150 años construyendo nación con ingenio propio

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A historical perspective regarding US public research universities

Universidades públicas de investigación en Estados Unidos. Una perspectiva histórica

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ABSTRACT

The 21st century is a time of both great promise and great anxiety. Economic institutions, technological tools and societal aspirations connect us all globally. We share a pivotal role in common; research universities around the globe have this and can continue to play it in economic development through people, knowledge, know-how and facilities. The current economic climate is manifest in increasing pressure on research universities to expand their impact by fostering innovation leading to the creation of new industries and jobs whilst also developing a proficient workforce and the next generation of leaders, whether in academia, government, industry or non-profit areas. The purpose of this paper is to provide a historical context regarding several broad developments that have shaped the role of USresearch universities in relationship to the economy. Purdue University is used as case study to illustrate the specific challenges and opportunities which it has experienced over many decades during its growth and evolution as a research university. We would also like to join in celebrating the Universidad Nacional de Colombia's School of Engineering's150-year tradition in technology and innovation. We hope this paper provides some vision regarding the future of engineering education within a global economic context .

Keywords: research university, innovation, engineering education.

RESUMEN

El siglo XXI es un tiempo de grandes promesas y ansiedades a la vez. Las instituciones económicas, las herramientas tecnológicas y las aspiraciones sociales nos conectan a todos a nivel global. Lo que tenemos en común es el papel fundamental que las universidades de investigación desempeñan en todo el mundo y pueden seguir haciéndolo en el desarrollo económico mediante las personas, el conocimiento, las habilidades y las instalaciones. El clima económico que todos estamos enfrentando se manifiesta en la crecientes presiones sobre las universidades de investigación para ampliar su influencia por medio del fomento a la innovación, que se traduce en nuevas industrias y empleos, a la vez que se desarrolla una fuerza laboral competente y la próxima generación de líderes, ya sea que éstos se desempeñen en la academia, el Gobierno, la industria, o en organizaciones sin ánimo de lucro. El propósito de este documento es proporcionar un contexto histórico con respecto a varios desarrollos importantes que han configurado el papel de las universidades de investigación en Estados Unidos con relación a la economía. Purdue University se utiliza como estudio de caso para ilustrar los retos específicos y oportunidades que ha experimentado en el transcurso de muchas décadas en su crecimiento y evolución como universidad de investigación. El artículo ofrece perspectivas sobre recursos financieros, calidad, acreditación, gestión, responsabilidad, educación en ingeniería y modelos educativos. También nos gustaría unirnos a la celebración de los 150 años de tradición en tecnología e innovación de la Facultad de Ingeniería de la Universidad Nacional de Colombia. Esperamos que este trabajo proporcione una visión de futuro sobre la educación en ingeniería, en un contexto económico global. Además, Purdue aspira a convertirse en una universidad internacional en el cumplimiento de su objetivo estratégico de hacer frente a desafíos mundiales. Purdue University se enorgullece de sus convenios con el Ministerio de Educación, Colciencias, Colfuturo y el Programa

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Fulbright, para desarrollar investigación colaborativa en tecnologías claves de interés mutuo en el marco del Instituto de Investigación Científica Avanzada Colombia-Purdue (*Colombia-Purdue Institute for Advanced Scientific Research (CPIASR)* (ver: http:// enginering.purdue.edu / cpiasr) y de participar en el programa de Colombia dirigido a educar a un número significativo de candidatos a doctorado en un futuro próximo. Hoy en día Purdue tiene más estudiantes procedentes de Colombia que de cualquier otro país de América Latina, y está deseoso de ser partícipe en el desarrollo futuro de Colombia. Gracias a esta asociación Purdue y Colombia están trabajando juntos para hacer frente a retos globales, a la vez que construyen una relación de largo plazo .

Palabras clave: universidades de investigación, innovación, educación en ingeniería.

