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Industry-Academe Collaboration for Research and Development

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ABSTRACT

Four forms of industry-academe linkage activities involve the sharing of economic value arising out of the generation of intellectual property: collaborative R&D, commissioned research, technology licensing, and the creation of spin-off companies. The Philippines is still in an emergent stage in all these forms. It has concerns that are the same as or similar to those of some other developing ASEAN countries.

While there are particular government regulations that can hinder R&D initiatives, the Philippine legal environment, in general, can be considered enabling for the development of R&D capability in both academe and industry and for technology commercialization. The scales of S&T manpower-building programs and R&D expenditures, however, fall short of the potential enabled by legislation. The scales are at least an order of magnitude below those of countries that have successfully embarked on R&D capacity-building in the past decades. As a manifestation of this overall weakness, industry-academe collaboration in R&D is also feeble.

This paper recommends the implementation of a massive S&T manpower-building program employing the existing systems of science high schools and public and private HEIs, the creation of a university of science and technology if total current HEI capacity proves inadequate, and the transformation of some existing public universities into research universities. With an overall improvement in R&D capability, R&D collaboration and technology commercialization will also be enhanced.

Keywords: industry-academe, university-industry, R&D, collaboration, commercialization

LIST OF ACRONYMS & ABBREVIATIONS

AdMU	Ateneo de Manila University
AFTBI	Agricultural Food Technology Business Incubator
BOI	Board of Investments
BPAP	Business Processing Association of the Philippines
CeBuinIT	Cebu Business Incubator in IT
CHED	Commission on Higher Education
CLSU	Central Luzon State University
COCOPEA	Coordinating Council of Private Education Associations
COMSTE	Commission on Science, Technology and Engineering
DA	Department of Agriculture
DBM	Department of Budget and Management
DENR	Department of Environment and Natural Resources
DepEd	Department of Education
DLSU	De La Salle University
DND	Department of National Defense
DOE	Department of Energy
DOH	Department of Health
DOST	Department of Science and Technology
DOST PCIEERD	DOST-Philippine Council for Industry, Energy and Emerging Technology Research and Development
DOST-SEI	DOST-Science Education Institute
DTI	Department of Trade and Industry
DTI-IPO	DTI-Intellectual Property Office
ERDT	Engineering R&D for Technology
ESEP	Engineering and Science Education Project
GERD	Gross Expenditure on R&D
GFA	Government Financing Agency
HEI	Higher Education Institution
HVAC	Heating, Ventilation and Air Conditioning
IAL	Industry Academe Linkage
ICT	Information and Communications Technology
IIT	Indian Institute of Technology
IP	Intellectual Property
IPR	Intellectual Property Rights
ITSO	Innovation and Technology Support Offices
JCI	Junior Chamber International
MAPUA	Mapua Institute of Technology
MEP	Master of Engineering Program
MIT	Massachusetts Institute of Technology
MOOE	Maintenance and Other Operating Expenses
MSME	Micro, Small and Medium Enterprises
MSU-IIT	Mindanao State University-Iligan Institute of Technology

NSC	National Science Consortium
NSDB	National Science Development Board
NUS	National University of Singapore
OECD	Organisation for Economic Co-operation and Development
OJT	On-the-Job Training
PASUC	Philippine Association of State Universities and Colleges
PATE	Philippine Association for Technological Education
PBEd	Philippine Business for Education
PCARI	Philippine-California Advanced Research Institutes
PDP	Philippine Development Plan
PEZA	Philippine Economic Zone Authority
POC	Proof of Concept
POV	Proof of Value
PSHS	Philippine Science High School
RA	Republic Act
RDI	Research and Development Institute
RSHS	Regional Science High School
RSE	Research Scientists and Engineers
SCS	Scientific Career System
SEIPI	Semiconductor and Electronics Industries in the Philippines
SME	Small and Medium Enterprises
SMED	SME Development
STI	Science, Technology and Innovation
SUCs	State Universities and Colleges
TBI	Technology Business Incubator
TESDA	Technical Education and Skills Development Authority
TRC	Technology Resource Center
TLO	Technology Licensing Office
TTO	Technology Transfer Office
UP	University of the Philippines
UPCOE	UP College of Engineering
UPCOE-IGLAP	UPCOE- Industry and Government Linkage with Academe Program
UPLB	UP at Los Banos
UPLB-CTTE	UPLB Center of Technology Transfer and Entrepreneurship
UP-MSI	UP Marine Science Institute
UP-NIGS	UP National Institute of Geological Sciences
UP-TTBDO	UP Technology Transfer and Business Development Office
UST	University of Santo Tomas

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INTRODUCTION

The WEF Global Competitiveness Report of 2012-2013 [1] categorizes the Philippines as being in transition from the factor-driven stage of competitiveness to the efficiency-driven stage. The country's ultimate goal should be to reach the innovation-driven stage. To reach that goal, among the items that it has to do is to vastly improve its R&D innovation system, in which it is currently ranked 94th in a field of 144 economies. An aspect of such a system is university-industry collaboration in R&D, in which it is ranked 79th.

Industry-academe collaboration can take various forms. This study concentrates on those that involve the sharing of the economic value derived from the generation of intellectual property: 1) joint or collaborative research; 2) sponsored or commissioned research; 3) technology licensing; and 4) the spinning off of technology-based companies from university laboratories. [2]

Joint or collaborative research in this context means research in which both or all of the parties make a substantial contribution to the resource requirements. Sponsored and commissioned research means research requested by and essentially paid for by an external party, "sponsored" having less of a connotation of commerciality than "commissioned." The sharing of intellectual property rights will depend on the relative value of the resources, tangible and intangible, contributed by each party.

Using the loose meaning of collaboration as "working together", sponsored and commissioned research may be described as "collaborative" if the research work is spread out to a number of entities.

In the title of this study, "collaboration" uses the loose definition and may therefore mean research in which the resource requirements are shared between industry and academe or in which the requirements are paid for by industry and the work shared between the parties.

