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"Spurring Technological Innovation in America's Legacy Sectors"

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"Taking Covered Wagons West"

U.S. is good at the *NEXT BIG THING*

Don't like your neighborhood?

Take your covered wagon over the mountains to new territory!

This is true in technology –

- The U.S. likes standing up technology in new territory, in open fields - like computing
- We pack our Tech Covered Wagons and *Go West, leaving Legacy problems behind*

U.S. Innovations Like to Land in Unoccupied Territory -- ***Legacy Sectors are Occupied Territory…***

- In Legacy Sectors, new technology must ***parachute into occupied territory*** -
  - and it will be shot at
- U.S.: not good at going ***Back East*** over the mountains
  - - at revisiting established territory and bringing innovation to it - ***we don't do West to East***
    - We do biotechnology, we don't go back and fix the health care delivery system
- ***Yet huge economic gains*** not just from the new but fixing the old

Can we innovate our way out of our big 21st Century problems?

- The big ones –
  - Climate – including food and water
  - Jobless Innovation
  - Health care delivery
  - Improve Education/address inequality
- To do this we have to confront our Legacy Sector barriers
  - These are *"hidden in plain sight"*
  - To solve our big public challenges, *we have no other move …*
- So how do we do it?

Bringing emerging technologies into Legacy Sectors is not "*Mission Impossible*" --

- Areas where innovation has transformed Legacy Sectors:
  - The "Revolution in Military Affairs" in the Defense Sector in the 90's
- Sectors where we now see the potential for new innovation:
  - Advanced Manufacturing
  - New Energy Technologies
  - Driverless Cars
  - Commercial Space
  - Online education

A Unifying Analytic Framework

To explain **common features of barriers to innovation** in legacy sectors, we:

- Built on work of earlier scholars
- Created a unifying analytic framework that encompasses the many steps in the innovative process:
  - R&D, prototype, invention, demonstration, testbed, manufacturing, market launch
- Classified the active role of government in innovation into models of "innovation dynamics:"
  - Pipeline, induced innovation, extended pipeline, manufacturing-led, innovation organization
- Explained the effect of context on the demand side for innovation
  - Economics, politics, law, culture

Take-home Lessons

- Innovation researchers need ***to pay more attention to "Legacy" sectors*** that resist disruptive innovation
- The barriers to innovation in different ***Legacy sectors have much in common***
- The economic, political, cultural, social, and legal ***context of innovation can be as important as the innovation system***
- ***Manufacturing is a Legacy sector*** that is an important source of both jobs and innovation
- Encouraging innovation in Legacy sectors requires ***attention to the entire innovation process***. *It should both consider R&D and anticipate and confront barriers to scale up and market launch*

Resistance to Innovation in Entrenched Legacy Sectors:

Legacy Sectors:

- Provide incentives to producers that **do not align with societal objectives**
- Are well-positioned **to resist disruptive innovation**
- Are defended by **technological/ economic/ political/ social/cultural/legal paradigms:**
  - *Institutions, infrastructure, policies, regulations, public attitudes, social systems, knowledge systems, career paths, political support,*
- and numerous **market imperfections**

Innovations in Legacy Sectors:

- *Face **no special obstacles IF they fit the paradigm***
- *Face high obstacles if they do **NOT** fit prevailing business models–*
  - *-- especially if they are driven by externalities like environment, climate, public health or safety*
- *These obstacles **are defended by powerful vested interests** and share* common features
- *Governments sometimes inhibit innovation and sometimes guide it into desirable directions.*

Legacy Sectors in the US Include:

- Fossil Fuel Energy
- Manufacturing
- The Electric Grid
- Transportation
- Higher Education
- Health Delivery
- Buildings
- Agriculture
- Defense

- These and similar legacy sectors constitute more than **half the US economy**
- **Their resistance to innovation drags down economic growth**, job creation and response to environment, safety, public health, and other **public goods**