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Introduction

The historical background and context for US public research universities is discussed first. This can be divided into four main eras describing universities' evolving research roles and diverse support:

1. Pre-World War II era: The federal government provided relatively little support for research in universities. However, university research partnerships with industry flourished during the early years of the 20thcentury;

2. Post-World War II era: A major change in federal research policy occurred through the establishment of a comprehensive framework for supporting both basic research and mission-focused research necessary for government agencies to perform their missions in post–World War II era. Vannevar Bush, President Roosevelt's science advisor, outlined this policy in the seminal 1945report *"Science, The Endless Frontier"*;

3. Post-Sputnik era: Federal investment in academic research and scholarships at universities accelerated to provide the technology and skilled workforce needed to meet mission needs; and

4. "Game changer" era: The enactment of the1980 Bayh-Dole Act was a novel idea (game changer) allowing universities to retain patent rights to inventions resulting from federally-funded research at their institutions. This legislation provided a new framework for innovation among faculty at research universities. This era also saw the federal government's increasing role in providing educational support grants in various forms for a variety of stakeholders: block grants to the states for primary and secondary education, Pell "need-based" scholarships, job retraining grants and veteran education-support grants.

Pre-World War II era

US research and development (R&D) was primarily conducted by industry at the beginning of the20thcentury.

The US federal government provided relatively little support for research at universities during the pre-World War II era, covering the first forty years of the 20thcentury.Large corporations led the expanded use of scientists and engineers in conducting pioneering research focused on burgeoning industrial sectors such as the chemical, petroleum, steel, telephone, radio, transportation, electrical lighting and machinery and household appliances sectors. In tandem, the federal government, through its National Bureau of Standards, provided measurement and physical standards for organising a national system of weights and measures, improving manufacturing quality systems and enhancing public safety through improved materials. University research partnerships with industry flourished during the early years of the 20thcentury.

US federal expenditure on R&D during the 1930s accounted for about 20% of total national effort (Mowery and Rosenberg, 1993, p. 132); industry accounted for two thirds, as it does today in the United States. Scientific and engineering research at universities grew considerably in scale and quality during the first half of the 20thcentury-inboth state and private universities. Breakthrough research and newly-created academic programmes responsive to local industry needs grew while state-supported land grant universities remained focused on agricultural and industrial development.

Post-World War II era

*The Post-World War II era started with a new framework for supporting basic research at universities and the research necessary for federal agencies to perform their missions in the post-World War II era. Vannevar Bush, President Roosevelt's science advisor, outlined this policy in his 1945 report "Science, The Endless Frontier."*It provided a framework for organising scientists and engineers to work together toward a common goal of addressing national needs on an unprecedented scale. The all-embracing objective was to," cultivate a steady stream of scientific knowledge *to promote the progress of science, to advance national health, prosperity and welfare and secure national defense."* (The National Science Foundation Act of 1950, Public Law 81-507)(National Science Foundation's mission statement). This framework outlined the complementary roles of government, industry and universities regarding scientific enterprise:

-Federal government's role would generally be to support basic science, not its application;

-Industry's role would be focused on applied research; and,

-Research universities would be responsible for producing the pool of fundamental knowledge from which industry could draw.

Federal support for university research would be provided through a system of grants awarded to principal investigators. Grants would be awarded based on scientific merit determined by objective peer reviewers. Congress established the National Science Foundation (NSF) in 1950to serve as an independent federal agency devoted to supporting non-defence basic research and education in all scientific and engineering disciplines.

The share of university research supported by industry declined during the 1950s from a peak of more than 8% of academic research in 1957 (a share that has not been achieved in any year since) to less than 3% in 1967 (Mowery, 2009, p. 10).

Post-Sputnik era

A tipping point in US federal investment in research at universities occurred with the launch of Sputnik in 1957 and the beginning of the space race. Investment in academic research and scholarships at universities accelerated to provide the technologies and skilled workforce necessary to land a man on the moon and return him safely to Earth.

Federal research policies have shifted since the end of the Cold War. Support for non-defence research has increased in relative terms, even though the fraction of federal R&D support relative to the national total has steadily declined (Landau and Rosenberg, 1992, pp. 81-82).Federal support for basic research at research universities has increased relative to that conducted in federal laboratories. Federal support for small business R&D has also steadily increased in the interest of job creation and global competition in emerging technologies. This support arose largely in response to the financial crisis of the Great Depression and the pressures of World War II. The creation of the Small Business Administration (SBA) in 1953 was the result of a Federal Reserve study that determined that small business could not get the credit needed to keep pace with technological advance.