This first section of the study looks at the Philippine experience over a wide range of industry-academe linkage activities. Three papers complement this section and are appended as annexes. They look at the particular experiences of the Mindanao State University – Iligan Institute of Technology (MSU-IIT), the Central Luzon State University (CLSU) and the University of the Philippines at Los Banos (UPLB). In the succeeding section, the U.S. experience, which has served as a model for other countries, is discussed. The experiences of other Asian countries are also described. Complementing this section is another appended paper that looks at the determinants of collaboration in selected countries.

The legal environment affecting R&D in general and industry-academe R&D collaboration in particular are examined in the succeeding section. The laws are briefly explained and the country's experiences that were enabled by these laws are examined, quantitatively where possible.

The next section presents an investment calculus for R&D. This calculus serves as the basis for an attempt to define the appropriate roles of academe, industry and government and to locate the area where R&D collaboration can thrive. This section also examines the need for research universities.

The last section gives the study's recommendations. It includes recommendations that will generally enable R&D in academe and industry, such as a massive S&T scholarship program and the creation of research universities. It includes recommendations for incentives for collaborative activities and the removal or amendment of hindering government regulations. Lastly, it recommends that, with its limited resources, the country place bets of technologies.

INDUSTRY-ACADEME LINKAGE IN PHILIPPINE SCHOOLS

All schools transfer knowledge to industry through its graduates, whom it imbues with the requisite understanding, knowledge, skills and values to be able to work in industry. This transfer occurs in the course of the school's performance of its basic mission to provide instruction to its students.

Linkage activities involving undergraduate students

Among the industry-academe linkage activities involving undergraduate students are:

- on-the-job training (OJT)
- summer student apprenticeships
- plant visits
- industry scholarship grants to students
- career talks
- job fairs
- student leadership camps
- industry-sponsored design contests

On another plane, academe and industry collaborate in the formulation of undergraduate curricula. This occurs at two levels. At the inter-sectoral level, this linkage happens through industry representation in CHED's Technical Panels and at the level of dialogue between industry sector organizations, such as SEIPI and BPAP on the industry side, and school associations, such as PATE and COCOPEA on the side of academe. Of late dialogue among industry, academe and government about the desired learning outcomes of academic programs is happening under the auspices of the PBEd. At the individual school level there could be school committees, which go by various names such as visiting committees or advisory committees. Through these committees, industry leaders, mostly alumni, are invited to give advice on curricular matters. Usually the needs of industry are incorporated through the customization of the 12-credit-unit free electives provided for in the government-mandated curricula. These 12 units are designed as tracks that cater to industry needs and sometimes even to specific vendor-company needs, as is common in the IT sector.

Linkage activities involving senior-year and graduate students

Some linkage activities involve senior-year and graduate students along with faculty members. These activities include:

- industry technical seminars for academics
- academe technical seminars for industry people
- fora to share information on R&D needs and capabilities

The last item is a preparatory activity leading to discussions on collaborative and sponsored or commissioned R&D projects.

Under the DOST-administered Engineering and Science Education Project (ESEP) a new master's level program called the Master in Engineering Program (MEP) was instituted. It called for the solution by the student of a nontrivial problem in industry as an academic requirement in lieu of a master's thesis. The student would be in practicum during this phase of his studies. This academic program continues to exist in some of the ESEP schools.

The De La Salle University (DLSU) has an undergraduate/graduate practicum system that it implements through its Industry-Academe Linkage (IAL) Program, in which companies join. Member companies give a research proposal to the students. The students or groups of students do the research for a period of one-year and submit a thesis on the basis of that research. [3]

Embedded training laboratories

Industry may put up training laboratories in schools, sometimes for eventual donation, to have their own personnel trained by faculty members and to have students trained for eventual hiring by the company. A control systems company put up a control systems simulator lab (used in their contact centers to remotely trouble shoot client equipment) and a diesel engine company set up an engine lab at the Mapua Institute of Technology under these terms.

Exchange of personnel

The exchange of personnel is a form of knowledge transfer between industry and academe. It may be implemented through faculty immersion or internship programs, usually over the summer months, and by adjunct professorship programs. Secondment of faculty members to industry is also a mode of exchange.

Faculty immersion programs can enrich undergraduate education because of the exposure of faculty members to industry. It can also be a way for the schools to help solve problems in industry. *Faculty secondment* is focused on the solving of industry problems. It may be noted that secondment of SUC faculty members is allowed under the Technology Transfer Act of 2009.

Adjunct professorship programs involve the giving of professorial appointments to industry experts. They lend currency to the content of the school's courses. It is also a way by which companies are able to identify future good hires.

Professorial Chairs

Industry may endow professorial chairs to which faculty members of a school may be appointed. Usually industry prefers to give it to a faculty member who is doing work in a field that is relevant to the company's operations. A usual requirement is for the faculty member to do research in that field or even on a particular problem that the company is wrestling with and deliver a technical paper towards the end of the term of appointment.

Shared R&D Facilities

The UP College of Engineering's Industry and Government Linkage with Academe Program (UPCOE-IGLAP), lists among its programs the sharing of facilities between the government and industry sectors and the College.

University-made, technology-infused products

Schools can also sell products that contain technologies they have developed.

Through retail and bulk sale (to the Department of Agriculture), the Central Luzon State University (CLSU) sells its improved tilapia fingerings and broodstocks. See Annex B.

The University of the Philippines at Los Banos (UPLB) sells seeds and tissue culture technologies for orchids, makapuno and banana. See Annex C.

Testing services

Academe can also offer testing services to industry. This makes use of laboratory equipment and faculty expertise. The perceived independence and credibility of schools is a major consideration in this transaction.

CLSU offers product evaluation, efficacy and bioassay tests, and adaptability trials. UPLB does testing of the efficacy of finished products and toxicity testing. The UPCOE, Mapua and other engineering schools do scientific and engineering testing services: chemical testing, water testing, soil testing, concrete testing, steel bars testing, electrical/electronics testing, *etc*. The UP Institute of Chemistry provides laboratory services that include the chemical analyses of the following: environmental and biological samples, food and food products, mining and metallurgical samples, industrial products and raw materials. UP has a microbiological lab and a DNA lab that offer a host of services through the University's Office of Extension Coordination. There are a number of other universities that engage industry in this manner.