Legacy Sector Paradigms Block Disruptive Innovation with --

- Perverse Subsidies
- Established infrastructure
- Public Habits and Expectations
- Financing Mechanisms
- Knowledge and human resources structure
  - *All Favoring Established Technology*
  - *All Backed by Vested Interests*

<u>Market Imperfections</u>:

- Network Economies
- Non- Appropriability
- Lumpiness
  - (minimum investment size)
- Need for Collective Action
  - *These issues are well known to specialists – but the fact that legacy sectors have features in common is less well appreciated*

Fossil Fuels as the 'Poster Child' Legacy Sector:

Paradigm-Compatible innovations (e.g., fracking) expand smoothly;
renewables and conservation must overcome obstacles favoring established technology

Legacy Characteristics:

- Perverse prices that do not reflect externalities
  - (no carbon charge)
- Established infrastructure
- Public expectations of cheap energy
- Career paths and university curricula favor coal, oil, gas
- Regulatory requirements place obstacles before wind and solar
- Limited r&d compared to revenue
- ***All defended by powerful vested interests***

Market Imperfections Hindering New Technologies/Renewables :

- Perverse subsidies
  - (depletion allowances and tax incentives)
- Network Economies
  - (charging stations)
- Non- Appropriability
  - (conservation investments)
- Lumpiness
  - (minimum investment size for CCS, next gen nuclear, enhanced geothermal)
- Need for collective action
- Short time horizon of venture financing

Other Legacy Sectors Display Many of These Obstacles to Disruptive Innovation --

- The Electric Grid
  - Network economies
  - Non-appropriability
  - Vested interests (state regulators)
- Industrial Agriculture
  - Needs for collective action for research
  - Vested Interests (agribusiness)
- Transport
  - Infrastructure
  - Regulatory impediments (to driverless cars)
  - Network Economies
  - Standards and Legal Regimes
- Health Delivery
  - Network economies
  - Lack of performance standards (for digital patient records)
  - Non-appropriability
- Higher EdUcation
  - Fixed career paths
  - Institutional structure
  - Public expectations
  - Perverse pricing
  - Needs for collective action (for learning science research and implementation)
  - Vested Interests (faculty)
- Buildings
  - Non-appropriability (for conservatIon investments)
  - Need for collective action (for R&D)
  - Regulatory Impediments (building standards)
- Military – both legacy *and* innovative
  - Disruption-resistant services and financial models
  - Disruption-fomenting DARPA and change agents like Perry, Admiral Rickover

Legacy sector paradigms are elements of an *"Innovation Context"* at the *sectoral* level

The *Innovation Environment* = the ***sum*** of the *innovation System* and the *innovation Context*

Innovation System Consists of:

- Firms, institutions and policies that carry out, encourage, facilitate, and support research, development, innovation, and development of technical capacity
- This is a common subject of innovation research

Innovation Context Consists of:

- The political, economic, social, legal, and cultural *context* for innovation
- This is as important as the innovation system in determining
  - Whether innovation does or does not take place
  - Whether innovations improve environment, safety, or health
- Context: *en*abling *or* *dis*abling --
  - *Legacy sectors suffer from a* ***disabling innovation context***

Innovation System *versus* Innovation Context

Innovation System

- **Institutions:**
  - R&D laboratories, universities, research institutions, education, resource evaluation, standards, consulting, engineering, STEM organizations, innovative firms, technical publications, supporting services
- **Policies and Programs:**
  - R&D support, basic and applied
  - Science, technology and innovation policy
  - Protection of Intellectual property
  - Support to research and graduate education,
  - support to venture capital, risk capital investment
  - Prizes for innovation
  - Public procurement for innovative technology

