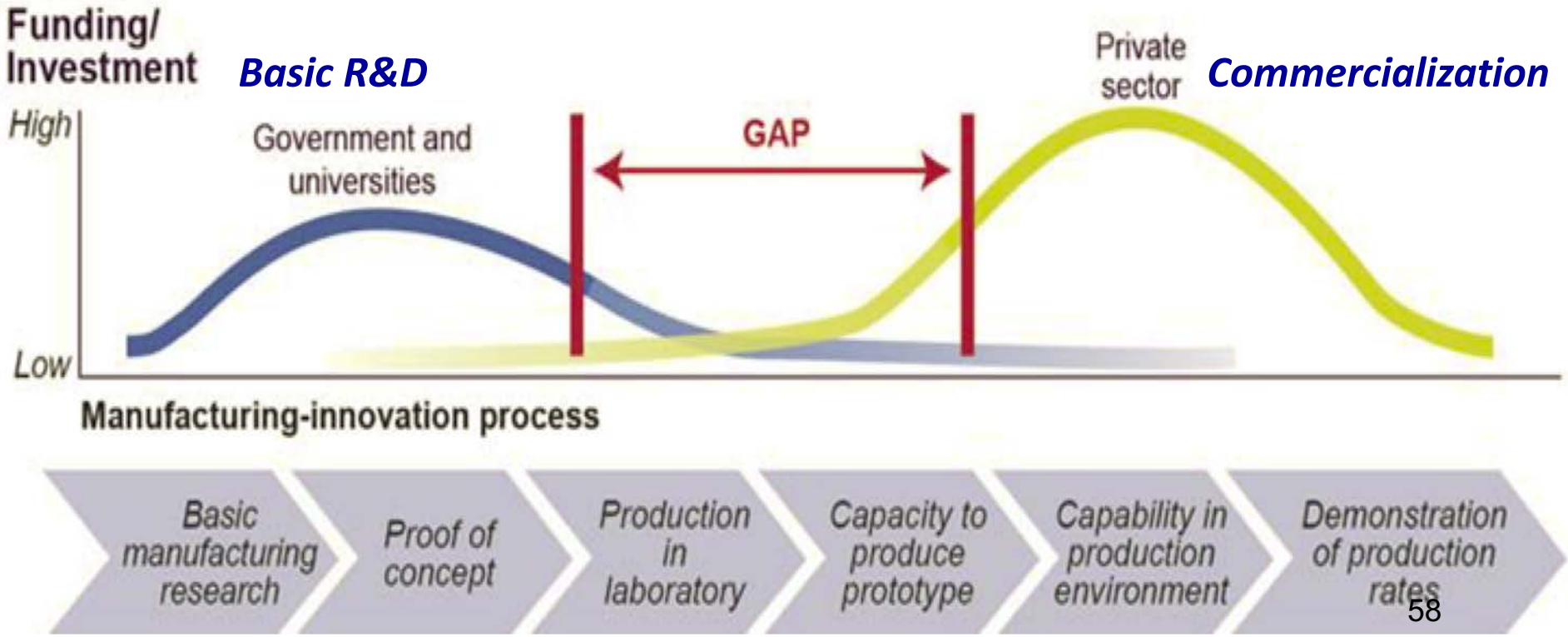


Source: US Dept of Energy. These images are in the public domain.

Institutes: Addressing the "Scale-up" Gap

Focus is to address market failure of insufficient industry R&D in the "missing middle" or "industrial commons" to de-risk promising new technologies