Consultancy services

Schools can also offer consultancy services institutionally or through individual faculty members. This is a way of applying knowledge to solve specific problems or help address specific concerns of industry.

Schools usually have a preference for institutional consultancy in order to control the time and resources devoted by the school to such services. In any case, many schools provide consultancy services to industry over a wide range of areas.

It should be noted that the Technology Transfer Act of 2009 facilitates consultancy by individual SUC faculty members.

Research and technology commercialization linkage activities

All of the above activities involve the interchange of knowledge between industry and academe. In the case of sale of goods, new knowledge is already encapsulated in the product. In the case of consultancy services, the final report belongs to and may be copyrighted by the client.

In the above cases, IP issues may be part of the agreement, as in the case of MSU-IITs OJT and plant visit arrangement with PHINMA (Bacnotan Steel Corp.), which required that the "disclosure of results like publications needed their permission." See Annex B. In all cases, however, with the possible exception of research done by a professorial chair holder, the returns and sharing of the economic values arising out of intellectual property rights does not arise as an issue.

Box 1. BASIC RESEARCH, APPLIED RESEARCH, AND DEVELOPMENT

"*Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.*" [4]

"*While research and development are often lumped together for purposes of analysing the sources of technological advance, they should not be. (Basic) Research is the activity of making basic breakthroughs into new areas, such as biotechnology – deepening knowledge, if you will. Development is the expansion of technological knowledge in already existing areas – widening knowledge. In between there is an area, usually called applied research, in which the basic science is in place but some fundamental engineering breakthroughs have to take place to implement empirically what is already known scientifically. The Manhattan Project atomic bomb research during World War II was essentially applied research. Einstein and other physicists had shown that a bomb was theoretically possible, but was it practically doable?*" [5]

The industry-academe linkage activities in which such an issue arises are as follows: [2]

- Joint or collaborative research
- Sponsored or commissioned research
- Technology licensing of the school's intellectual property rights; and
- Creation of spin-off companies by university faculty, researchers or students.

Basic research

Based on the definition of basic research in Box 1 above, CLSU reports having done 5 basic research projects in collaboration with industry. Sevilleja reports in Annex B that basic research has been confined to the aquaculture field, in particular, the genetic improvement of tilapias. When the initial support of the government and international development agencies terminated, CLSU turned to the private sector "*in order to sustain the genetics and breeding work, to continue the conduct of researches, and to retain the trained personnel.*"

Mendoza in Annex C states that UPLB conducts basic research in such areas as taxonomy and systematics of organisms, and gene sequencing and characterization. She states that the funding for such projects, while without industry counterpart, is usually justified by their future applications in industry. Industry, however, has also funded basic research at UPLB such as developing systems to rejuvenate very old fruit orchards and conducting the terrestrial flora and fauna inventory of selected areas in Oriental Mindoro, studying diversity of non target organisms in regulated field trial sites, developing appropriate nursery and plantation designs, and developing protocols for the mass rearing of insects.

Applied research and development

UPLB does the following applied research: efficacy and toxicity testing of finished products; socio-economic studies on impact of products or technologies; field evaluation and epidemiology; and survey, assessment and planning. On the development end, UPLB does: developing a prototype and process for commercial wood plastic composite pallets using rice hull; developing the use of distillery effluent as fertilizer; developing mechanical tray-type dryer; and developing systems to rejuvenate mango orchards. See Annex C.

CLSU is doing product evaluation; efficacy and bioassay tests; adaptability trials; product design, testing and evaluation; and evaluation and demonstration of prototype model. See Annex B.

Collaborative R&D

Out of DOST-PCIEERD's 111 ongoing projects in year 2012, only 2 have industry-academe linkage. In both cases, the private companies are considered as "cooperating agencies." They either put in funds, equipment or service for the project, or they will commercialize the R&D output. These projects are:

- *The Establishment of Microbial Succession of Starter Culture for Rice Wine (Tapuy) Processing*; DOST is the funding agency; UPLB Food Science Cluster is the implementing agency; Tropical Fruit Winery is a cooperating agency.

- *Establishing the History of the Philippine Island Arc system: Clues from the Rocks of the Zambales-Pangasinan Region.* DOST is the funding agency; UP-NIGS is the Implementing agency; PHILEX Mining Corp. and Phil-Asia are cooperating agencies.

The Mapua Institute of Technology has just concluded the following commissioned research projects for private companies:

- *HVAC System Improvement for Energy Conservation in (a) Manufacturing Plant*;

- *Electrical Arcing Characteristics*.

<u>Patents and technology licensing</u>

Schools have started to establish their own Technology Licensing Offices (TLOs). CLSU created one in 2007 implementing IP policies and guidelines that had been approved by its Board of Regents. Likewise in 2007 the UP Board of Regents created the Center for Technology Transfer and Entrepreneurship (CTTE) at the UPLB. The UP System recently renamed its TLO as the Technology Transfer and Business Development Office (TTBDO). Last February 2, 2012, the University issued a memorandum which mandates the withholding to public access of theses, dissertations and defense proceedings until potential property rights on their content are fully protected by law.

UST enunciated its IP Policy and created its TLO in 2009. The school does extensive research as reported biennially, but linkage with industry is not indicated. The university has built a 4-story building, called the Thomas Aquinas Research Complex, to house its laboratories and other research-related facilities. [6] Mapua has issued its IP Policy and is in the process of establishing its TLO.

UPLB has licensed the following technologies: [7]

- 5 Inbred lines of maize, licensed to Ayala in 1995 for PhP 2.32 M;

- *Sinta* papaya hybrid licensed to East West Seeds at 7% royalty of gross sales, from 2005-2007, royalty amounted to PhP1.822 M;

- Bio N of UPLB Biotech is licensed to private companies through the Technology Resource Center (TRC).