Science, The Endless Frontier defined the USnational research system as residing in its research universities, the locus of most basic scientific research and graduate and postgraduate education in the United States. The government committed itself to becoming the major sponsor of scientific research in universities in the post-war world. This turned out to be a "game changer" for the US research enterprise, a national scientific enterprise in which basic research funded at universities by federal dollars produced new technological concepts that were further developed into new products and services by private industry. This symbiotic system of scientific and technological research has been a prime engine of US economic growth and improved quality of life for US citizens for more than half a century.

"Game changer" era

The 1970s was a time of diminishing US innovation, intensifying competition from Europe and Asia, declining US productivity and rising unemployment, making economic competitiveness and quality improvements become major national priorities. United States' universities were producing potentially useful research; however, innovations were not being transferred to the private sector as quickly or as efficiently as the economy demanded to achieve the desired impact.

New technological advancement transfer from the public to the private sector posed a significant chasm. The development of quicker, better and more efficient ways of turning university discoveries into market applications was the catalyst for change. University research partnerships with industry flourished early in the 20thcentury; however, the world changed. The volume of federal research funding sent to research universities in the 1950-1970swas extraordinary, resulting in a decline in the number of university-industry partnerships in the years following World War II.

In the light of such decline, the US government initiated a series of actions to rebuild the nation's competitiveness during the 1970s by providing incentives for such university-industry partnerships. The initiative included:

-Establishing tax credits for research by industry;

-Funding public/private research cooperative agreements; and

-Easing antitrust regulations to encourage research partnerships.

The most far-reaching of these actions for universities was the Bayh-Dole Act (Patent and Trademark Amendments,1980).Bayh-Dole was designed to energise technology transfer from universities and federal laboratories to business and industry. This was accomplished through a fundamental shift in government patent policy.

Prior to Bayh-Dole legislation, the federal government owned the rights to any patentable discovery emerging from research supported by federal funds. Few research results were transferred to the private sector market place under this arrangement. The government's patent rights were transferred to universities with the enactment of

Bayh-Dole, enabling each institution to decide whether income derived from a patented invention went to individual researchers or the university, or was shared by both. Bayh-Dole's primary aim was to ensure that public investment in basic research served national economic growth; this new income stream was a benefit for universities, but in most cases has proven to be a secondary factor.

The Bayh-Dole legislation has had a significant impact. It has provided a compelling incentive for universities and industry to partner in commercialising scientific discoveries. Specific impacts have included:

-US patents awarded to university faculty increased fourfold between 1988 and 2003, from 800 to 3,200 (Atkinson and Pelfrey, 2010, p. 3); and

-Technology transfer offices on research university campuses became ubiquitous, offering the expertise and tools for faculty to move research results into the commercial sector.

Concerns were raised when Bayh-Dole was first enacted; it was speculated that it would turn research universities into "job shops" for private industry and threaten the overall integrity of their research and educational missions. There were cases when universities conducted proprietary research for industry and "job shops" did emerge. However, both history and experience have shown that universities and their industry partners have managed to negotiate successful research arrangements acknowledging respective differences in mission and culture for both universities and industry.

Irrespective of a track record of more than 30 years of measurable progress, complaints still arise that universities are not actively and adequately leveraging technology transfer tools and opportunities. The data speaks for itself and conveys a more positive view regarding tangible impacts. A 1997 analysis of US industrial patents found that publicly-funded institutions (universities, government laboratories and other public agencies) in the United States or foreign countries wrote 73% of the papers cited (McMillan *et al.,* 2000, p. 1).

The Small Business Innovation Research (SBIR) Program was established in 1982to provide increased opportunities for small businesses to:

-Meet federal R&D needs;

-Increase employment;

-Foster and encourage participation in technological innovation by socially and economically disadvantaged persons; and

-Increase private-sector commercialisation of innovations derived from federal R&D.