Innovation Context

- **Political**
  - Stable, relatively free of corruption and overregulation
- **Economic**
  - Macroeconomic environment, exchange rates, business climate, trade & competition policy, tax system, stability
  - Access to finance
  - Physical infrastructure and connectivity
- **Legal**
  - Labor, commercial, commercial transactions, immigration, bankruptcy, pensions, property
  - Functioning and reasonably honest court system
- **Cultural attitudes toward**
  - Risk, novelty, individualism, competition, cooperation, university-industry cooperation
  - Importance of family, class, alumni connections, religion
  - Acceptance of social mobility, promotion on merit, failure, gender/sexual preference, ethnic origin

US Innovation Owes a Great Deal to its Favorable National Innovation *Context*

Positives

- Economic
  - Huge, relatively unregulated internal market
  - Flexible, mobile labor market
  - Stable macroeconomics, favorable business climate
  - Portable pensions
- Social and Cultural
  - Welcomes novelty, competition, disruption
  - Proud of individualism
  - Accepts risk of failure
  - Rewards merit
- Legal
  - Basic legal structure: IP, commercial and property protections, bankruptcy flexibliity

Despite . . .

- Spotty educational systems
- Neglect of physical infrastructure
- Neglect of legacy sectors, especially mfg.
- Neglect of environmental externalities, especially climate
- Lack of understanding of role of government in the innovative process,
  - leads to opposition to
    - "corporate welfare"
    - gov't investment in later stage technology

A *Disabling Innovation Context* can Derail Innovation in Part or All of a *National* Economy

- Kleptocratic ***Russia*** and ***North Africa***
- The over-regulated 'License Raj' in Post-Colonial ***India***
- Obstacles to "next big thing" innovation in
  - ***Germany*** – though strong in high-quality manufacturing
  - ***China*** – though strong in manufacturing scale-up and IT adapted to local markets
  - ***France*** – though strong in infrastructure
- The US can learn from the strengths of other countries -- despite its success in IT and biotech

Five Models of Innovation Dynamics

3 are New

-- Legacy sectors create barriers to innovation – understanding them helps us to choose policy instruments to overcome these barriers.

1. The Pipeline:

- Technology-Push, Technology-Supply
  - Federally supported research pushes basic research
  - New technologies develop and push into markets
- Dominant model underlying US innovation policy

2. Induced:

- Technology-Pull, Demand-Pull
- Industry spots market niche
- Technology advances (often incremental) are pulled to meet demand
- Innovation can be induced by changes in markets or policy
  - Environment, safety, public health, gov't incentives, prizes

Models of Innovation Dynamics, Con't

3. The Extended Pipeline - *NEW*

- Technology-Push
- But Government technology support at every stage
- Defense Department support to R, D, demonstration, testbed, initial market creation

4. Manufacturing-Led Innovation - *NEW*

- Initial production can be highly innovative –
  - Design a product to fit a market, redo the science, highly creative engineering
  - Example – Japan's creation of Quality Manufacturing
  - An important but underappreciated source of innovation

Models of Innovation Dynamics, Con't

5. Innovation Organization – *NEW*

- Encompasses the four other models
- Goes beyond them to take account of broad context and structure into which innovation is to be introduced
- To innovate in legacy sectors, need all four models,
- Need *change agents* to orchestrate the full innovation environment and the actors within it to address new technology and broader policy and institutional issues

→ *Manufacturing has not been considered a source of innovation;*

→ *Three of the Five models involve a major government role*

Example: Manufacturing and "Full-Spectrum Innovation"

Manufacturing :

- Both a **Legacy sector** (has a locked-in tech/economic/political/social paradigm) ***and*** **a Model of Innovation Dynamics**
- So: an especially important legacy sector
- U.S. thinks of R&D as key to innovation – hasn't recognized **production as an innovation stage**
  - – yet it's highly creative and critical to the innovation system
  - **Germany, Japan. Korea, Taiwan, China all organize their innovation systems around manufacturing**

The Innovation Spectrum:

- After WWII, U.S. organized its innovation system to do "full spectrum innovation" –from R&D through production at scale
  - *"innovate here/produce here"*
- Got the full range of gains from every stage