The UP Marine Science Institute (MSI) got its first patent in 1981 for an "*improved process of extraction of vegetable cum carrageenan from Philippine seaweeds.*"

The UP Diliman has these patents and utility models [8]

- Salivary IgA E. histolytica Detection Kit
  Inventor: Windell L. Rivera, Angeline Odelia C. Concepcion, Alexander Edward S. Dy

- Cyclic hexapeptides, process and use thereof
  Inventor: Gisela P. Concepcion

- In vivo method for selecting antibodies, their derivatives and antibody-mediated therapies against breast cancer
  Inventor: Gisela P. Concepcion

- Method for detecting TAG-72 using CC92 and CC49 monoclonal antibodies and use thereof for cancer diagnosis, prognosis and monitoring
  Inventor: Gisela P. Concepcion

- Method for Generating High-Contrast Images of Semiconductor Sites via One-photon Optical Beam-Induced Current Imaging and Confocal Reflectance Microscopy
  Inventors: Ceasar S. Saloma, Vincent Daria, Jelda Jane Miranda

- Microorganism and the use thereof for producing heptylprodigiosin and the use of heptylprodigiosin
  Inventor: Gisela P. Concepcion

- Process for the preparation of mitoxantrone
  Inventor: Gisela P. Concepcion

- Synergistic combination of marine compounds and use thereof in the treatment of cancer
  Inventor: Gisela P. Concepcion

- Titanium Nitride Thin Film Formation on Metal Substrate by Chemical Vapor Deposition in a Magnetized Sheet Plasma Source
  Inventor: Henry J. Ramos

- Two Color (Two Photon) Excitation with Focused Excitation Beams and a Raman Shifter
  Inventors: Ceasar A. Saloma, Wilson O. Garcia, Jonathan Palero

Utility Models

- Seaweed-Based Air Freshener Gel
  Inventors: Marco Nemesio E. Montaño, Banaag Glorioso-Lajera

- Time Keeping Device
  Inventors: Prof. Michael Angelo Pedrasa, Prof. Jhoanne Rhodette A. Ibabao, Prof. Joy Alinda P. Reyes, Prof. Emerson C. Tan

It may be noted the number of technologies that have been licensed has been very paltry. A most telling observation has been made that the academics, who are in "the committees", do not have enough entrepreneurial knowledge and attitude. What is required is to bring in managers, perhaps MBAs, who are more steeped in management than in any particular technology. They are the ones who can deal, for example, with the high cost of maintaining patent protection and of the proper valuation of the technologies being marketed. [9]

Spin-offs

Dr. Tess Espino put up UPLB's first start up six years ago. The company uses enzyme technology to make virgin coconut oil. Also at the UPLB, STEMP Biotech Inc. was registered in 2007 based on a business plan and technology called *Enhanced Solo (Papaya with long shelf life and ring spot virus resistance)*. [7]

At UP Diliman. Dr. Gisella Concepcion put up two companies in 2004 based on her research work as a faculty member at the UP Marine Science Institute: *Biomart Asia, Inc.*, which produces skin care products made from terrestrial and marine herbal extracts; and *Vivotech Labs, Inc.,* which offers animal testing services using a facility certified by BAI and which markets recombinant vaccine design services. [10]

The UP Diliman Enterprise Program has spun off a number of companies. [11] These are:

- ***Greenapple***, which specializes in software and web development for the mobile and tablet platforms. The company provides custom iOS development for enterprises, as well as applications for selling on the iTunes App Store.

- ***Mayad,*** which produces light, photorealistic 3D models that can be accessed through the web and which are perfect for visualization and real estate.

- ***GSMetrix*,** which specializes in custom instrumentation technology. It has expertise the fields of medical instrumentation, remote monitoring systems, control and automation.

- ***Itemhound*,** which provides timing services for running and motorsport race events.

Technology Business Incubators (TBI)

In order to encourage and support the formation of spin-offs, schools have set up TBIs.

In 1991, the UPLB Science and Technology Park was established with the assistance of the DOST. It now has 2 incubator buildings, the Foods and Feeds Building and the Tissue Culture Building. In 2011, DOST again gave support to accommodate 17 more incubates in the Park. [12]

In 2010, CLSU implemented a project for the establishment of an Agricultural Food Technology Business Incubator (AFTBI) with support from PCAARRD-DOST; This TBI was institutionalized in 2011. See Annex B.

The UP–Ayala Land TechnoHub is an IT hub jointly developed by the UP Diliman and Ayala Land ,Inc. The PEZA approved it as an IT Park in 2009. This status makes the export-oriented company locators eligible for temporary tax holiday, permanent reduced rate of corporate income tax and other incentives. The park has SMEs and big companies as locators. The U.P. South Technopark , with 9 locators, is also a joint project of UP Diliman and Ayala Land, Inc.

UP Cebu College has its Cebu Business Incubator in I.T. or CeBuinIT, a joint effort with the DOST. It offers office space, mentoring and coaching. It currently has 11 locators. One of its locators, Tripsiders, which provides an online service to find trips and activities in the Philippines**,** recently got seed funding of USD 30,000 from Launchgarage**.** The seed funding was spent over six months to accelerate the start-up's development work. [13]

Technopreneurship bootcamps

There is another means of encouraging spin-offs – the technopreneurship bootcamp. In such camps, industry experts mentor participants on the creation of start-up companies; participants get to pitch their ideas about start-ups to a panel of experts in competition.

For two Saturdays in May 2012 students, professors and even alumni of the Mapua Institute of Technology developed technology ideas with potential for commercial success. This technopreneurship bootcamp was organized by the Junior Chamber International (JCI) Manila in partnership with Mapua. The industry partners for the event were IdeaSpace Foundation, Inc., Smart Communications, Inc. and Microsoft Philippines. There was an emphasis on the development of apps. [14]

Ateneo de Manila University (AdMU) was the site of a another technopreneurship bootcamp staged in partnership with Smart Communications, Inc. and IdeaSpace Foundation, Inc. [15]

An entrepreneurship camp was also held in Cebu last October 2012 by the Philippine Development Foundation, Inc. and Developers Connect (DevCon). Dubbed ***hack2hatch***, 22 operational startups were mentored one-on-one by experienced investors and company founders from Silicon Valley. They all pitched their proposals in a competition. This activity was not specifically aimed at schools, however. [16]

Summary

The widening spectrum of linkage modes between Philippine schools and industry simply reflect the growing importance being given to knowledge generation and application as a mission of schools. To instruction-related linkages have been added research-related and business-related linkages in which economic value generation and sharing are an important consideration.

