Quadruple Helix and "Mode 3" Knowledge Creation: Moving from Tactical Fragmentation to Strategic Integration

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KEYNOTE LECTURE
ICEIRD 2009
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World Economy in a New Era
21st-Century Drivers of Change

- **Network Ubiquity**
  - **–More than a billion Internet users and three billion wireless subscribers, worldwide**
- **Open Standards**
  - **–Widely-adopted technical and transaction specifications**
- **New Business Designs**
  - **–Horizontally-integrated operations**

TWO KEY POINTS ON GLOBALIZATION

1. Globalisation will continue and it will continue to create pressures to reallocate economic resources across sectors, firms and occupations.

Globalisation means unbundling. All sorts of economic relationships were bundled spatially to avoid or minimise transportation; this situation implied that the price of many goods, services and wages were set in local markets, not global markets. This bundling meant that workers' pay was tied to the bundle's average productivity. By pure logic, we know that the link to the average dragged down the wage of some workers while pulling up the wages of others. Unbundling breaks the link to the bundle's average. Workers will increasingly get paid what they are worth on the world market. This will lead to gains and pains from trade.

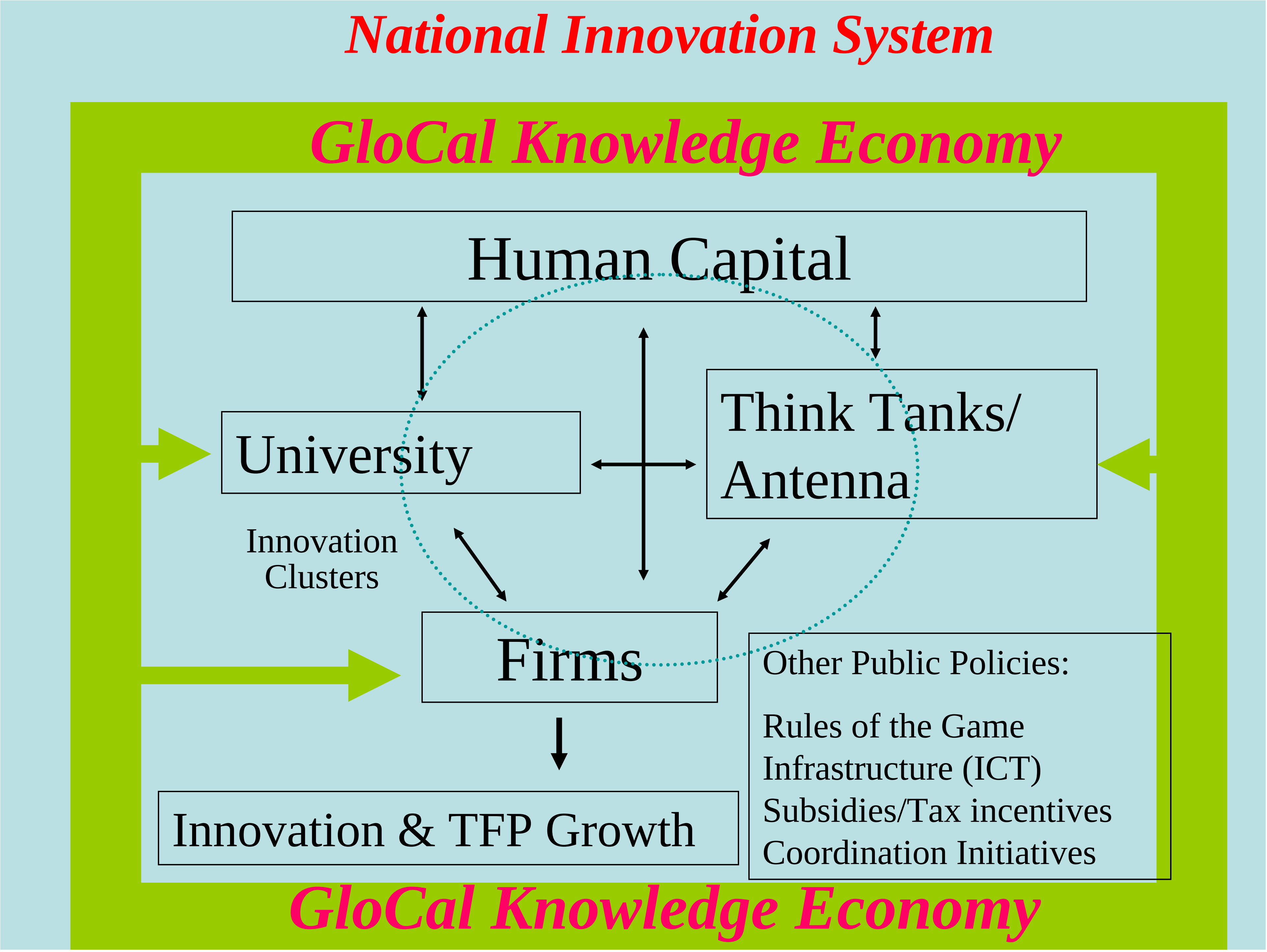
2. The direction and nature of the change is impossible to predict with any accuracy.

Government statistical collection procedures were set up to track the post-war industrial boom when jobs were associated with particular firms and particular firms were associated with particular sectors. Now, jobs are associated with particular tasks and tasks are increasingly reallocated across firms across sectors (outsourcing) and across nations (offshoring). Economists do not have detailed knowledge of exactly what caused the bundling in the first place, so they will not be very good at predicting how the unbundling will occur, i.e. which tasks will be offshored and which will not. Moreover, as firms experiment with unbundling, they are learning that some jobs really cannot be done in India. It turns out that even firms do not fully understand the linkages among the tasks that had been bundled geographically for so long. However, it seems clear that it is probably not true that the biggest adjustments will be made by low skilled workers as it was in the past. Many unskilled workers are performing tasks that are entirely shielded from global competition due to their very nature; it is much easier to offshore a financial analyst's job than it is to offshore a shop assistant's job.

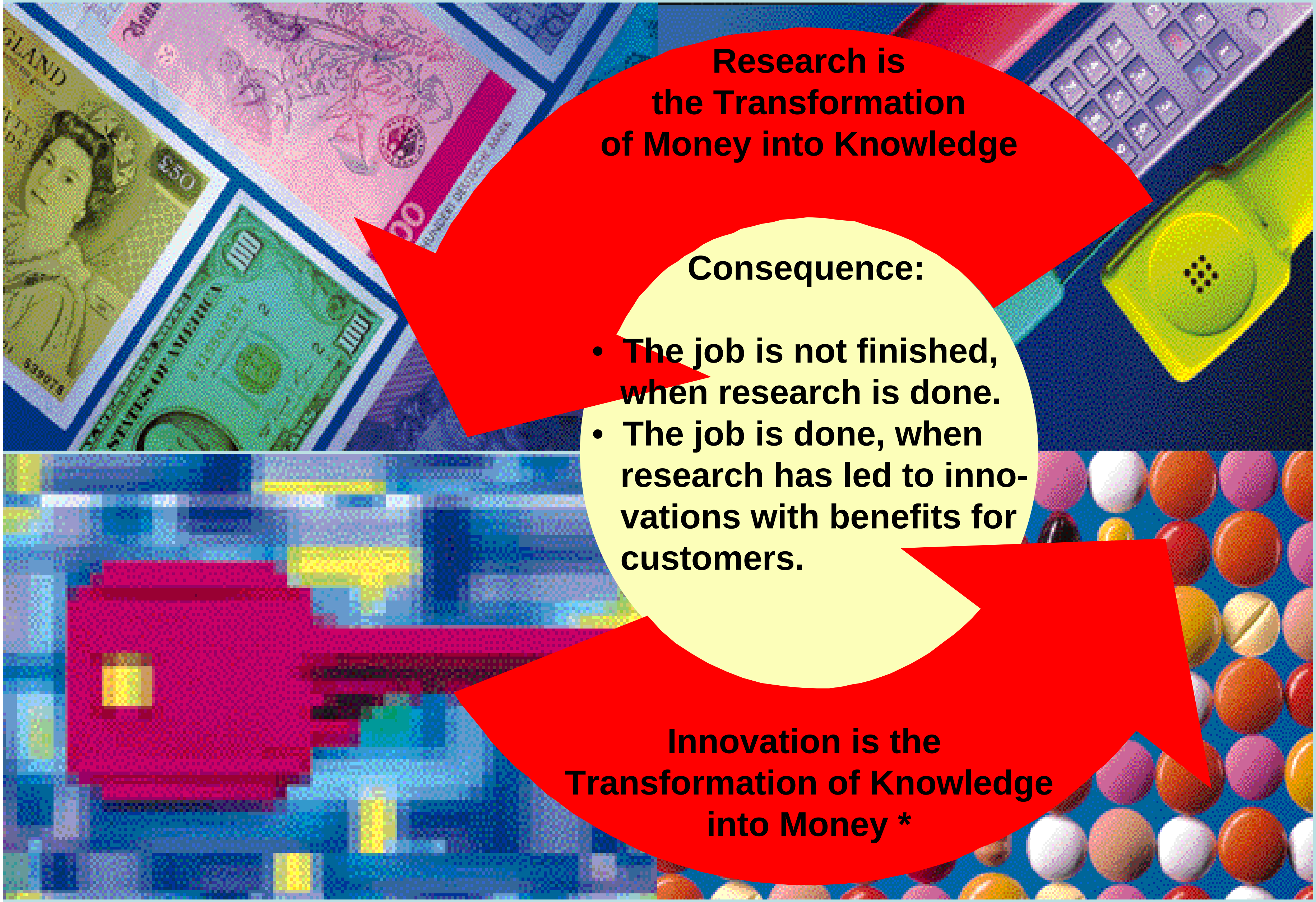
INNOVATION DEFINED

•*Innovation resides at the intersection of invention and insight, leading to the creation of social and economic value*