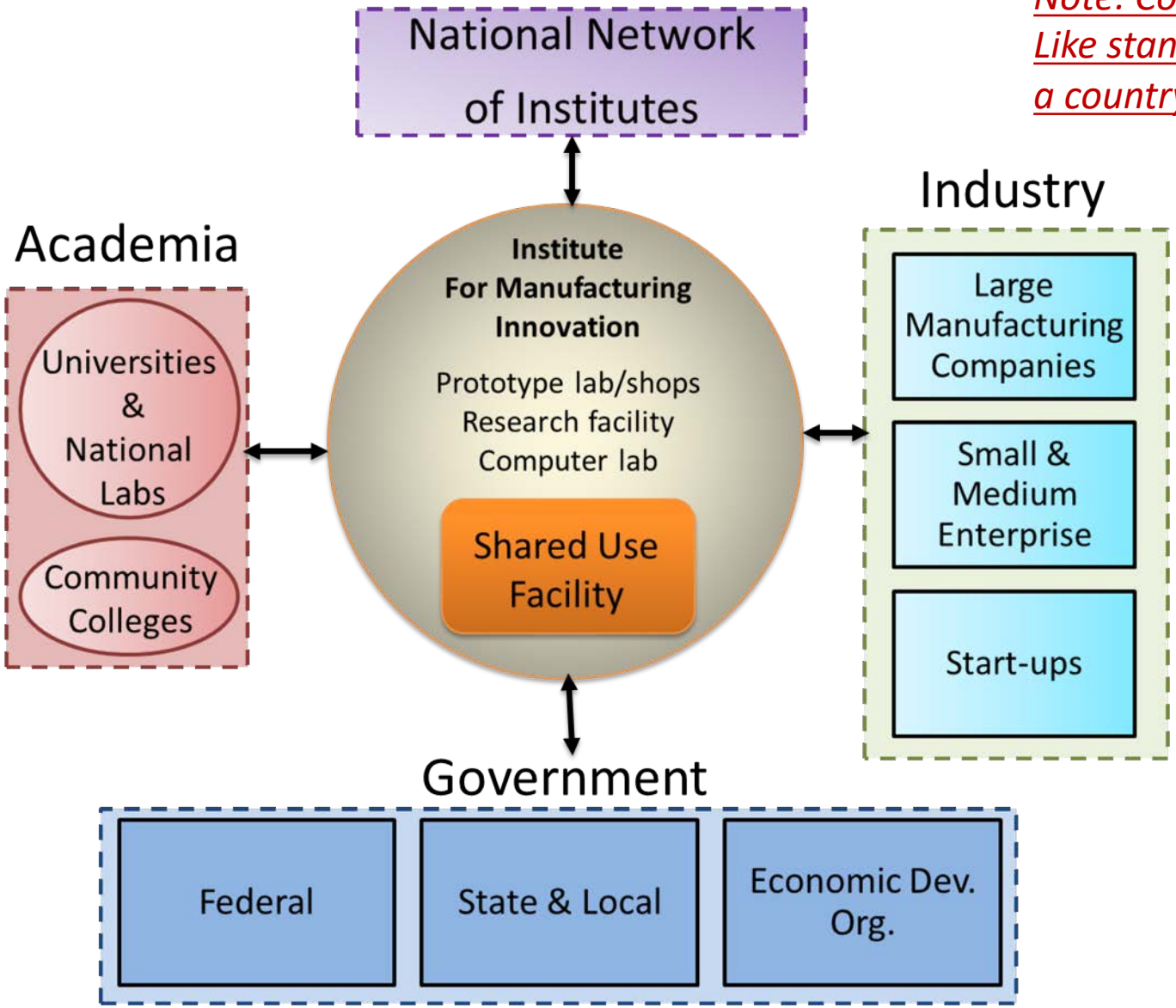
(slide: DOC)