In the face of global economic competition such growing linkages in research and technology commercialization are a positive development for the country. The only caveat, which have been voiced in other countries and which perhaps would be relevant to the Philippines when resources become sufficient, is that Philippine schools, specifically those that are publicly funded, could lose independence in the formulation of its basic research agenda.

Philippine schools engage in the whole-range of industry-academe linkage activities. Technology licensing and spin-offs are relatively recent. Collaborative and commissioned research works are very modest in scale.

INTERNATIONAL EXPERIENCE

In this section the experience of other countries are looked at for possible lessons for the Philippines.

The United States of America

In the US, the three most influential factors that set the course for industry-academe linkage are:

- the seminal report submitted by MIT Prof. Vannevar Bush to President Franklin Delano Roosevelt entitled *Science the Endless Frontier* [4] ;
- the Bayh-Dole Act or the Patent and Trademark Act Amendments of 1980; and
- the Small Business Innovation Development Act of 1982.

The Bush report laid down the basic paradigm of R&D in the US after the Second World War: basic research is to be done in the universities with funding from the federal government and applied research and development will be the done by industry; the schools supply the scientific capital, previously sourced from European science, and assure the flow of scientific talents to industry; and instruction and basic research become integrated in the graduate schools of US universities. This report stimulated the blossoming of research in academe, the results of some of which, though encumbered by IP issues, supplied the bases for new products, processes and systems that were very successfully marketed by US firms worldwide.

What were these IP issues? The government retained ownership of all patents granted from government-funded research. The government also retained the rights to license the patents to the private sector, but did so only on a non-exclusive basis. This was unacceptable to companies, which wanted to develop products to which it had exclusive rights to sell. Thus, many government-funded technologies generated in universities never got transferred to industry and never benefited the public. [17] By 1980 the U.S. government had accumulated 28,000 patents, fewer than 5% of which were commercially licensed. [18] The Bayh-Dole Act of 1980 changed all that by permitting a university, small business, or non-profit institution to retain the title on any patent issued for inventions made using federal research funds. The result was a very large increase in the number of university patents.

A number of countries - including Japan, Taiwan and the Philippines (in the Technology Transfer Act of 2009) - have enacted their own laws similar to the Bayh-Dole Act.

The Small Business Innovation Development Act in 1982 awarded federal research grants to small businesses, defined as those with less than 500 employees. These grants were purportedly given to projects considered too risky even for venture capitalists. The law reserves 2.5% of the total extramural research budgets of all federal agencies with extramural research budgets in excess of $100 million for contracts or grants to small businesses. Examples of companies that benefited from such R&D grants are Symantec, Qualcomm, DaVinci and iRobot. [19, 20]

Asia

As in the previous section on the Philippine experience, technology commercialization is categorized as follows:

- Joint or collaborative R&D
- Sponsored or commissioned R&D
- Technology licensing
- Formation of spin-off companies

The above categories, the first two of which were defined in the introduction, are very distinct in so far as a school or a company can make a decision on whether to focus on one category or the other depending on the relative merits of each. On the side of academe, for example, there could be a preference for spin-offs over technology licensing because of the lack of companies that have the capabilities to commercialize technologies from the universities. On the side SMEs, there could be lack of interest in technology licensing and collaborative research due to an absence of absorptive capacity for university-generated technologies or due to a simple preference for owning their own patents through commissioned research (which licensing will not give them). [2]

The practices of technology commercialization of selected schools in Asia are here considered. The university profiles are shown on Table 1. The said practices and other data are shown on Tables 2, 3 and 4 for a number of economies representing a range of degree of economic development.

The case of Japan deserves special mention. Historically, the strong links between the imperial universities and large firms in the 1920’s and 1930’s were broken after the Second World War with the breakup of the Zaibatsu's and the "*rejection of the role of a role for universities in support of the military-industrial complex*." [21] The national universities, as public institutions, are very restricted in their ability to accept R&D funding from industry. Their professors are civil servants, who, in general, are not allowed to accept personal compensation from commercial firms for their research. They thus restrict their collaboration with industry to "*time-honored informal relationships*." The degree of collaboration thus shows up not in patent licenses nor research funding but in coauthorship statistics! [21] See Box 2 below

Box 2. THE JAPANESE MODEL OF TECHNOLOGY TRANSFER

"*The defining principle of (the Japanese model of technology transfer) is the mobilization of knowledge through informal but well-articulated networks. In its simple (and most over-simplified) form, the model works like this: In return for intellectual property emerging from academic laboratories, industry tends to compensate the academic inventors in the form of donations. The use of donations as the preferred form of industrial support is a product of Japanese law, which since the Second World War has prohibited direct industrial support of university research. Faculty members use these donations to conduct research work in their laboratories, When the research leads to something of relevance to industry, that research is informally transferred to industrial partners who patent the discovery. These same industrial sponsors also tend to hire the graduate students from the university laboratory. In this way, the system tends to create a productive cycle. Large R&D-intensive firms sponsor academic research of direct relevance to them through donations, which in turn support relevant academic research. The results of the research are transferred to those sponsors via intellectual property ownership and transfers of human capital. More donations come in, more research get done, more graduate students are trained, more patents go to firms supporting the research, more graduate students get hired by the same firm, and so on. It is important to point out that this informal system appears to be an effective way of cross-pollinating the channels for technology transfer, in that it involves the transfer of formal codified knowledge along with human capital (in the form of graduate students familiar with the technology).*" [21]

Seen in this light, it may be said that the main mode of industry-academe linkage in Japan is collaborative research. Nothwithstanding the productive cycle generated in the Japanese industry-academe linkage, however, Japan still felt the need for some reforms during the period of economic stagnation of the 1990's. Between 1998 and 2004 it enacted 4 laws to reform the legal framework governing IP management and industry-academe collaboration. [2]

- *The 1998 Law to Promote the Transfer of University Technologies (The TLO Law).* This established a system to approve and subsidize university TLOs. It legitimized the transparent, negotiated, contractual transfer of university discoveries to industry and channeling of royalties back to the inventors, the laboratories and the university.