•*US National Innovation Initiative*


National Innovation System
GloCal Knowledge Economy
Human Capital
University
Think Tanks/
Antenna
Innovation
Clusters
Firms
Innovation & TFP Growth
Other Public Policies:
Rules of the Game
Infrastructure (ICT)
Subsidies/Tax incentives
Coordination Initiatives
GloCal Knowledge Economy

PUTTING THINGS PERSPECTIVE:



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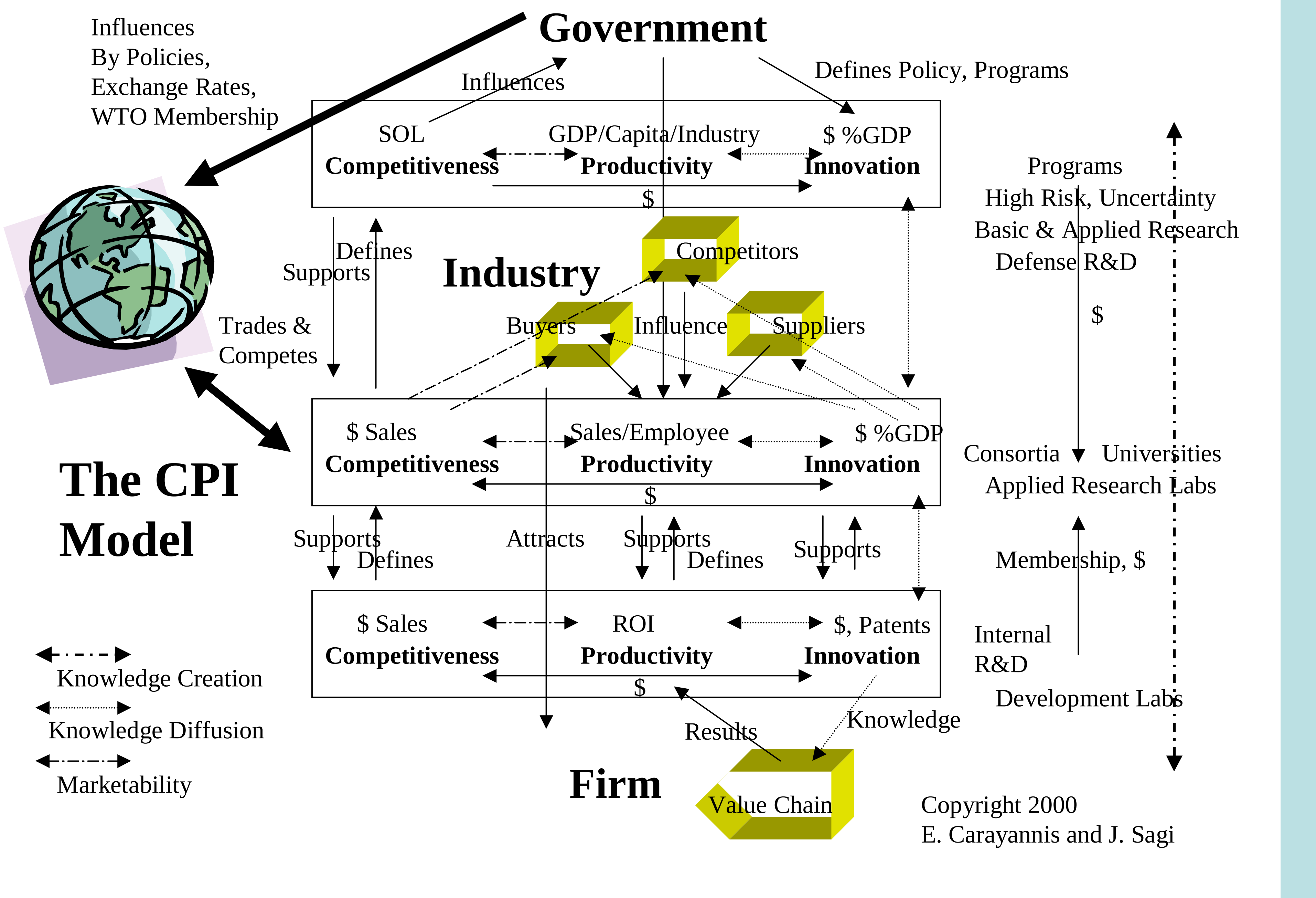
PUTTING THINGS PERSPECTIVE:



THE US INNOVATION ECOSYSTEM BENCHMARK

The Innovation Ecosystem

The dynamic system of interconnected institutions and persons that are necessary to propel technological and economic development has been described by PCAST and others as the U.S. innovation ecosystem (see the PCAST report *Sustaining the Nation's Innovation Ecosystem*). This ecosystem includes a range of actors from academia, industry, foundations, scientific and economic organizations, and government at all levels. While widely recognized as non-linear and iterative, in its most simplified form the innovation process can be viewed as generating both new knowledge (education and training) and technology (development and commercialization) that is moved from basic discovery research to the marketplace. In this model, the results of basic science, primarily funded by the Federal government and private foundations, are translated into applied science or basic technology, where research is in turn funded by a variety of public and private entities, with venture capital often providing additional funding as the science and/or technology mature. If the research results are successful and appropriate for the marketplace, they are then turned into commercial (or publically beneficial) processes and products that drive the economy. A host of conditions influence this ecosystem, such as legal and regulatory considerations. The organization of the innovation ecosystem is not rigidly planned with well-defined roles for the various actors. As a result, the relative positions of each actor, as well as the conditions encouraging or restraining the innovation process, can change continually.

Within this broad definition, five aspects of a partnership can be identified:

1. **Production** – PPPs may be distinguished by what they produce, including new knowledge that may result in measurable quantities such as bibliometric and/or economic outputs. Typically, PPPs will also produce unquantifiable forms of knowledge such as expertise, tacit "know-how," craft knowledge, and skills. They may also produce technologies including protocols, prototypes, and other translational products.

2. **Learning** – PPPs always entail learning. Formal learning within a PPP can be distinguished from informal learning or "learning by doing." The former captures training programs for faculty, post-doctoral fellows, and/or graduate students that may be a part of a PPP. The latter includes uncodified knowledge attained by individuals participating in a PPP. These two types of learning often occur together.

3. **Acquisitions and exchanges** – PPPs may also be characterized by the capital, personnel, and funding resources acquired and/or exchanged by the participants.

4. **Structure** – PPPs are most often characterized by their membership and the boundaries they span, the geographical proximity of the partners, the level of formality of the collaboration, the centrality of the collaboration, and the complexity of the collaboration.

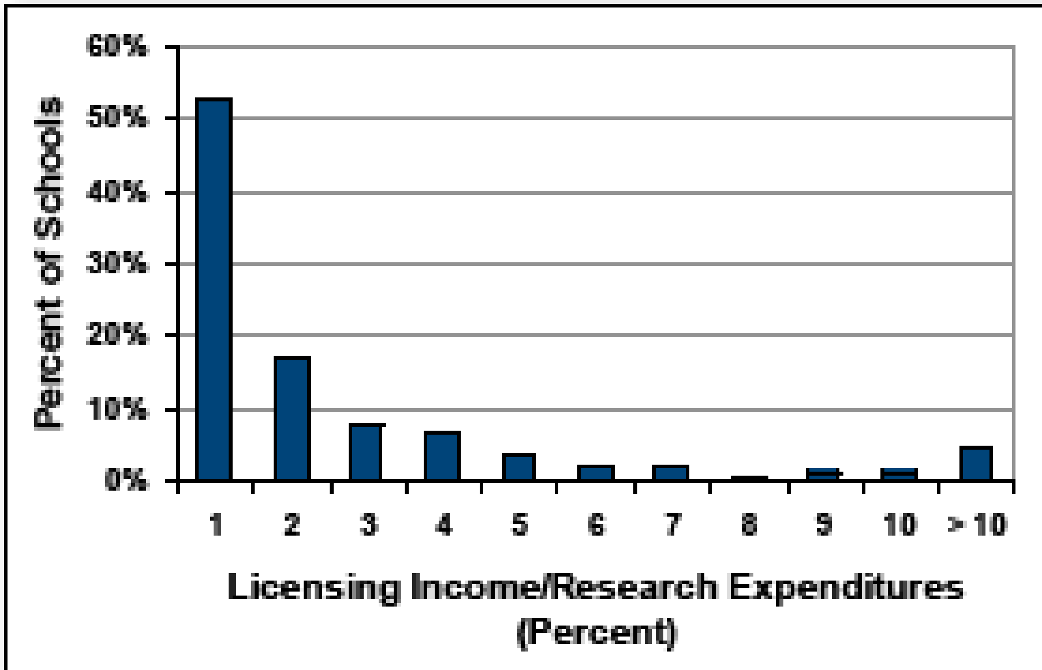
5. **Context** – PPPs must also be framed in the broader contexts in which the PPP is situated. The context of a PPP may be disaggregated into the following categories:

   - Structural context – Constraints and opportunities for behavior and productivity that are "internal" to the partnership, for instance the amount of funding.