Another "game changer" was the federal government's increasing role in providing educational support grants in various forms: block grants to the states for primary and secondary education, Pell "need-based" scholarships, job retraining grants and veteran education-support grants. Universities found new responsibilities and financial resources in such grants.

The Bayh-Dole Act is viewed as having been successful in meeting its objectives. However, while the legislation provided a general framework for promoting expanded use of the results of federally-funded R&D, there was recognition of a need to update the law to better align with the 21st century's global marketplace. The Senate (S.23) and House (H.R. 1249) passed the Patent Reform Act of 2011 (America Invents Act) in March and June 2011, respectively, to improve patent quality while supporting and encouraging innovation leading to improved competiveness, economic prosperity and job growth. The House and Senate need to reconcile these bills and present a draft law to the President for enactment. This is expected to occur once the debt limit issue has been resolved.

Purdue university: a case study

Purdue university has had a long history, emerging in the 19thcentury as the result of a local philanthropist, John Purdue, and the enactment of the Morrill Act, signed by President Lincoln in 1862.This Act stated that each state would receive land from the federal government for establishing branches of learning related to agriculture and the mechanical arts (now known as engineering).

Purdue university was founded as a land grant institution in 1869 with a mandate for education, research and service and began classes with six instructors and 39 students in 1874.Today Purdue is still fully steeped in its land grant heritage as evidenced by the 3 pillars of its New Synergies Strategic Plan:

-Discovery with delivery;

-Launching tomorrow's leaders; and

-Meeting global challenges.

Purdue is a system of five separate campuses throughout the state of Indiana, having a total enrolment of around 72,000 students. Purdue's research portfolio, faculty and student demographics, and partnership relationships have evolved over the decades in alignment with national evolution as follows.

1. 1900-1940: Government-sponsored research was limited during this period and Purdue, as a land-grant university, focused on the agricultural and industrial development of the state of Indiana. However, as the century progressed, Purdue's research became more national in scope, and federal research funding became more plenti-

ful. It was during this period that Purdue established a national reputation as one of the nation's premier engineering schools.

2. 1940-1970:There was a steady increase in government sponsored research after World War II. Following the "Sputnik moment" the emphasis on space-related research at Purdue increased dramatically, enabling the university to become the "cradle of astronauts."Neil Armstrong, the first man to set foot on the moon, and Eugene Cernan, the last man to leave the moon, are among the twenty-two astronauts who graduated from Purdue.

3. 1970-2000:This period saw a steady increase in technology transfer and patents and the rapid growth of Purdue's Research Park to support the growth of start-up companies spawned from Purdue research.

4. 2001-2011:Discovery Park was established during this period, fostering interdisciplinary research, new partnerships and a rapid growth in federal research support. Discovery Park, covering 16 hectares, represents a $500 million investment in unique interdisciplinary facilities, cutting-edge equipment and shared space for collaborative projects in anno-technology and the biosciences, learning research and innovation and entrepreneurship programmes. It also houses research centres in the life and health sciences, bio energy, food security, earthquake engineering and information technology.

Colombia-Purdue university partnership

Purdue aspires to become an international university in fulfilling its strategic goal of meeting global challenges. Purdue university is proud of its partnerships with the Ministry of Education, COLCIENCIAS, Colfuturo and the Fulbright Program for conducting collaborative research in key technologies of mutual interest under the "Colombia-Purdue Institute of Advanced Scientific Research" agreement (CPIASR, see: http://enginering.purdue.edu/cpiasr)" and participating in Colombia's programme for educating significant numbers of PhD candidates over the next ten years. Today, Purdue has more students from Colombia than any other country in Latin-America and we are excited to be a partner in Colombia's future development. Through this partnership, Purdue and Colombia are working together to address global challenges while building a long-term relationship.

Funding resources

Purdue has continued to focus on providing quality education at an affordable price. Purdue has received national recognition from Princeton Review as being one of the "best value" US colleges and universities. How do we accomplish that, given the continuing financial stress placed on the university? This involves several fundamental tools and processes.