- *The 1999 Law of Special Measures to Revive Industry (the Japan Bayh-Dole Act).* This was intended to produce the same effect as the Bayh-Dole Act

- *The 2000 Law to Strengthen Industrial Technology*. This established procedures permitting university researchers to consult for, establish and even manage companies. It also streamlined the procedures for company-sponsored, commissioned and joint research. It eliminated the bureaucratic obstacles that dissuaded companies from using contractual sponsored research, rather than donations, to fund university research. However, it still did not allow the use of sponsored research funds to cover the salaries of permanent administrative and teaching staff.

- *The 2004 University Incorporation Law.* This gave national universities independent legal status. This enabled the universities to require assignment to them of employee inventions.

Another Asian country, Taiwan, reformed its system when in 1999 its legislature approved the *Fundamental Science and Technology Act*, which adopted most of the provisions of the Bayh-Dole Act of the US.

Technology commercialization activities in Asian countries outside of Japan picked up largely in the 2000s, with governments instituting policy reforms in their higher education systems. The initial response had been to use the US model including the establishment of Technology Transfer Offices (TTOs), invention disclosure systems, IP management policies and royalty-income sharing policies.[2] Asian universities have since developed tangible and intangible support activities to spur technology commercialization: incubator facilities, large scale science parks, entrepreneurship education programs, seed funding programs, mentoring, networking, and university-owned enterprises to market the university's knowledge assets directly.[2] Except for the last item, all these are also being done in the Philippines, although relatively lately, as discussed in the previous section.

On the side of academe, there has been a preference for spin-offs over technology licensing because of the lack of companies that have the capabilities to commercialize upstream technologies from the universities, except for Japan and Korea. There are, however, also hindering factors in the formation of spin-offs, namely [2]:

- Lack of early-stage angel investor and venture capital
- Lack of sophisticated lead-users in the domestic economy to serve as customers
- Lack of entrepreneurial drive and business skills among university faculty and students
- Lack of models and mentors
- Fear of failure as a cultural trait

The last three factors can be addressed by the creation of technology business incubators and by entrepreneurship education, among other things. The first two factors may need government support and incentives. There are a few angel investors and venture capitalists in the Philippines, some of which had volunteered to act as mentors in the 2012 *hack2hatch* bootcamp in Cebu as discussed in the previous section.

Among the incentives given by schools to its faculty members are income-sharing policies for royalties, permission to sit in the board of existing companies and start-up companies based on their inventions and permission to do consultancy work. Poh [2] *states, "...The share of net income that accrues to individual faculty inventors ranges from 20% to a very high 70%. The TTO (Technology Transfer Office) takes a relatively small cut, averaging slightly more than 10% of net income, with a few ... universities reporting that their TTO receives zero income...."* [2]

It must be noted that it takes some time - in some cases longer than 20 years [2] – for universities to achieve financial sustainability in their technology transfer activities. In justifying investments in such technology transfer activities, government has to take into account long-term social returns. (See Box 10 in the next section.) Private schools are well-advised to take into account the long payoff periods.

On the side SMEs, it has been observed that they have minimal participation in technology licensing and collaborative research. This has been ascribed to the lack of absorptive capacity of the SMEs for these university-generated technologies. Another reason offered in the case of the newly industrialized economies is that the SMEs have a preference for owning their own patents through commissioned research, which licensing will not give them. Taiwanese SMEs, in particular, expresses this preference as shown in Table 3 below.

In order to encourage collaborative research, there should be support from government. In Singapore, the government has instituted a scheme in the form of Proof of Concept (POC) and a Proof of Value (POV) grant modeled after the small business grant scheme of the US. The Taiwanese government has extended the joint R&D consortium scheme to the university context. This scheme, which enables SMEs to pool resources to participate in state sponsored collaborative R&D, has been successfully implemented in the government-owned Industrial Technology Research Institute (ITRI) [2] The Philippines, through the Joint Congressional Commission on Science, Technology and Engineering (COMSTE), is trying out such a scheme.

With such considerations cited above on both academe and industry side, it is clear that government policies that encourage and support technology commercialization in academe must be complemented by policies that enhance the absorptive capacity of industry. It is shown in the next section that the Philippine government is attempting such a balanced approach as shown in the legal framework it has built.

Tables 1 and 2 below are taken from Reference 2. Tables 3 and 4 have been put together by the author to summarize the text of Reference 2. As shown in Table 4, the situation of India and the ASEAN developing economies (characterized by technology commercialization being still at emerging stage; focus being on consulting and contract research, with less emphasis in joint/sponsored research, IP creation and commercialization; and enterprise creation being hampered by gaps in the entrepreneurship support system, especially venture capital and early-stage funding) could very well be that of the Philippines.

Table 1. Profile of Select Asian Universities, FY 2006 [2]

		Total academic staff FY 2006	Students enrolled FY 2006	% graduate students FY 2006	No. of graduates FY 2006 (% of national graduates in parentheses)	R&D expenditure FY 2006 in USD million[a]	No. of research publications FY 2006 (SSCI)
Mature industrialized economy	Kyushu University	2,274	18,622	36.5	4,183	68.6	3,885
	Tohoku University	2,675	17,849	39	4,796	234.2	4,312
	Tokyo University	4,444	28,952	49	7,662 (7.6%)	468.6	6,887
Newly Industrialized economies	HK University of S & T	450[b]	9,000	36	na	39.5	Na
	Korea Advanced Institute of S & T	745	7,336	58.8	1,687 (0.1%)	123.2	1.407
	National Taiwan University	1,869	32,233	45.3	7,494	170.8[c]	3,546
	National Taiwan University of S & T	883	9.246[d]	44.1[d]	3,153	6.0c	na
	National University of Singapore	1,944	29,305	22.6	8,559	117.1[f,g]	3,367
Emerging giant economies	Indian Institute of Technology Bombay	402[b]	1,451	64.7	1,451	33.1	650[h]
	Indian Institute of Technology Madras	360[b]	1,566[g]	64.8[g]	1,267	43.6	650[h]
	Tsinghua University (China)	6,945	31,786	56.6	na	186.5	2,874[g,i]
ASEAN developing economies	Mahidol University (Thailand)	9,562	23,815	34.8	na	19.7	698
	Multimedia University (Malaysia)	715	20,410	3.5	2,983 (6.84%)	2.2	168[j]