   - Scientific and technical context – Constraints and opportunities for behavior and productivity that are "external" to the partnership and characteristic of the broader scientific field, for instance the existence, or lack thereof, of comparable programs or projects, outlets for publishing findings, etc.

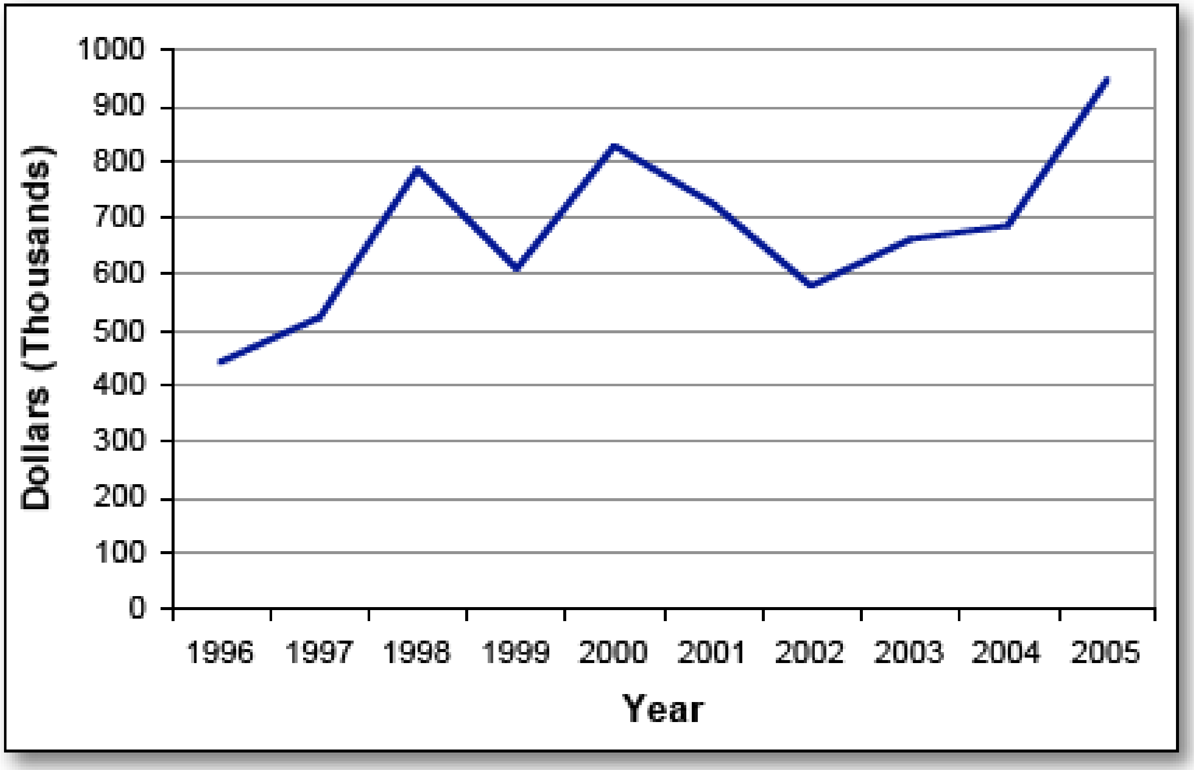
   - Institutional context – Constraints and opportunities that are related to the extent to which factors such as the academic reward structure and intellectual property rights influence the partnership's host institution and other key stakeholders.

Figure 10. Percent of Licensing Income to Research Expenditures, as reported by respondents to the AUTM Licensing Survey FY2006



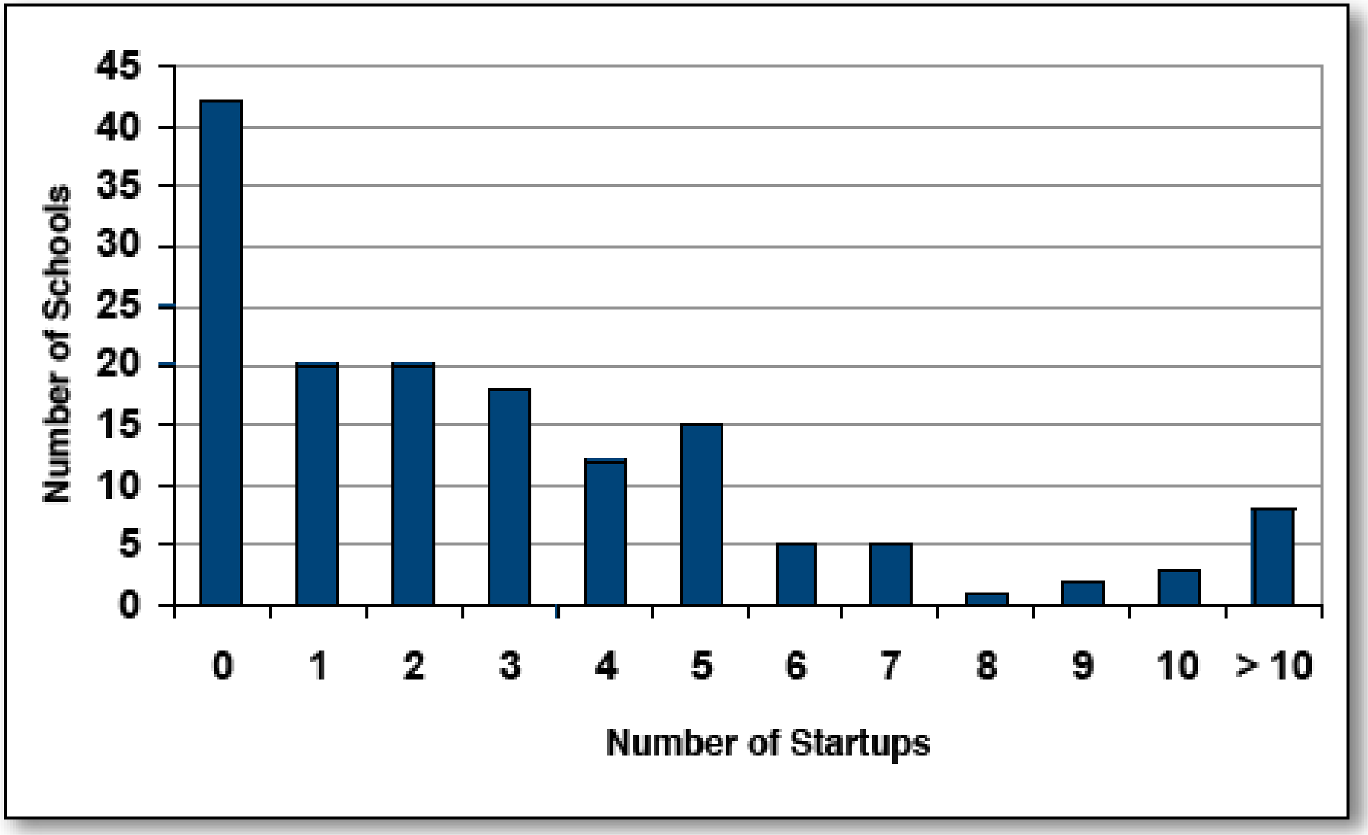
Source: AUTM Licensing Survey FY2006

Figure 11. Median net royalties from academic patenting activities, 1996–2005



Source: NSF S&E Indicators 2008

Figure 12. Number of startups launched, as reported by schools responding to the FY2006 AUTM Licensing Survey



Source: AUTM Licensing Activity Survey Data, FY2006

[30] Association of University Technology Managers' FY2006 Licensing Survey.

Challenges with Technology Transfer Between Universities and the Private Sector

As described in the previous section, in a very broad sense technology transfer is critical to every stage of the innovation process. In general, PCAST finds the policies governing this system between university and industry to be reasonably effective; however, even extremely successful partnerships identified IP negotiations as a significant barrier and a continual challenge in the development of new partnerships. Ultimately, successful technology transfer negotiations often depend on individual efforts, particularly those of the leadership, from each organization having a strong desire to establish partnerships. In discussions with university and industry leaders, PCAST identified a number of potential barriers that can arise in the technology transfer process. These include IP negotiations as well as support for graduate students, publications, and other issues. Differences in interpretation and implementation of the Bayh-Dole Act, even among and within various universities or industries continues to be a challenge.