The Institute Design

Creating the space for Industry & Academia to collaborate

Note: Complex model: Like standing up a country



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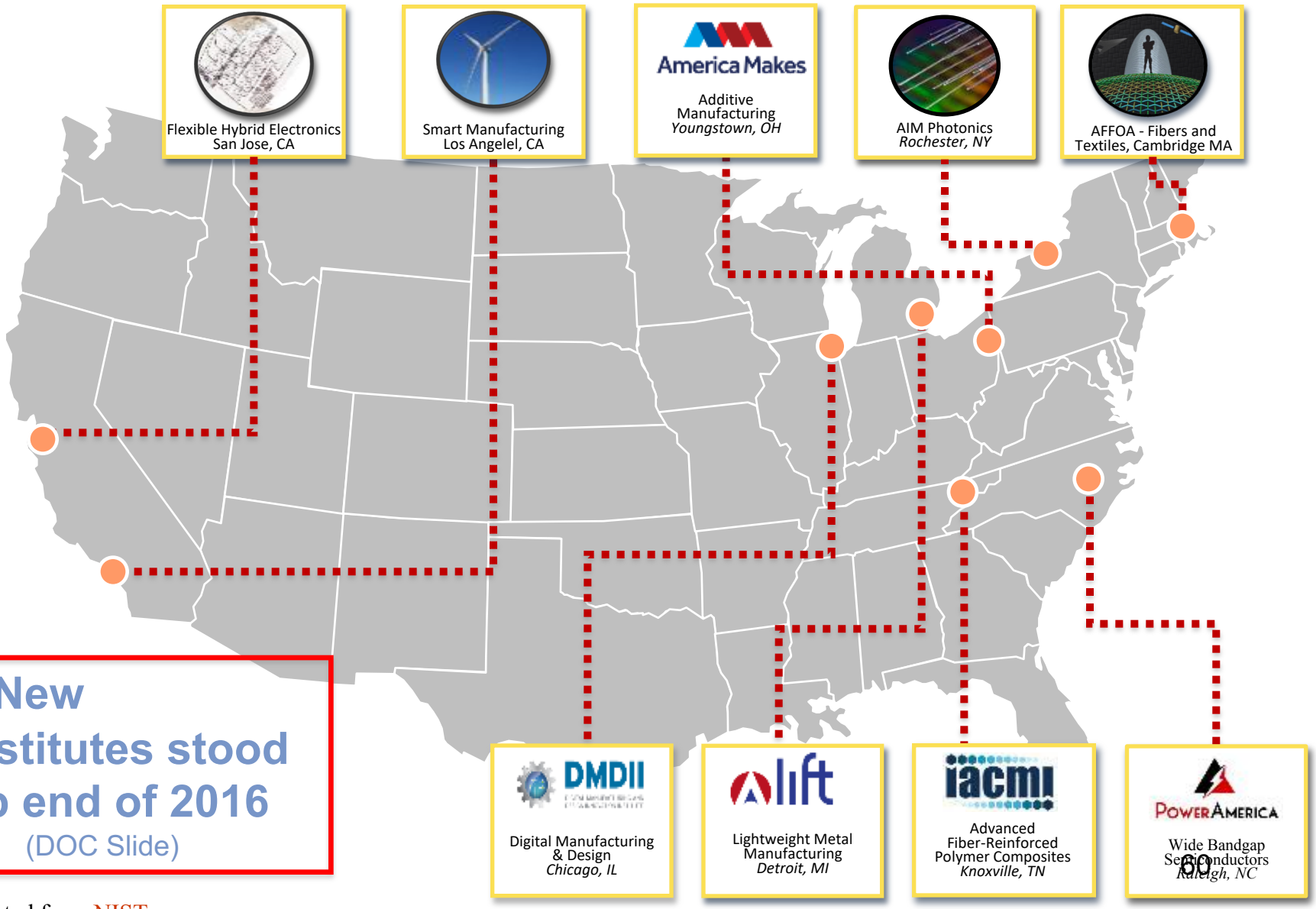
Mfg. Institute Network Status and 2016 Plans



5 New Institutes stood up end of 2016

(DOC Slide)

Image adapted from NIST.

The 9 Manufacturing Institutes as of fall 2016:

- Additive Manufacturing (3D Printing)
- Digital Manufacturing and Design Innovation
- Lightweight and Modern Metals
- Next Gen Power Electronics
- Advanced Composites Manufacturing
- Photonics
- Flexible Hybrid Electronics
- Advanced Functional Fibers
- "Smart" Manufacturing – adv'd controls, sensors, platforms

Next Five Institutes named at the end of 2016 & beginning 2017:

- *Defense Department*
  - *Bioengineering for Regenerative Medicine*
  - *Assistive and Soft Robotics*
- *Energy Department*
  - *Modular Chemical Process Intensification*
  - Sustainable Manufacturing —*Recycling and Remanufacturing*
- *Commerce Department:*

  open topics – industry/university collaborations proposed: *bio mfg.*

1) Clear, unique Institute Focus

Each Institute has a clear mission based on a critical Industry need

Opportunity:

Lightweight composites:

- Major benefits to energy efficiency, renewable power generation – auto, aerospace, wind
- Problem: overcome barriers to deployment
- How: advanced technologies to make composites
- Means lower cost, faster production, using less energy
- readily recycled

- **Big Idea:**
- The Institute: world-class resources to partners
- develop new low-cost, high-speed, and efficient manufacturing and recycling process technologies
- promote widespread use of advanced fiber-reinforced polymer composites.

Focus on:

- cut overall manufacturing costs of advanced composites by 50 percent
- reduce the energy used to make composites by 75 percent
- increase the ability to recycle composites by 95 percent
- In ten years

2) Clear Industry Value Proposition

Each Institute to create value for industry participation in return for cost-share funding

- **Access to Shared RD&D Resources:** access to equipment, from lab to full-scale, to for demonstration -- reduce risk for industry investment
- **Applied R&D**: significant government, industry, and academic funding for innovative solutions to member challenges
- **Composites Virtual Factory**: access to end to end commercial modeling and simulation software for composite designers and manufacturers through a web based platform.
- **Workforce Training**: Provide specialized training to prepare current and future workforces for the latest manufacturing methods and technologies

