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

But 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 innovation entry:
  - Advanced Manufacturing
  - New Energy Technologies
  - Driverless Cars
  - Commercial Space
  - Online education

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
  - Education/inequality
- To do this we have to confront our Legacy Sector barriers
  - These are "*hidden in plain sight*"
  - We have no other move …
- So how do we do it?

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, including both R&D and confronting barriers to scale up and market launch.*

Resistance to Innovation in Entrenched Legacy Sectors:

Legacy Sectors:

- 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:

- *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 can both inhibit innovation and guide it into desirable directions.*

Legacy Sectors in the US Include:

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

Fossil Fuels as a Legacy Sector:

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

Legacy Characteristics:

- Perverse prices
  - (no carbon charge)
- Established infrastructure
- Public expectations of cheap energy
- Career paths
- University curricula
- Regulatory requirements
  - (Wind and solar)
- *All defended by powerful vested interests*

Market Imperfections:

- Perverse subsidies
  - (depletion allowances)
- Network Economies
  - (charging stations)
- Non- Appropriability
  - (conservation investments)
- Lumpiness
  - (minimum investment size for CCS, next generation nuclear, enhanced geothermal)
- Venture financing with a time horizon suited to IT

Other Legacy Sectors Display Many of these Obstacles --

- The Electric Grid –
  - network economies, non- appropriability, vested interests (state regulators)
- Industrial agriculture
  - Perverse subsidies, needs for collective action, vested interests
  - (agro-business)
- Transport
  - Infrastructure, regulatory impediments, network economies, standards
- Higher Education
  - Career path, institutional structure, public expectations, perverse price structure, needs for collective action, vested interests (faculty)
- Health Delivery
  - Network economies, non- appropriability, lack of inter-operable standards
- Buildings
  - Non- appropriability, needs for collective action, regulatory impediments
- Military
  - Disruption-resistant services and
  - Disruption- fomenting DARPA and individuals like Adm. Rickover

Legacy sector paradigms are elements of an unfavorable "Innovation *Environment*" at the *sectoral* level.

Innovation System is:

- 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 is:

- The political, economic, legal, and cultural *context* for innovation
- As important as the innovation system in determining
  - Whether innovation does or does not take place
  - Whether innovations improve environment, safety, or health
- Can be enabling or *dis*abling --
  - *Legacy sectors suffer from a* ***disabling innovation context***

In Sum, 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*

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 other countries
  - despite its success in IT and biotech

5 Models of Innovation Dynamics

➡ 3 are New

-- Legacy sectors create barriers to innovation -- to overcome them, need to understand the models for how innovation comes about:

1. The Pipeline:

- Technology-Push, Technology-Supply
- Federal research pushes basic research
- new technologies develop and push into markets

2. Induced:

- Technology-Pull, Demand-Pull
- Industry spots market niche
- Incremental technology advances are pulled to meet demand

Models of Innovation Dynamics, Con't

3. The Extended Pipeline - *NEW*

- Technology-Push
- but Government technology support at every stage
- Defense Dept: R, D, demo, testbed, initial market creation

4. Manufacturing-Led - *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
  - Part of the innovation process

Models of Innovation Dynamics, Con't

5. Innovation Organization – *NEW*

- Encompasses the four models
- Goes beyond them to take account of broad structure into which innovation is to be introduced
- To innovate in legacy sectors, need the four models, but need to orchestrate them and the actors within them to enable entry

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

→ *3 of the 5 models involve a major government role*

Manufacturing-Led Innovation

Manufacturing :

- Both a Legacy sector (has a locked in tech/economic/political/social model) *and* an Innovation Dyanmics Model
- So: 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 innovation system
  - Germany, Japan. Korea, Taiwan, China – organize their innovation systems around manufacturing

The Innovation Spectrum:

- U.S. organized its innovation system after WW2 to do "full spectrum innovation" – did the R&D through the production at scale
- *"innovate here/produce here"*

Manufacturing-Led Innovation, con't

Now:

"innovate here/produce there"

- Shifting production stage offshore

- ***RISK***: manufacturing is an innovation stage – run the risk of *"produce there/innovate there"* - in sectors where manufacturing and innovation are linked

Manufacturing-led Innovation, con't

- Job creation issue:
  - U.S. lost 1/3 of manufacturing jobs in 2000-2010 – still haven't come close to recovering
  - Manufacturing jobs are highest job multipliers
  - Manufacturing is the way the economy scales innovation-based growth, not services (slower scaling)

- Lose full-spectrum innovation, pay significant price
  - in job creation,
  - in speed of economic recovery,
  - But particularly -- *in innovation capacity*

Implications:

- Stimulating innovation in legacy sectors requires *full-spectrum innovation policy*
  - Need to fill system gaps at front and back ends
- 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
    - Note: With "Advanced Manufacturing" - jobs likely indirect, and spread through value chains dependent on mfg.

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: Gap Analysis of the Innovation System

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

Step 5: Filling the Innovation System Gaps

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?**
  - There are new technologies enable the 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 cost sharing – federal and state – enables 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, and innovation organization -
  - which *encompasses the others* – applying the innovation organization model requires application of the other four models
- *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)