External:

1. Close and sustained relationships with state of Indiana government officials (the governor, members of the legislature, the Indiana Commission for Higher Education (ICHE), the Indiana Office of Economic Development) to justify and sustain state of Indiana appropriations;

2. Competitively successful research teams vying for federal research grants;

3. On-going development supported by our strong and supportive (generous) alumni;

4. Relationship building with key industry partners (e.g. Eli Lilly, John Deere, Hewlett-Packard, Boeing, Caterpillar, Kimberly Clark, Ford Motor Company, Exxon Mobil, GE) which invest in Purdue as an entry point for Purdue graduates to join their workforce; and

5. Steady improvement in national academic quality ranking.

Internal:

1. Improvements to our business model to increase general funds;

2. Increases in endowments to attract and retain faculty;

3. Innovative use of facilities and administrative (F&A) cost recovery;

4. Growth of the Purdue Research Foundation;

5. Expansion of auxiliary enterprises (e.g. Purdue Research Parks);

6. Support by the Research Vice-President for research infrastructure (pre-award and post- award); and

7. Buying-out teaching time for research and career development.

These types of tools and processes are essential for a high-performance, sustainable and world-class research university. Although Purdue continues to demonstrate a positive trend in faculty and student attraction and retention, federal research awards, student graduation rates and world-class facilities, Purdue recognises the imperative to look for new business models for the coming decade. What does that mean?

-New means of educational delivery and virtual research (classroom information technology, open source internet, global networks, Hub technology, e-publications);

-New ways of doing business (innovation, entrepreneurship, greater productivity and efficiency) to benefit Indiana's economy;

-Larger-scale research initiatives (multi-team, multi-univer-

sity, national and international scale centres of excellence);

-New student populations (career-long continuing education, veterans' education, professional Master's degrees, areas of concentration, certificate programmes, international students, etc.);

-New partnerships (academic, government, and industry); and

-Expanded international engagement (student abroad experiences, faculty and student exchanges, graduate and post doctorate internships, research partnerships, joint research institutes, dual degrees).

As we look to the evolving relationship with industrial partners, there are a number of key principles informing and promoting a mutually beneficial relationship honouring an independent, high-quality academic environment yet aligned with industry's needs (workforce, research, technology transfer, etc.).

Likewise, our partnerships with industry have continued to evolve and expand in such key areas as agriculture, chemicals, transportation, noise and vibration control, pharmaceuticals, electronics, energy systems, information and communications technology and propulsion.

Quality, accreditation, stewardship, audit, accountability

US non-profit colleges and universities are, for the most part, self-governed. The board of trustees appoints officers (e.g. president/chancellor, provost, chief financial officer and treasurer), the president/chancellor appoints administrative heads, the faculty set curricula, courses, academic standards and degree qualifications. They also select, promote and grant tenure to faculty and rule on faculty misconduct. State universities have considerable latitude in developing resources beyond those provided by state appropriation. However, colleges and universities are also held to high accountability and quality standards and are subject to audits, inspections, surveillance and oversight.

For example, as a public, incorporated university, Purdue university is subject to extensive oversight and scrutiny by state of Indiana authorities (including the ICHE and the Indiana Board of Accounts), federal authorities (specific federal agencies, congressional committees, inspectors general and the National Science Board) and its own Board of Trustees. The ICHE approves all degree programmes to ensure coverage and balance and eliminate undue or inappropriate redundancy. The Indiana state Board of Accounts conducts annual audits of expenditure to include federal expenditures. Purdue university also engages an external certified public accounting firm to conduct an independent audit under the oversight of the Board of Trustees' chairman of the audit and insurance committee. The university's annual operating budget, its independently audited financial report and its annual report of internal audits are all posted openly on Purdue's web site.

The Board of Trustees provides stewardship for all university administration and academic activities and routinely requests governance reports from university administrators on specified functions and programmes. The Board consists of ten members. The governor of the state of Indiana appoints seven members, including one student member. The alumni appoint the remaining three members.