"Innovate Here, Produce There"

- Both MNCs and start-ups are shifting production offshore = "**innovate here/produce there**"
- *Led to:* Loss of "industrial ecosystem" -
  - supply chain support, vendors, consultants, university programs and education, training, applied research labs thinned out
- *Led to:* SMEs left high and dry
- *Led to:* ***jobless innovation*** in sectors where manufacturing and innovation are linked
  - Aerospace, capital goods, pharma

Loss of Manufacturing Means Loss of Full-Spectrum Innovation and hence Job Loss

- Loss of Jobs:
  - U.S. lost 1/3 of manufacturing jobs in 2000-2010 – still haven't come close to recovering
  - Although software led to new firms (Uber, eBay, etc.) manufacturing jobs are still the highest job multipliers
  - Manufacturing is the way the economy scales via innovation-based growth, not services (slower scaling)

- Loss of full-spectrum innovation causes significant loss:
  - in job creation,
  - in speed of economic recovery,
  - But particularly -- *in innovation capacity*
  - *Risk of* ***"produce there/innovate there"***

Implications:

- Stimulating innovation in legacy sectors requires *full-spectrum innovation policy*
  - Need to fill system gaps
    - at front end of the innovative Process: R&D, prototype
    - At back end end of the innovation process:
      - demonstration, testbed, manufacturing, market launch
- Active government role *Beyond the Pipeline Model:*
  - Support research to create disruptive technologies
  - Changes in policy to remove obstacles to market launch
  - Recognition of manufacturing as source of innovation and jobs

Launching Innovation into Legacy Sectors

A Five-Step Framework

Step 1: Strengthening the Front End of the Innovation System

- No innovation without innovations
- Form critical innovation institutions,
- Use the "island bridge" model - put innovators on a protected island but linked to decision makers,
- Build a "thinking community" to build and support ideas,
- Link technologists to operators,
- Create "connected science and technology" – links between front and back end stages and actors

Launching Innovation in Legacy Sectors, Con't

Step 2: Identifying the Launch Paths for Emerging Technologies

Step 3: Matching Support Policies to Technology Launch Pathways

Step 4: Analyzing Gaps in the Innovation System

- Ex's – ARPA-E, Adv'd Manufacturing Institutes

Step 5: Filling the Gaps in the Innovation System

Launching Innovation in Legacy Sectors, Continued

The Change Agent Role

- Innovation requires *orchestration*:
  - institutions and individuals prepared to intervene in legacy systems
- They must apply "Innovation Organization" Model

How do we know these steps work in Legacy Sectors?

- These steps were way DOD did "Revolution in Military Affairs"
- Also the essential design behind Advanced Manufacturing initiatives and recent Clean Energy Initiatives

Case Study - "Advanced Manufacturing"

- **Idea – innovate in production technologies and procesess --**
  - to dramatically grow manufacturing productivity and cut production costs
  - to put developed country production in competition with regions with low labor costs
- **Will technology development support this?**
  - **New technologies enabled** - use of information, autonomy, computation, software, sensing, networking, cutting-edge materials and other emerging capabilities from sciences
  - Enable **new manufacturing models**: network centric, advanced materials, nanofabrication, mass customization, distribution efficiency, energy efficiency, etc.
- **Where will the jobs be?**
  - "Advanced Manufacturing" jobs likely indirect, spread through **value chains dependent on mfg**., on **input and output side of mfg**.