Notes:

a. Converted to USD from various national currencies using exchange rate as of January 2009
b. Tenure-track only
c. FY 2007, research funding from academia-third party collaboration only(includes funding from government, industry and other sources)
d. 2008
e. Definition of R&D spending at the National Taiwan University of S&T is nt consistent with that used for the other universities; hence the figures are not comparable
f. Data is for research funding
g. Data is 2005
h. Data is for SCI-extended publications
i. Data is fir SCI publications only

Table 2. Indicators on Direct Technology Commercialization Activities in Select Asian Universities, FY 2006 [2]

		TECHNOLOGY COMMERCIALIZATION ACTIVITIES							
		JOINT/SPONSORED RESEARCH WITH INDUSTRY			TECHNOLOGY LICENSING TO EXTERNAL PARTIES			SPIN-OFF FORMATION	
		% of research sponsored by industry	Value of *contract* research from industry per $'000 R&D spending	Value of *collaborative* research from industry per $'000 R&D spending	Licenses per 100 patents	Licenses per 100 academic staff	Growth in number of licenses, FY 2004-06 (%)	Spin-offs per 100 patents	Spin-offs per 100 academic staff
Mature industrialized economy	Kyushu	4.0	53.5	365.1	357.1	1.1	104.1	71.4	0.2
	Tohoku	5.7	291	74.4	204.3	1.8	159.1	0	0
	Tokyo	24.8	8.1	57.6	574.6	8.1	63.8	0	0
Newly Industrialized economies	HKUST	17.1	na	na	na	na	na	na	na
	KAIST	13.6	na	na	8.8	9.3	61.2	na	na
	NTU	Na	na	na	72.9	2.3	na	na	na
	NTUST	9.1[a]	na	na	133.3	3.6	3.2[c]	na	na
	NUS	7[b]	na	41.8	13.3	0.3	-52.9	4.4	0.1
Emerging giant economies	IIT Bombay	47[b]	247.7	66.5	na	10.7	na	na	1.2
	IIT Madras	33	228.4	111.7	na	na	na	28.6	1.7
	Tsinghua	39.5	na	na	na	na	Na	na	na
ASEAN developing economies	Mahidol	22.1	220.9	na	37.5	0.1	73.2	12.5	0.03
	MMU	21.2	na	na	na[c]	0	na	na[c]	0.6[d]

Notes:

a. FY 2007, basis for computation is research funding from academia-third party collaboration only (includes funding from government, industry and other sources)
b. Basis of computation is research funding in FY 2005
c. No patents granted to MMU in 2006 (cumulatively, MMU only has one issued patent at end of 2006)
d. Does not involve any formula licensing of technology or intellectual property from the university
e. Growth based on FY 2005-06

Table 3. Features of Technology Commercialization in Select Asian Universities (summary based on Reference 2)

Mature industrialized economy	Kyushu	Engage heavily in collaborative research with large companies to the detriment of spin-offs; recent reforms; Kyushu has cluster-based projects to transfer knowledge to the local regions and communities
	Tohoku	
	Tokyo	
Newly Industrialized economies	HKUST	New forms of joint ventures for the take up of university technology by industry; tech transfer not seen as an end in itself but as a means to strengthen industry-academe research collaborations
	KAIST	Maximizing income at the pre-patent-filing stage, rather than licensing patents; strong and consistent government support
	NTU	Most industries in Taiwan are SMEs, "*which prefer to have full ownership of their patents and prefer to engage universities through commissioned research rather than licensing agreements*." Big issue is lack of qualified professionals in technology transfer and licensing; highlight the importance of individual entrepreneurial faculty; recent reforms
	NTUST	
	NUS	Attracting foreign talent; entrepreneurial university model; experiential entrepreneurial education; emphasis on spin-offs
Emerging giant economies	IIT Bombay	TTO, incubation unit; lack of venture capital; success spin-off stories
	IIT Madras	Spin-off creation without formal institutional arrangements although there is an incubation unit; focus on rural development; lack of venture capital; success spin-off stories
	Tsinghua	Technology contract as the most important source of research funding; joint research centers; university science parks; university-owned enterprises; IP transfer and licensing; one organization to manage IP creation and research collaboration and another to manage IP commercialization
ASEAN developing economies	Mahidol	Top-down reform for universities to link with industry; transitioning of public universities to autonomous universities with less bureaucracy and greater capability for technology development; encouraged incubation and set up a fund for setting up TLOs in universities; intellectual capital portfolio a new phenomenon and informal channels and personal contacts remain the principal mechanisms of technology transfer; issues include: pressure to generate income, level of understanding of university stakeholders about technology commercialization, financial requirements, and absence of entrepreneurial culture.
	MMU	Private university; top-down reform to make universities more business-oriented; traditional forms of IPR and technology licensing considered too slow; emphasis on consultancy (made compulsory for all academic staff) and student technopreneurship; main challenge is financial and answer being sought in closer links with industry to provide laboratory facilities, consultancy opportunities and grants for R&D

Table 4. Analysis of Technology Commercialization in Select Asian Universities (summary based on Reference 2)