Specific federal agencies conduct special audits within their mission areas. For example, the Occupational Safety and Health Administration (OSHA) under the US Department of Labor (DOL) will audit health and safety practices, DOL will audit human resource practice, the Environmental Protection Agency (EPA) will audit environmental protection practice and the Equal Employment Opportunity Commission (EEOC) will audit equal opportunity practice. Research funding agencies will audit compliance with laws and policy regarding the care of animals and human subjects used in research and settle on sanctions for scientific misconduct regarding agency-funded programmes. The Office of Management and Budget (OMB) will audit compliance with regulations regarding recovery of facilities and administration costs. The Inspectors General (IG) from any of these agencies can audit issues involving fraud, waste and abuse and scientific misconduct in the expenditure of federal funds. Congressional committees can issue subpoenas to secure any documents under the Freedom of Information Act (FOIA).

Quality management and continuous improvement are embedded attributes at Purdue university. Quality management practices received a boost when Motorola Corp., winner of the prestigious Malcolm Baldrige National Quality Award, established a partnership with Purdue university in the 1990s to inculcate administrators and faculty with best quality management practices.

Quality among the faculty is enhanced by faculty selection, promotion, tenure and curriculum review. Quality management throughout the university is substantially enhanced through independent peer reviews by non-governmental accreditation agencies. The North Central Association of Colleges and Schools accredit at university level, and other accreditation associations, such as the Accreditation Board for Engineering and Technology (ABET), accredit special programmes such as engineering, technology, nursing, management and medical programmes. Faculty and administrators from member universities of the accreditation associations conduct such peer reviews. Quality is enhanced as recommendations made by these accreditation reviews are implemented.

Performance metrics are established both by Purdue and the ICHE. In the latter case, these metrics may include

time to degree, retention rates, graduation success and research growth. Purdue university tracks national and international rankings, faculty membership in honorary academies and societies, prestigious prizes, such as the 2010 Nobel Prize in Chemistry awarded to Professor Eichi Negishi, and outstanding faculty and student achievements. Purdue also tracks the economic impacts of state investment. These metrics are key drivers in Purdue's continuous improvement efforts.

Engineering education

The overarching challenge of engineering education at Purdue university is to devise and implement improved strategies at all levels of education, from pre-kindergarten through graduate school. Particular focus is placed on first -year engineering education, by introducing activity-based learning and research experiences that spark research questions among our faculty and graduate students.

Goals include recruiting the best diverse student talents, developing a compelling base of engineering education research to drive engineering education reform, prepare engineering leaders to be proactive in addressing the challenges of the 21st century and building a stronger pipeline to help foster student interest in engineering. Purdue's School of Engineering Education is at the centre of this programme, being the only known engineering department in the US having tenured faculty focused on engineering education as their primary role.

As one looks at the 3 million students worldwide who earn a first university degree in science and engineering, half graduate from Asian universities, more than 600,000 of them in engineering. In the US we know that numbers alone cannot be our only concern. However, we must do better in attracting students to engineering careers, especially in attracting more women and other underrepresented groups in engineering.

A more important question is what kind of engineers will we need in the future and how can we prepare students today for the challenges ahead?

One conceptual framework for answering this question is "collaborative advantage". Collaborative advantage raises the question of what kind of engineers can flourish in the context of third-generation globalisation. What education can we provide that will ensure that they are well-prepared to lead? One answer is the way in which engineering is conducted. The trend today is towards more interdisciplinary work, greater collaboration and international participation in research projects. These "boundary-crossing experiences" require more than technical knowledge and skills. They rest on well-honed "collaborative skills" including the ability to cooperate and communicate across disciplines, distances, and cultures. Purdue seeks to become an international university in advancing education as well as research through collaborative partnerships

More than most, engineers need to become leaders in the new "global innovation system". Modern cyber infrastructure enables engineers to scan research frontiers at velocities that are orders of magnitude faster than ever before. To respond to such realties, Purdue university invests in world-class computational resources and Hub technology that enables virtual communities throughout the world to share data and to conduct collaborative modelling and simulation analysis.