There is also debate concerning the changing roles and impacts of university technology transfer offices and university leaders in negotiating IP agreements. Various sectors of industry have criticized some universities for employing the same technology transfer approach for pharmaceutical- and biotechnology-related discoveries as they use for information technology inventions. Additionally, a university's approach to negotiating technology rights (such as a volume model instead of focusing on potential "homerun" technologies, or an income model) appears to have a significant impact on the formation of successful partnerships. Whatever the approach or strategy, the commitment to transparency, particularly from the private sector, is essential throughout the process.

Open innovation has the potential to drive innovation in academia, the private sector, and government.

The changing paradigm from a linear innovation pathway to one more accurately described as a dynamic ecosystem highlights the many novel areas of input and collaboration that support innovation. Individuals and entire regions of the globe that would historically never interact can now collaborate on a research project in real-time. The private sector is increasingly utilizing this previously untapped resource to support their R&D efforts. These "open collaborations" or "open innovation" systems can be utilized to augment both corporations' existing internal R&D infrastructure and university collaborations. For some companies, such "distributed co-creation" could serve as a primary mechanism for new discoveries, while corporate research teams could then focus their attention on directed applications for new technologies.[37]

Over time, corporate R&D centers may tend to focus on incremental improvements to commercially successful technologies and thereby risk failing to position themselves to develop or identify disruptive innovations. Opportunities for mass collaboration provide a mechanism by which corporations may expand their R&D talent pool and seek rapid innovative solutions to their R&D questions. Companies such as InnoCentive and Proctor and Gamble, among others, have taken steps to harness mass collaboration in developing novel business models to drive innovation. Firms are developing different structures and approaches to utilize open innovation to address varied goals. This concept is too new to draw definitive conclusions about whether and how specific organizations should implement it. Additionally, not all challenges, such as IP ownership and the increased operational risks that will be faced in adopting such models, have been identified. Nonetheless, open innovation models have a number of elements that should be aggressively explored to utilize these extraordinary collaboration platforms. As a potential disruptive technology for promoting innovation, these platforms could be utilized by Federal agencies that fund or conduct research.

Targeted Prizes to Enhance Innovation

"Idea challenges" and various prize systems can serve as open innovations that complement a range of diverse approaches for innovation promotion. The use of inducement prizes and awards was prevalent in PCAST's study of research partnerships, and Federal agencies, industry, and foundations identified them as potential sources of some types of innovation. Such inducement prizes foster innovation to meet specific, future objectives. These objectives can pertain to many different stages of research, including basic research (for example, the Wolfskehl Prize to prove Fermat's Last Theorem and the Kavli prizes in the areas of neuroscience, cosmology, and nanoscience), applied research (for example, prizes in cryptography such as the Data Encryption Standard (DES) Challenges awarded for recovering the secret key used to DES-encrypt a plain-text message), and technology development (for example, the Defense Advanced Research Projects Agency (DARPA) Grand Challenge).

While the concept is not new – the use of inducement prizes to foster innovation spans nearly three centuries – there has been a renewed discussion regarding the use of prizes, and a growing number of foundations, government agencies, and private companies provide prizes of increasing size for developing solutions related to space travel, genetic sequencing, and energy efficiency, among others. The nature of the challenges and the significant awards offered by the X PRIZE Foundation have also renewed interest in the use of inducement prizes.

In 2006 Congress directed NSF to establish a prize program and the National Academy of Sciences recently released a report outlining a series of detailed recommendations for how to carry out such a program.[38] While this prize program must be balanced with NSF's primarily role and that of several other Federal funding agencies in supporting basic research through merit-based, investigator-initiated research utilizing competitive awards, PCAST identified the increased use of targeted prizes as a transformative element that can support innovation. While prizes impact innovation in a holistic manner and are not specific to university-private sector partnerships, successfully competing for innovation prizes will likely foster close collaboration between these communities.

The connection points between partners in the innovation ecosystem need to be strengthened to reduce barriers to collaborations.

PCAST members continue to find that there is a need to strengthen connections between the various partners in the innovation ecosystem. Despite the increase in cross-sectoral collaboration seen over the past twenty years, there still appear to be substantial difficulties in forming such collaborations. Some of the barriers identified by PCAST include misalignment of cultures, management structures, and goals; and differences in IP, proprietary information, and publication policies. One critical element in this context is the fundamental difference in both time-lines and motivations for industry and universities. Particularly in the current economic environment, corporations and their shareholders are focused on short-term returns. Long-term research programs that can lead to technology innovations often require significant investments and run counter to this philosophy. While not attempting to fundamentally change this business model, it is critical for potential partners to understand and acknowledge these forces and plan accordingly early in the process.

Many novel approaches are being pursued to turn the connection points into opportunities. For example, the UIDP[39] is developing a software tool to streamline the negotiation of IP clauses in collaborative research agreements. After learning directly from companies that dealing with the university was very cumbersome, the Medical School at the University of Pennsylvania established a central Office of Corporate Alliances that creates a "one-stop shop" for managing partnerships between faculty members and outside sponsors, reducing administrative burdens and regulatory concerns for both sides. The office also works with both sides to define broad areas of interest and expertise, to build strategic, long-term alliances rather than individual sponsored research agreements. The Energy Biosciences Institute is pursuing a novel hybrid approach towards public-private partnerships that co-locates both open and proprietary research, allowing fundamental science results to be shared by all, while BP can initiate proprietary work inspired by such research. Others, such as Intel's Lablets, encourage cross-sectoral sabbaticals for faculty and researchers in industry. Further strengthening of the connection points will be crucial for increasing the participation in public-private partnerships.

Key Elements/Guiding Principles to enhance research partnerships

Given the diversity of ways in which partnerships occur, it is clear that there is no "one size fits all" approach to strengthening connection points between partners. However, there is consensus on some key elements, or guiding principles, that have been found to minimize barriers to successful partnerships. A detailed list of these principles, based on PCAST's experiences and those provided by several presenters, are included in Appendix A and B.

11. ***Formalize and enhance opportunities and incentives for researchers to have flexibility in moving between academia, industry, and government.***
Decision makers in academia, industry, and government should examine their organization's mechanisms available for researchers to move between sectors, and work to formalize and enhance them when appropriate. Incentives to reward collaboration and encourage teamwork should be offered. Carnegie Mellon University, for example, has allowed faculty members to take extended sabbaticals to serve as co-directors of Intel's Lablets, so that they can build relationships with industry partners while remaining a part of the academic community. Developing mechanisms to allow flexible exchange of researchers will promote the participation in cross-sectoral partnerships. For example, academic institutions could provide flexibility in the tenure process to acknowledge the importance and time commitment required to pursue these opportunities. These activities can support the mission of the university by both generating new knowledge, increasing professional development of faculty and ultimately enhancing the training of students via faculty who can share these experiences.

Federal R&D funding agencies should continue to explore options, through grants and various fellowships, to provide flexibility for researches to engage in sabbaticals and career transitions across academia, government and the private sectors. The Federal government should develop hiring practices and rewards that promote this flexibility within Federal agencies and develop policies to encourage universities to support these career paths among their faculty. Early career scientists and engineers should be specifically targeted through such programs, to both fully utilize their innovative potential and to provide an early opportunity that will provide benefits throughout their careers. These practices can also be integrated into the structure of Federally funded university research centers/programs such as NSF's Engineering Research Centers, NSF Science and Technology Centers, the NIH's Clinical and Translational Science Awards, the NIH National Cancer Institute designated Cancer Centers and other large university research centers and programs funded through Federal agencies.