Case Study - Steps for "Advanced Manufacturing"

- **Innovation on the Front End**
  - need federal R&D coordination - better organized around new manufacturing models
- **Develop New Launch Pathways**
  - New technology strategies developed by collaborations between industry-university-gov't agency experts, for new manufacturing models
  - Manufacturing Institutes – bring together small and large firms with university research to innovate new technologies and process – focus on TR levels 4-7, demonstration, testing, pilot production
  - Gov't/Industry cost sharing – federal and state cost sharing enables industry sharing cost of technology de-risking
- These steps help **Fill the Innovation System Gaps** from the hollowing-out of the manufacturing ecosystem – but scale-up financing still a gap
- **Change Agents** – in industry, gov't, agencies, with support from top gov't levels

Wrap-Up

- *Legacy sectors* – most of the economy – resist innovation unless it fits their *technological/economic/political/social paradigm*
- Legacy sectors share in common a series of *barriers and market imperfections*
- *"Innovation environment"*– needed new term for dealing with legacy sectors – encompasses national innovation *system* and innovation *context*
  - Legacy sectors are found *in All Economies*– Asian and European national environments have legacy features

Wrap-Up, Con't

- For innovation to enter legacy sectors, need to understand *the 5 Models for Innovation* –
  - pipeline, induced, extended pipeline, manufacturing-led, innovation organization –
  - Legacy sectors require the "innovation organization" model, which
  - *encompasses the others* –requires application of the other four models
  - Means focus on whole innovation system, both R&D and policy
- *Manufacturing* - particularly interesting – *both a legacy sector and model for innovation AND A DRIVER OF JOBS*
  - Needs to be seen as part of the innovation process
- *Bringing innovation into legacy sectors – five step framework*
  - Strengthen early stage innovation,
  - understand innovation launch pathways and tie policies to them,
  - analyze the gaps in the sector's innovation system and fill them
  - utilize change agents, a needed ingredient

Background Info: Bonvillian & Weiss – Fall 2015

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Technological Innovation in Legacy Sectors --

- **Explores the entrenched "legacy" sectors**, comprising over half the economy, that resist disruptive innovations that could stimulate economic growth, generate jobs, and improve safety and the environment.
- Argues that we **need to rethink existing strategies for promoting innovation –** the authors' new framework identifies the barriers common to these legacy sectors and proposes a systematic approach for overcoming them.
- Creates a new, **unified, systems approach to innovation policy**, focused on overcoming two deep problems in the U.S. innovation system: **expanding economic growth** and **raising the rate of creation of well-paying jobs**.

Early Reviews -

- "Bonvillian and Weiss have written an **important book**... Of particular value is their **analysis of the structural obstacles to disruptive innovation in these sectors, and how those obstacles can be overcome**."

  - Jeff Bingaman, former U.S. Senator and Chairman of the Senate Committee on Energy and Natural Resources

- "This **remarkable book** by William Bonvillian and Charles Weiss offers **new insights, analysis, and solutions** about one of the most important long-term challenges facing our economy: how to introduce technological innovations in legacy sectors."

  - Arun Majumdar, Precourt Professor at Stanford University, and founding Director of ARPA-E

Early Reviews – Con't

- "Because innovation is central to driving progress it's unfortunate that innovation policy analysis is all too often one-dimensional. *Technological Innovation in Legacy Sectors* provides a **sorely needed antidote, providing compelling analysis of how innovation actually occurs – or does not – and what governments need to do to accelerate the pace**."
  - Robert D. Atkinson, President, Information Technology and Innovation Foundation (ITIF)

- "Bonvillian and Weiss show again that they are **master students of America's innovation system**."
  - Kent H. Hughes, Public Policy Scholar, Woodrow Wilson International Center for Scholars

Early Reviews - Con't

- "With this book Bonvillian and Weiss shine a **vivid light on one of the most critical and least well-examined challenges of American innovation policy**… I hope this book can **launch a vigorous national debate on a set of issues that have long hidden in plain sight**."
  - Henry Kelly, former President, Federation of American Scientists and senior official at the White House Office of Science and Technology Policy and the Department of Energy

- "**The book fills a major gap and should be read by anyone concerned with our 'jobless innovation**.'"
  - Irving Wladawsky-Berger, former IBM Vice President for Technology Strategy and cochair of the President's Council of Advisors on Science and Technology (PCAST)