An important additional strategy is to promote and support education in innovation and entrepreneurship. Engineers' ability to accelerate the pace at which new technological concepts can be transformed into marketable products and services is key to both "collaborative and competitive advantage."This requires both iterative trial and error strategic experimentation and the ability to learn from mistakes. Purdue university has invested in a variety of programmes including "conceptual design" that uses physical, mathematical and computational modelling and simulation. "Fast prototyping" is also taught, based on computational modelling and real prototype construction, testing and evaluation. A certificate programme in entrepreneurship and innovation, business plan competition, faculty "boot camps" and other novel approaches developed in Purdue's Discovery Park reinforces such learning experiences.

Purdue's engineering programme is thus aimed at providing its engineers with the following skills: leadership, teamwork, communication, decision-making, recognising and managing change, working effectively in diverse and multicultural environments, working effectively in the global engineering profession and synthesising engineering, business and societal perspectives. We believe that these abilities will provide the comparative and collaborative abilities needed by any21st century engineer.

For-profit colleges and universities

Education represents a major market sector in the US and private colleges and universities abound at all higher education levels. Some, such as the University of Phoenix, offer a broad range of Internet delivery courses covering many disciplines and degrees at all levels up to and including PhD. Numerous for-profit colleges also provide professional education in such fields as law, business, nursing, accounting, marketing, social services and law enforcement. Other colleges address needs for specialist training in such fields as manufacturing, construction, repair and maintenance, food service, health care, hospitality, law enforcement and industrial security.

Regarding higher education, the learning opportunities available from for-profit education providers are limited in scope. They do not usually provide the breadth of learn-

ing modes, mentoring, counselling, leadership training, laboratory experience, research opportunities, peer learning, team building and study abroad opportunities that a non-profit, private or state-supported institution provides as part of a holistic educational experience. However, for-profit education offers flexibility for a large segment of the US work force seeking specialised careers, desiring a work -study mode for acquiring knowledge and skills, or unable to meet the entrance requirements or costs of higher education at a non-profit college or university.

Transformational change

US research institutions are pursuing new models leveraging the strengths and competence of a variety of stakeholders (government, industry, academia) in conjunction with 21stcentury tools, including virtual research environments. The co-location of domestic and international researchers from university, industry, non-profit organisations and public agencies generates a dynamic environment for addressing old problems (grand challenges) in new and innovative ways. It also creates an environment that enhances new modes of learning and career opportunities for students. These innovative learning environments attract both undergraduate and graduate students interested in combining traditional in-depth knowledge from a single field with broadening and often global experiences in other fields.

Addressing grand challenge global issues requires researchers to work across disciplines to tackle systemic "wicked" problems. State-of-the-art research and computational facilities provide a means for unravelling such problems' complexity. Research universities can provide the opportunity for providing students and faculty with an innovation ecosystem designed to enhance discovery with delivery.

Looking to the future

Research universities are a key factor in driving confidence about US economic future. However, research universities and higher education institutions are facing significant fiscal challenges. Research universities must acquire more resources to sustain the ground-breaking, state-of-the-art impact achieved over the past half century, as well as modify their business models, this being an activity which Purdue university is actively engaged in today.

The level of increase of all federal research funding for universities in the US has recently fallen below cost-of-living rates. Most contracts and grants do not include sufficient support for recruiting graduate students in the numbers needed for national economic competitiveness in key industries nor do they adequately provide for needed postgraduate fellowships. Federal funding constraints have imposed an especially heavy burden on younger faculty members. The overall success rate for proposals submitted to NSF is around30%; the success rate for proposals from newly appointed PhDs is significantly less (Atkinson and Pelfrey, 2010, pp. 46-47). This highly competitive funding environment may discourage faculty, including younger faculty, from submitting proposals that are out of the mainstream but have the potential to yield major breakthroughs – the giant leaps that can address grand challenge, persistent problems.

Closing remarks

The US research enterprise in 2011 is experiencing both challenges and opportunities. Research universities have evolved and adjusted to global changes and national needs.

Human knowledge and expertise will be the key differentiators as the global community enters the second decade of the twenty-first century and the knowledge revolution continues to be a major driving force for economic development. Research universities' faculty and students will continue their important roles regarding creating economic value, integrating research with education and energising national innovation and entrepreneurial systems.

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