12. ***Develop and apply improved tools and metrics to measure the outputs of research partnerships and innovation to guide policies and incentive structures.***

Federal R&D funding agencies, in coordination with statistical analysis agencies (Bureau of Economic Analysis and others), should further develop tools and metrics to assess the products and outputs of targeted research collaborations. These measures could be integrated into appropriate funding program requirements and include measurements to assess:

   a. Technology innovation

   b. Workforce- human capital- capacity building

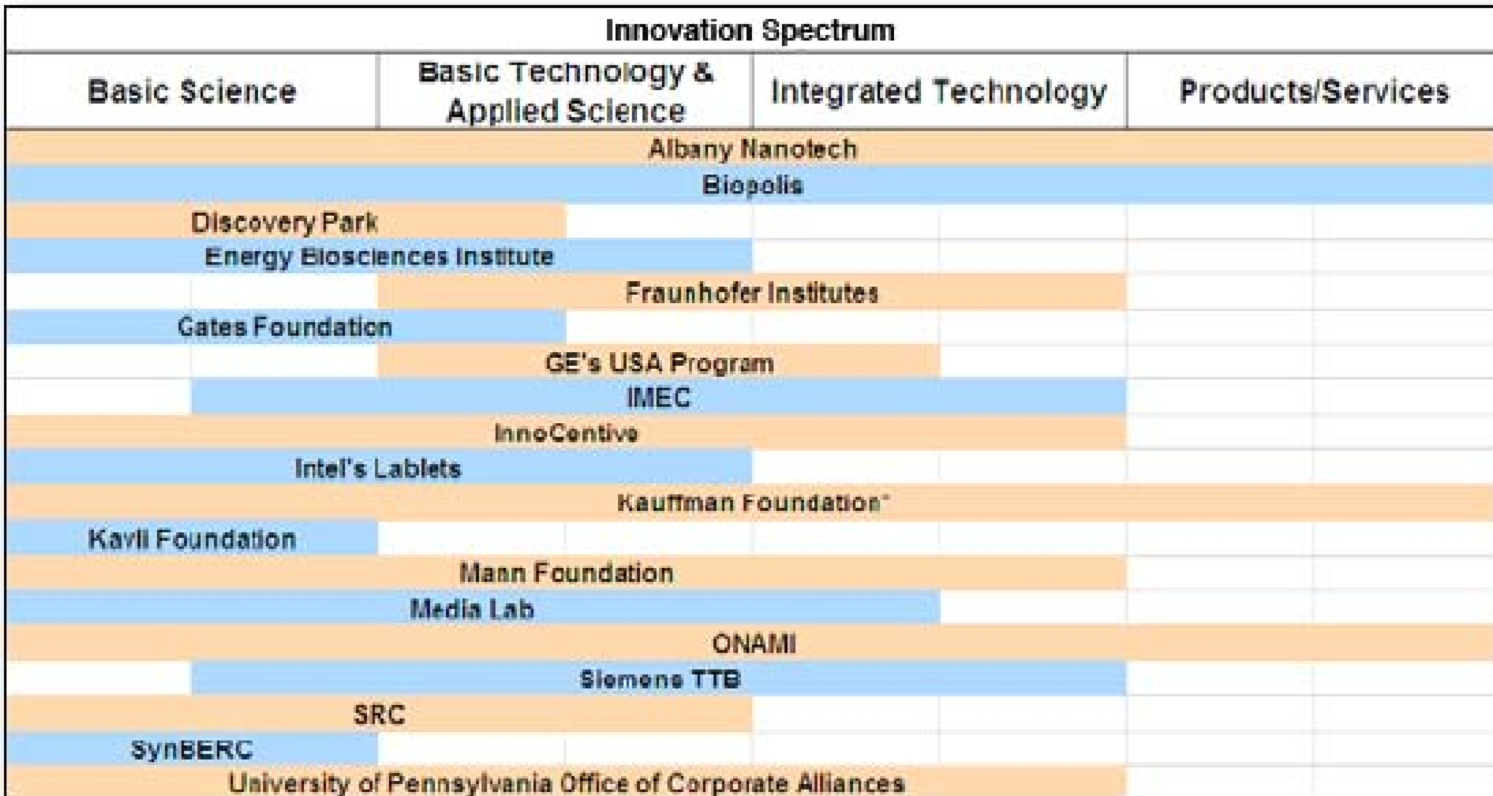
   c. Productivity

Using the competitiveness and innovation priorities identified in the American Competitiveness Initiative, a program should be initiated to more clearly define national and industry demands for technology innovation in these areas and the type and size of S&E workforce required to meet these demands.

NSTC and NSF's Science of Science and Innovation Policy program are exploring a number of issues related to these challenges and should be leveraged (with the Department of Commerce, Bureau of Economic Analysis and the Bureau of Labor Statistics, for example) and expanded, where appropriate.

Federal R&D funding agencies should also evaluate and implement strategies to expand and add flexibility to the metrics that govern the current incentive system, including those utilized by universities. This could be integrated into research center/program grants by providing incentives for industry participation, entrepreneurship activities and fostering State and local involvement. To provide flexibility for a range of university programs strong incentives should be provided for these components without strict requirements for all elements. Updated innovation measures should then be used to further guide the modification and transparency of incentive systems, permitting enhanced research partnerships.

Figure 13. Public-Private Partnerships, and selected foundations and other organizations that support partnerships, are described below, along with locations on the innovation spectrum



**The Kauffman Foundation funds research on the innovation spectrum itself*

Figure 14. Themes observed from Public-Private Partnerships

PCAST Themes								
Public-Private Partnerships (PPPs)	Targets a Specific Field, Technology, or Particular Area on Innovation Continuum	Develops Strategic Partner-ships	Utilizes a Consortia Model	Substantially Leverages Government Funding (State or Local)	Focuses on Open Collaboration	Provides Flexible or Novel Approaches to Address Technology Transfer	Links R&D, Education, Entrepreneurship, and/or Innovation	Establishes Clusters to Promote Innovation

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Albany CNSE	X	X		X		X	X	X
Biopolis and Fusionopolis	X	X	X	X		X	X	X
Discovery Park	X			X		X	X	X
Energy Biosciences Institute	X	X	X	X	X	X	X	
Fraunhofer Institutes	X	X	X	X		X	X	X
GE's USA Program	X	X					X	
IMEC	X	X	X	X		X	X	
Intel's Lablets	X	X			X	X	X	X
Media Lab	X	X	X		X	X	X	
ONAMI	X	X	X	X		X	X	X
Siemens TTB	X	X			X	X	X	
SynBERC	X	X	X	X			X	
SRC	X	X	X	X	X		X	
UPenn OCA	X	X				X		
Foundations that Support PPPs:								
Gates Foundation	X			X				
Kaufmann Foundation	X							
Kavli Foundation	X	X						
Mann Foundation	X	X						

Key Elements/Guiding Principles of University-Industry Partnerships

PCAST heard from several industry and academic leaders who have been involved in R&D partnerships. The following provides a detailed list of principles that were commonly cited as being critical in the development and maintenance of successful university-private sector research partnerships:

- ***Develop a shared vision and clear expectation for what the partnership will accomplish.*** Before entering a partnership, both parties should acknowledge each other's mission and the related objectives and constraints faced by both (these objectives and constraints are discussed below). Assessments of what each party can contribute, and the desired outcome of the partnership should be agreed upon.
- ***Address the image that some academics have of industry support as "tainted".*** Universities should acknowledge that some academics view funding from industry as having strings attached that negatively affect their research. Open and honest discussions held between parties can help address this issue.
- ***Establish porous boundaries between government, industry, and academia, by developing clusters and innovative regions.*** Developing innovative clusters and regions can reduce some of the hard barriers between partners. These clusters also can allow for a flow of inventions, ideas, and personnel between governmental, industrial, and academic institutions.
- ***Create a common organizational structure for research.*** One of the commonly cited barriers to partnerships between universities and industry is the misalignment of organizational structures. For collaborative research projects, a common organizational structure should be developed and agreed upon prior to beginning the project.
- ***Develop a strategic, long-term commitment.*** Long-term commitments are believed to deliver results that have more impact than isolated collaborative projects, and can provide a broader range of benefits to all parties involved.

- ***Enlist support from leadership and scientists.*** To fully develop successful relationships, support is required from both the researchers that will collaborate on projects and the leadership of each organization. Having a clear vision from leadership and engaging the scientists in developing and maintaining the partnership is vital for success.

- ***Focus on speed and nimbleness.*** Universities and industries typically have different time horizons regarding administrative requirements. While spending six months on reaching an agreement may be acceptable to academic partners, industry partners may be discouraged to continue as their research projects have specific timelines. Focusing on speed and nimbleness demonstrates a commitment to work with partners with more demanding time constraints, and allows for more time spent on research activities.

- ***Pre-negotiate IP and publication policies.*** Negotiations over IP are becoming more contentious and taking too much time. Of all respondents to a survey conducted by the Industrial Research Institute, 100 percent agreed that IP issues are an impediment to working with U.S. universities. Being a complex issue, there are a broad range of views on this issue and each partnership should develop its own arrangement based on the context of the collaboration. However, policies involving IP rights, publication of research results, funding of graduate students and post-doctoral fellows, and other issues should be negotiated in advance to resolve issues before they arise.

- ***Perform routine assessments.*** Scheduled reviews of research partnerships and the submission of progress reports can identify potential issues before they emerge or become insurmountable, and can allow for amendments to research priorities, as appropriate.