3) Strong Private-Public Partnership

Each Institute is operated by a consortium - a partnership of Industry, Academia and Government -- institute evaluation process now underway

A partnership of world-class companies including:

Top universities including:

Economic Development Council to leverage state support and investment

Institutes are a Work in Progress – Work Still Needed

- **Creating an Adv'd Mafacturing *System* – *still to be undertaken***:
  - *Create the network for info-sharing; governance mechanism*
  - *Technology Strategies* around adv'd mfg. technologies
  - *Industry-Univ-Gov't*. - collaborative advice – advisory panel
  - *Integrated adv'd mfg R&D across agencies*–feed-in to Institutes
  - *Scale-up financing* fund - $10 b – not passed; other options being explored

Critical Manufacturing Institute Role: **Workforce Training**

- Germany: Fraunhofer Institutes have a "Fraunhofer Academy"
- It trains apprentices for "mittelstat" small and mid-sized as well as large firms in the advanced technologies that its Institutes are creating
  - learning by doing, classroom and workplace
- *IT IS THE ADVANCED MFG. TECHNOLOGY DISSEMINATiON MODEL*
  - The way advanced manufacturing technologies get into company plants –
  - Learning walks on two feet, not via plans

Summary:

- Advanced Manufacturing Institutes –
  - IDEA: Apply the still strong US Innovation System to Manufacturing
  - Manufacturing Institutes evolving
- Still need work on –
  - Connecting the R&D System to the Institutes
  - Creating the Network
  - Workforce training
  - Scaling-up Startups

Class 4 Wrap-Up:

- Samuelson – new debate over what globalization does to the 200-year old economic doctrine of comparative advantage, where all players win in trade
  - IMPLICATIONS:
  - Growth economics teaches that innovation capability is key to a nation's growth.
  - But with a global market emerging in high skilled jobs, including services, most of the US workforce is in global competition, including its innovation capacity.
  - Can one nation now quickly displace another's innovation capacity and so capture its comparative trade advantage?
  - Bhagwati: "immerserating" – where high skill nation loses from slashed prices resulting from trade / this forces downward wage competition

Wrap-Up, Continued:

- Pisano and Shih
  - US can no longer make certain key advanced technology electronic components

Wrap-Up, Continued

- Nahn and Steinfeld
  - China up from 10% of world production in 2000 to 19% in 2011 – passed the U.S.
  - Has developed innovative new production scale-up capability
- Elements of China's model:
  - Backward design – take existing products and create cheaper models
  - Partnership of foreign design and Chinese mfg.= multidirectional learning
  - Technology absorption and collaborative development across networked production firms

Wrap-Up, Continued

- MIT Production in the Innovation Economy report (2013)
- Manufacturing is not Agriculture
- Our Manufacturing Firms are Increasingly "Home Alone"
- The Scale-Up problem for small, mid-sized, and start-up firms – most of U.S. manufacturing production strong
- Close linkage between innovation/production
- Workforce: to move to adv'd mfg., need skills training
- Germany's lesson on strong mfg. ecosystem
- Jobs – tie tradeable goods to tradeable services for scaleable growth
- (How our manufacturing sector affects our services sector)

Wrap-Up, Continued:

- Background – Offshoring Innovation?
  - Services 80% of US GDP; offsets US trade deficit in goods
  - US now shifting R&D offshore – innovation effect?
  - Drivers of Offshore Outsourcing:
    - IT availability worldwide
    - Low labor costs abroad
    - Availability of highly-education labor
    - Foreign gov't subsidies, weak regulatory regimes
    - Offshore partnering mechanisms now widespread
    - Access to new and large markets

Wrap-up, Continued

- **Bonvillian & Weiss – *Technological Innovation in Legacy Sectors, and Bonvillian – Donald Trump Voters***
  - US – does it need a new look at manufacturing? Hollowing Out?
  - What are some of the elements to consider in that approach:
    - Direct innovation factors
      - technological and related innovation
      - Talent
      - If growth is driven by innovation, that's the option
    - Can the U.S. seek productivity gains and innovate back into mfg. competition?
    - Remember the Hourglass

Wrap-Up, Continued:

- **Advanced Manufacturing Partnership Report – 2014**
- Manufacturing Institutes could be of bringing new innovation paradigms into US production sector – restore innovation as competitive basis
- Industry-Univ.-Gov't collaboration model – public/private partnership concept
- But: more work to be done:
  - Workforce education
  - Link institues to R&D system
  - Creating the Network of institutes

STS.081J / 17.395J Innovation Systems for Science, Technology, Energy, Manufacturing and Health

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