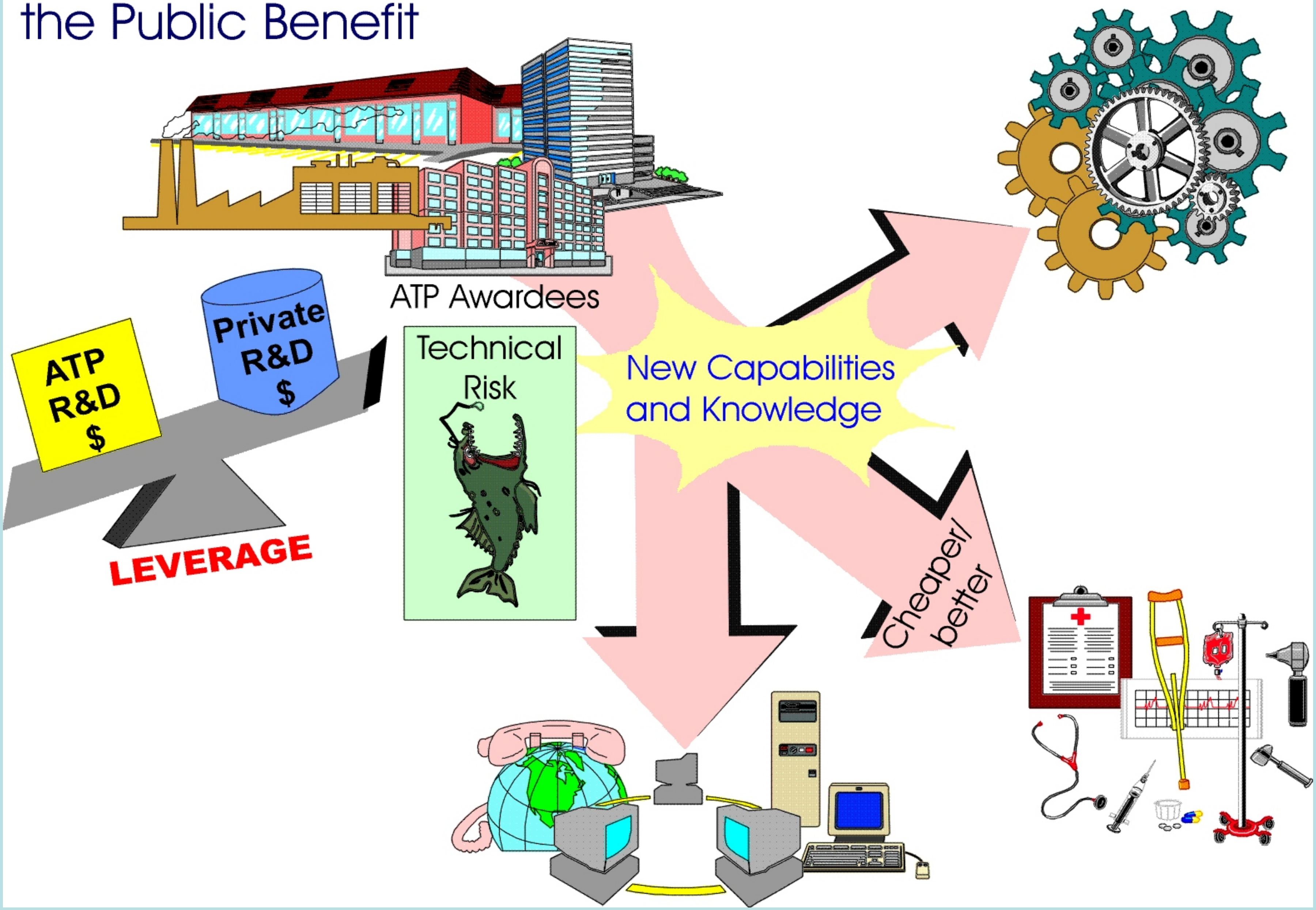
- ***Be transparent and consistent in action.*** It was noted that contentions over publications and IP could be avoided if both parties kept each other informed of results and their commercialization potential, both at the initiation of collaboration and throughout the partnership. Like all relationships, university-private sector partnerships are based on trust and communication, and these components are considered to be the most important preconditions for success.

Table 1: Characterizing university and industry partners' possible objectives, contributions, and constraints when entering into a public-private partnership.

	University	Industry
Objectives	• To benefit the public by adding to and sharing knowledge broadly • Educate and support an educated and well-trained workforce • Transfer technology and knowledge to enhance commercialization • Foster economic development at State and national levels	• Create and deliver new and improved products and services to enhanceprofitability • Locate advancements made by others that solve/answer general and specific problems faced by the industry partner • Develop and support an educated, well-trained, and competitive workforce
Contributions to the other partner's missions	• Training of future and current industry workforce (students) through undergraduate and advanced degrees (retention of trained work force) • Contribution to the general knowledge base for public benefit (publication) • Advancing the state of the art in a field • Acting as a filter to distill, from the general public knowledge base, a subset of that knowledge particularly applicable to industry's product needs (knowledge transfer) • Performance of specific research on behalf of industry (sponsored research) • Licensing inventions and developments (IP) for commercial purposes, including revenue generation (technology transfer) • Providing access to university-owned equipment, materials, facilities and specialized resources • Fostering economic development that expands markets • Objectively testing, evaluating and reporting on new technology.	• Employing students and graduates • Donating (equipment and money – either unrestricted or earmarked e.g., for scholarships, research, or facilities) • Providing either materials or funding for student internships and faculty sabbaticals • Employee time and knowledge donation through involvement in activities such as assisting student projects, guest lectures, service on thesis committees, service on advisory boards. • Enabling access to industry-owned equipment, materials, facilities and specialized resources • Providing leading-edge research directions • Providing financial and/or in-kind support for specific research activities of interest to the industry partner (sponsored research) • Paying technology licensing fees and royalties, which support ongoing research and educational programs • Contributing to general knowledge base (publication) • Bringing university contributions to the public in the form of goods and services (technology transfer)

THE US ATP BENCHMARK

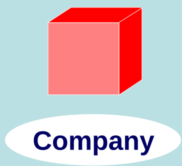
ATP Leverages private R&D Investment for the Public Benefit



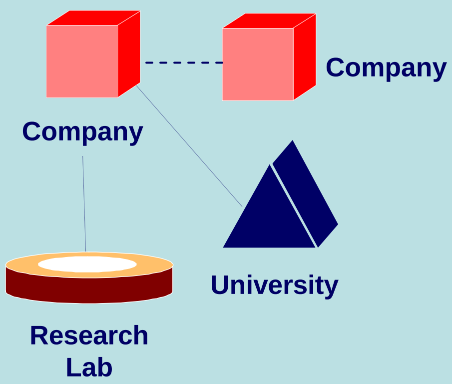
Two Ways to Apply …

As a Single Company:

Alone



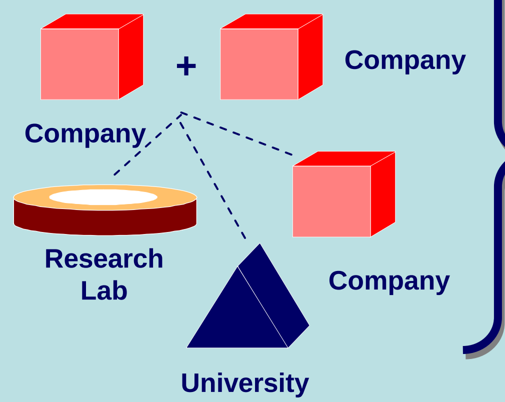
With Subcontractors



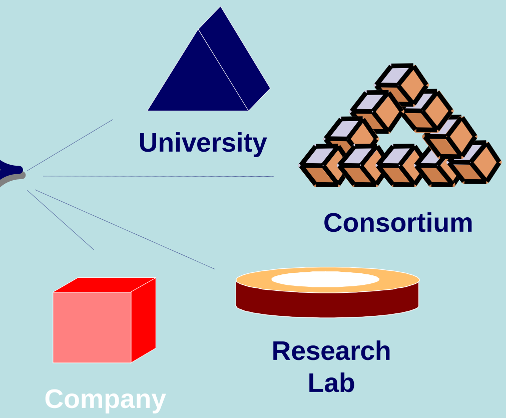
- **For-profit company**
- **3-year time limit**
- **$2M award cap**
- **Company pays indirect costs**
- **Large companies cost share at least 60% of total project cost**

As a Joint Venture:

Formal Alliances



With Subcontractors



- **At least 2 for-profit companies**
- **5-year time limit**
- **No limit on award amount (other than availability of funds)**
- **Industry share >50% total cost**

- ❑ *ATP encourages teaming arrangements*
- ❑ *Most projects involve alliances*

Need for ATP Funding

Branscomb's Darwinian Sea

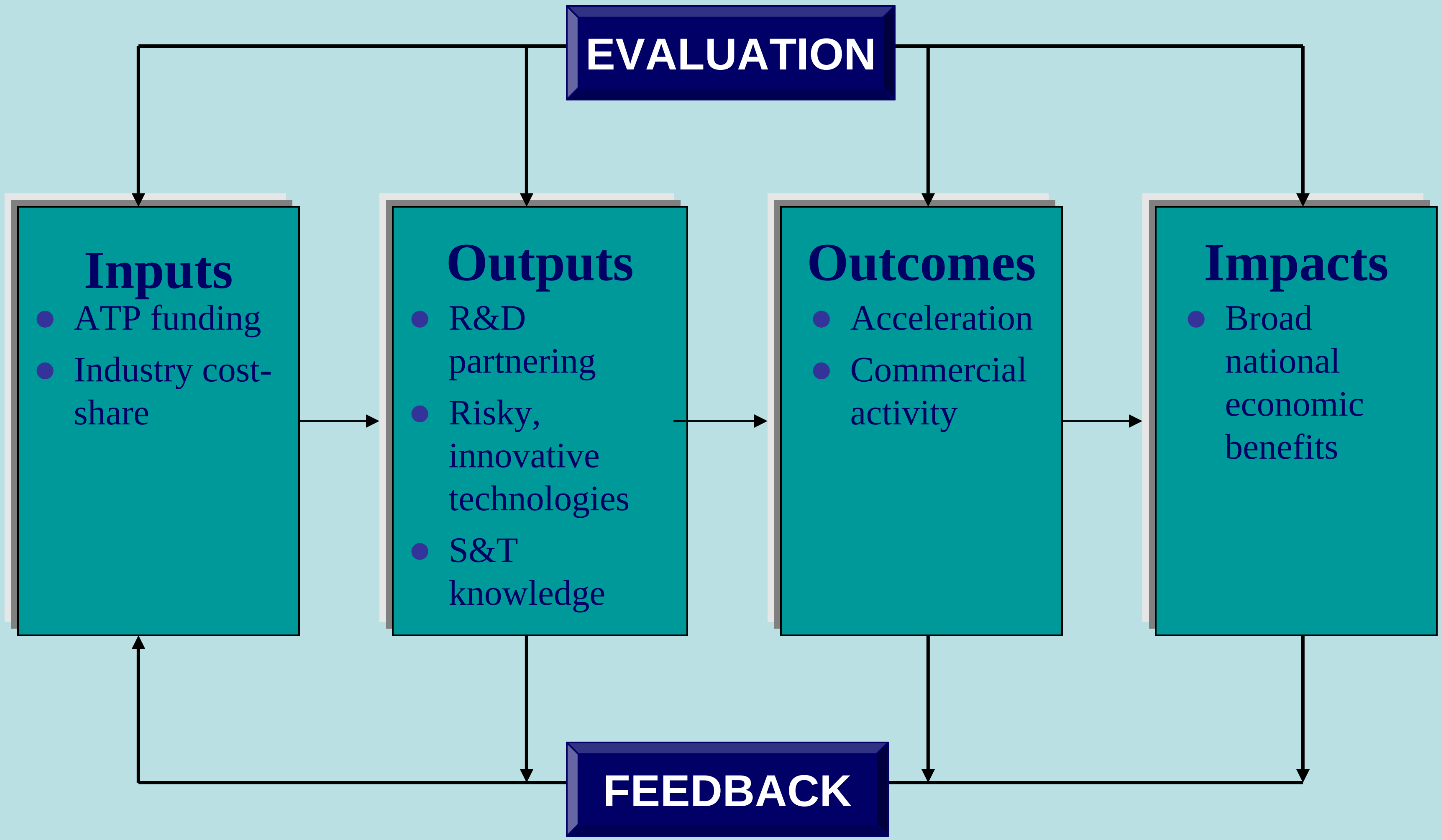
The Struggle of Inventions **to Become** Innovations

Research & Invention

Innovation & new business

"Struggle for Life"in a Sea of Technical and Entrepreneurship Risks

Measure Against Mission



Timeline:
What We Measure When

Short-Term

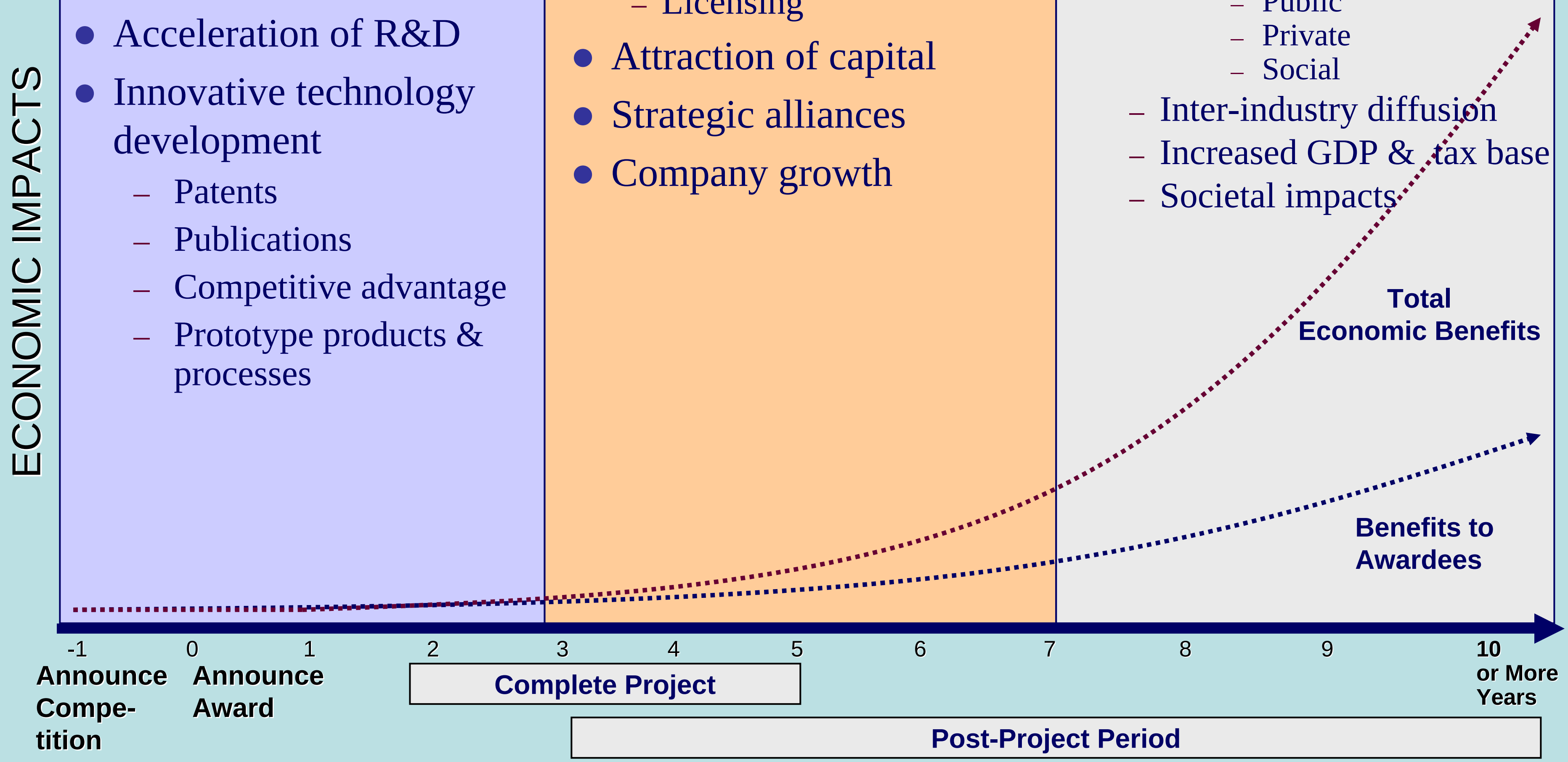
- Award/participant characteristics
- R&D partnering
- Acceleration of R&D
- Innovative technology development
  - Patents
  - Publications
  - Competitive advantage
  - Prototype products & processes

Mid-Term

- Commercial activity
  - New products
  - New processes
  - Licensing
- Attraction of capital
- Strategic alliances
- Company growth

Longer-Term

- Broad national economic benefits
  - Return on investment
    - Public
    - Private
    - Social
  - Inter-industry diffusion
  - Increased GDP & tax base
  - Societal impacts



Components of ATP's Evaluation Program

- Descriptive (statistical) profiling of
  - Applicants
  - Projects
  - Participants
  - Technologies
- Progress measures derived from
  - Surveys
  - ATP's "Business Reporting System"
- Real-time monitoring of research
  - ATP Staff visits
  - Company technical reports

Components of ATP's Evaluation Program

- Microeconomic case studies
- Macroeconomic projections of long-term impacts
- Methodological research
- Empirical assessment of project & program outcomes
  - Private returns
  - Social returns
  - "Public" returns

Partnership Effects
Reported to Date

- Increased R&D -- of the High Risk/Enabling/ Long-term Type
- Accelerated R&D/Accelerated Commercialization
- Enlarged-Scope R&D → Generic Solutions
- Research efficiency savings
- New opportunities from combing diverse technologies
- Solutions to complex systems problems
- Resolution of supply - chain Issues
- Projected net benefits from partnership projects
- Other effects

THE CHINA QUESTION:
Li Yuese nanti

- Few people, other than scholars, will be familiar with the story of the Cambridge don whose study of China's scientific history helped to change the West's appraisal of a civilisation once thought hopelessly backward.
- ***By the time Joseph Needham died in 1995, he had published 17 volumes of his "Science and Civilisation in China" series, including several that he wrote entirely on his own.***
- The Chinese began printing 600 years before Johannes Gutenberg introduced the technique in Germany. They built the first chain drive 700 years before the Europeans. And they made use of a magnetic compass at least a century before the first reference to it appeared elsewhere.
- ***So why, in the middle of the 15th century, did this advanced civilisation suddenly cease its spectacular progress?***
- So powerful has Needham's contribution been to the historiography of Chinese science that this conundrum is still known as ***"The Needham Question". Even the Chinese themselves use it: the phrase in Mandarin is Li Yuese nanti.***
- In 1936 three Chinese assistants came to work in his biochemistry laboratory. One, Lu Gwei-djen, who came from Nanjing, began teaching him Chinese, which ignited Needham's interest in the country's technological and scientific past. He retrained as a Sinologist and took a job in Chongqing as Britain's scientific emissary.

Chinafrique…

- FP: How does China's investment in Africa differ from the powers who came before it?

- SM: There are five major differences:
  - One, China has no colonial past.
  - Two, it has a pan-African approach, unlike Europeans who only worked in their former territories.
  - Three, China sets no political conditions on its cooperation (such as democracy and transparency). The only requirement is that the African country must sever its ties with Taiwan.
  - Fourth, China finances infrastructure, such as dams, roads, and railroads, and it constructs them with its own labor.
  - Fifth, China is the last centralized system and can easily offer "package" deals that include, to use Guinea as an example, a bauxite mine, a dam, a power station, a refinery, and a railway—all financed by the Exim Bank of China. Its North American competitors always refused to embark on refining, because they said there was not enough electricity in the country, even though 122 sites have been identified as ideal for constructing dams.

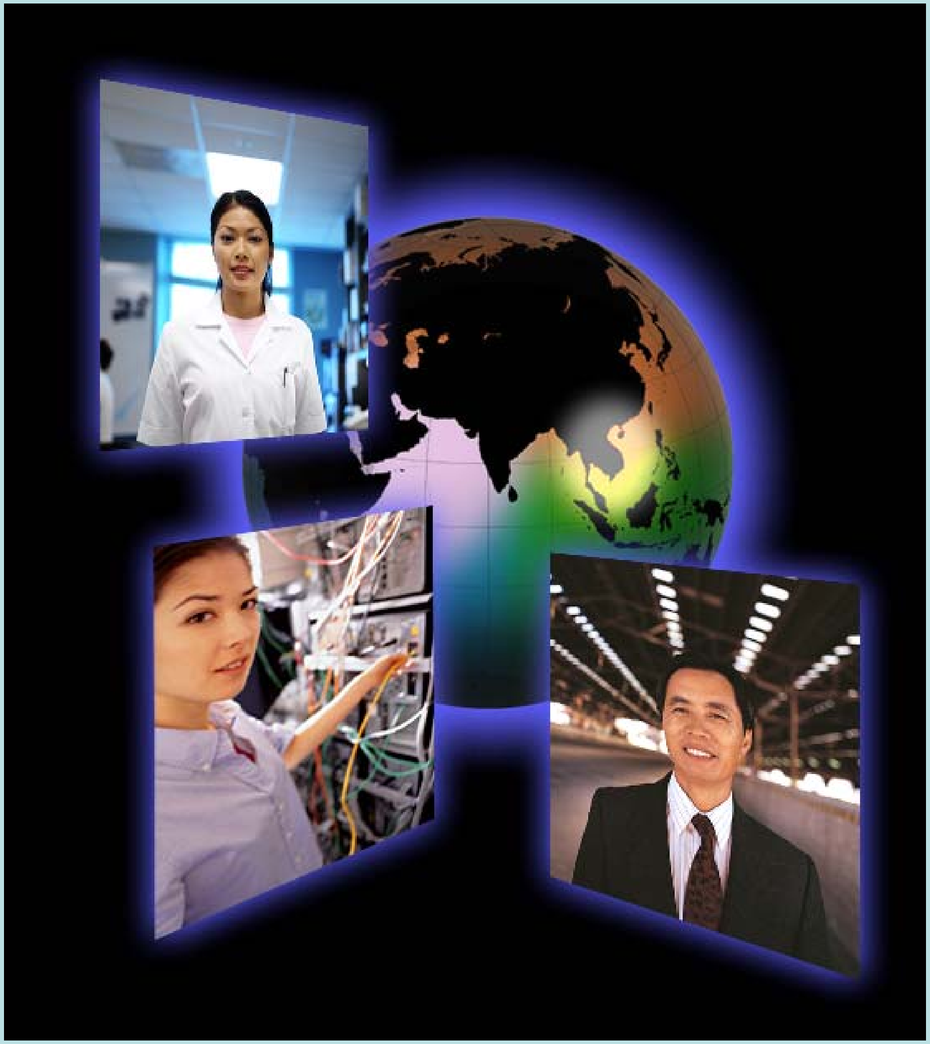
THE CHINA QUESTION Re-visited…:

Li Yuese nanti

- Needham never fully worked out why China's inventiveness dried up.
- Other academics have made their own suggestions: *the stultifying pursuit of bureaucratic rank in the Middle Kingdom and the absence of a mercantile class to foster competition and self-improvement; the sheer size of China compared with the smaller states of Europe whose fierce rivalries fostered technological competition; its totalitarianism.*
- With its unreformed one-party system, its rote-learning in schools and state control of big businesses, "new China" is hardly a haven for innovative thinking. Yet the Chinese continue to fret about the Needham question.
- A Communist Party chief of a middle school in central China recently said that it deserved deep thought and that the answer lay in an education system that fails to emphasize improving "character".
- A former government minister also referred to Needham's lament that China had produced no idea or invention of global impact for more than 500 years. Its contribution henceforth, the official said, should be "harmony".

Points to Remember…

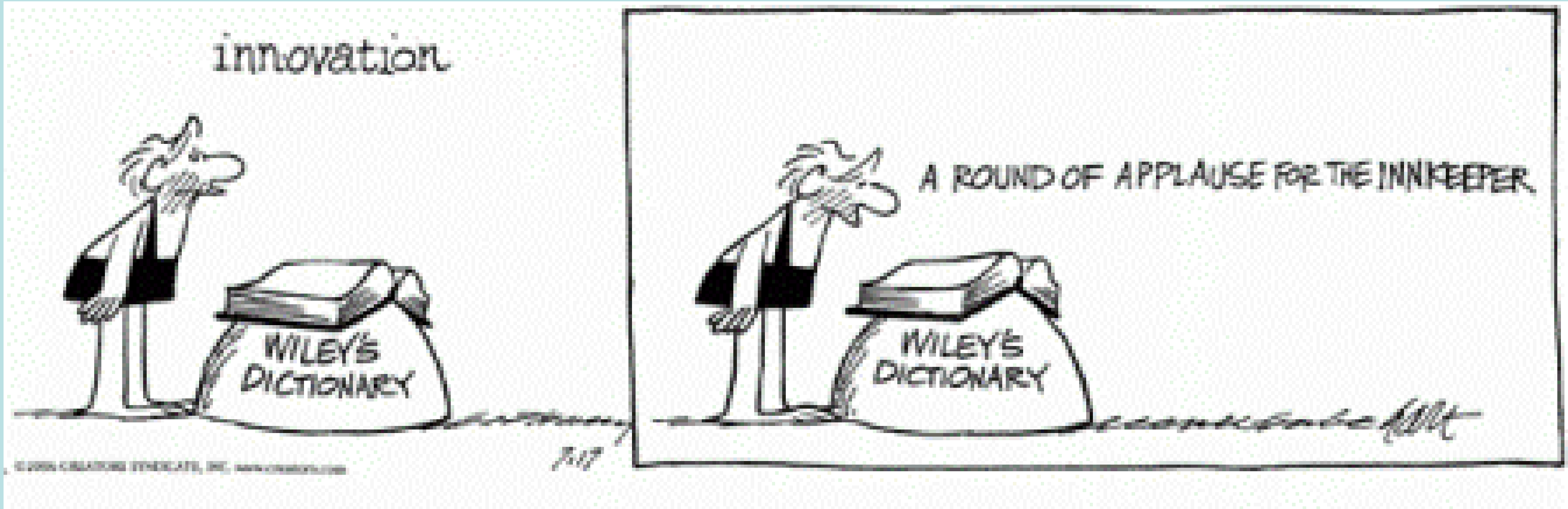
- **The brightest frontiers of knowledge reside at the intersection of technology, insight and traditional disciplines**
- **A collaborative, sustained commitment by industry, government and academia is essential**
- ***Innovation is a culture, not a department***
    - **Nick D'Onofrio,**
        - **IBM Sr. Exec. VP**
        - **Invited Lecture, GWU SoB, October 2007**



Words of Wisdom to remember...

"The innovator has for enemies all who have done well under the old, and lukewarm defenders in those who may do well under the new law."

Nicolò Machiavelli



Ending Thoughts...

- ***'Until philosophers are kings, or the kings and princes of this world have the spirit and power of philosophy,...*** **cities will never have rest from their evils - no, nor the human race as I believe...'**
  [Plato, The Republic, Vol. 5, p. 492]

- **'The lowest form of thinking is the bare recognition of the object.** ***The highest, the comprehensive intuition of the man who sees all things as part of a system*****.' [Plato]**

She – she !!! ☺