Mature industrialized economy	Kyushu	Adopted a relational approach with focus on building long-term cooperation and relationship with industry partners
	Tohoku	
	Tokyo	
Newly Industrialized economies	HKUST	Adopted a transactional approach, similar to that of leading US schools, which emphasizes patenting and their licensing to industry to generate returns to be shared among the faculty, department and central administration through a well-defined royalty income-sharing scheme.
	KAIST	
	NTU	
	NTUST	
	NUS	
Emerging giant economies	Tsinghua	Ambitious policy reforms; strategic focus on creating a number of world-class research universities; has enabled a number of universities to be more aggressive in adopting a commercialized and entrepreneurial approach; result shows in ability to attract large investments in science and technology parks and the creation of university-owned enterprises.
	IIT Madras	Less aggressive approach; technology commercialization still at emerging stage; focus is on consulting and contract research, with less emphasis in joint/sponsored research, IP creation and commercialization; enterprise creation hampered by gaps in the entrepreneurship support system, especially venture capital and early-stage funding.
	IIT Bombay	
ASEAN developing economies	Mahidol	
	MMU	

THE PHILIPPINE LEGAL ENVIRONMENT

The Philippine Constitution has specific sections on S&T development. It declares that "....*The state shall give priority to research and development, invention, innovation, and their utilization; and to science and technology education, training, and services...*" Further, "*The Congress may provide for incentives, including tax deductions, to encourage private participation in programs of basic and applied scientific research....*" and "*The state shall regulate the transfer and promote the adaptation of technology from all sources for the national benefit...*"

There are laws that support R&D in general and those that, in particular, also support academe-industry linkage for R&D. Two laws provide for scholarships for S&T programs, one of them up to the level of graduate degrees. One law provides for incentives for S&T personnel to join and remain in government service, including in SUCs. There are laws that provide R&D funding to specific sectors: agriculture and fisheries, renewable energy, and environment (clean water/clean air). There is a law to support R&D in SMEs and the SME's access to information on commercializable technologies. Lastly, there is a law to facilitate technology commercialization, much like the US' Bayh-Dole Act.

S&T Scholarships

The Philippine Science High School (PSHS) System Act of 1997 (RA No. 8496) provides for the integration of the existing science high schools into one system and for the expansion of such a system. See Box 3 below on the *Three Systems of Science High Schools.*

One concern about the system is that the nurturing of the PSHS scholars end after their graduation from high school. Many believe that, with or without scholarship, there should be a special track in college to continue the special education these scholars have already undergone. The same or similar arrangements should be made for the graduates of the other two science high schools systems. A more radical suggestion of establishing a tertiary and graduate school for these graduates and the S&T talents from other high schools has been proffered

The confluence of these streams of talents add up to a sufficiently large pool of young talents from which we can train enough S&T workers that will not only satisfy international benchmarks but will more importantly lead to credible R&D capability. See box below on the *Three Systems of Science High Schools.*

Box 3. THE THREE NATIONAL SYSTEMS OF SCIENCE HIGH SCHOOLS

From one campus in Diliman in 1964, the Philippine Science High School System had expanded to 11 campuses nationwide as of school year 2011-2012. From 1969 to 2011, the PSHS System graduated 14,265 students, 8,166 out of the main campus and 6,099 out of the other campuses taken together. [22]

It should be noted that aside from the PSHS System, there are two other national systems of science high schools: high schools in the *Regional Science High School (RSHS) Union* and the *ESEP High Schools* or the *Science and Technology High Schools*. The RSHS Union was established by the DepEd during the school year 1994-1995. It now has 18 campuses nationwide. Some RSHSs were formerly annexes of public secondary schools, while some were already established as specialized science high schools prior to 1994. Each of the 17 Regional Science High Schools are given by the government an allocation for Maintenance and Other Operating Expenses (MOOE) separate from other public high schools in the Philippines. The ESEP high schools, originally numbering 100 but now totaling 198 schools, were a product of the DOST-OECD supported Engineering and Science Education Project (ESEP). Upon project completion they were turned over to the DepEd. They now maintain special sections for science. [23]

The PSHS system graduates about 1,000 students every year from all campuses and the RSHS Union graduates about 1,700. As of SY 2011-2012, there were 47,776 students in the special science sections of all 4 year-levels of the ESEP High Schools. Very roughly, dividing the total by 4, there could be 10,000 graduates every year from this pool. Combined, the graduates from the three science high school systems number roughly 12,700 every year!

It must be noted that aside from the national systems of science high schools, a good number of cities and municipalities have their own science high schools. Furthermore, there are also the private science high schools. The graduates from these schools should be added to enlarge the talent pool further.

The Science and Technology Scholarship Act of 1994 (RA No. 7687) provides for scholarships for poor, talented and deserving students. While this law provides scholarships for the needy, an earlier law that created the National Science Development Board (NSDB) provides for merit scholarships. Together the two laws serve as the bases for the administration of S&T scholarships by the DOST-Science Education Institute (SEI). See box 4 on *Post-Secondary Scholarships* below.

Box 4. POST-SECONDARY SCHOLARSHIPS

From 2001 to 2007, the DOST awarded a total of 6,051 undergraduate scholarships. In academic year 2007-2008, it had 505 MS and 74 PhD active scholarships. In 2010, DOST provided for 721 MS and 428 PhD slots. These were all granted under the Science and Technology Scholarship Act and the NSDB Law. [24]

It may be noted that other scholarship programs have been implemented as a supplement to those implemented under the two laws. For example the government implemented an Engineering and Science Education Project (ESEP) in the 1990's. This project produced 1,000 Diploma graduates, above the target of 859; 1,045 master's degrees, slightly below the target of 1,087; and 212 PhDs, exceeding the target of 180. [25] A fraction of the master's degrees are Master of Engineering degrees, which involved solving a problem in industry in lieu of a thesis. This achieved a measure of industry-academe linkage although the original motivation was to provide an alternative to the MS thesis, the execution of which encountered big difficulties on the part of the students and the ESEP schools.

The ongoing Engineering R&D for Technology (ERDT) program has thus far produced 243 MS and 18 PhD graduates. The total intake of MS students as of November 2012 was 900, exceeding the target of 862. The total intake of PhD students was 151, which is lower than the target of 178. From among all the MS and PhD theses and dissertation under ERDT, apparently only two MS theses have been actively supported by industry, specifically by Analog Devices. [26]

In 2009 the 10 colleges and schools with established PhD programs in the basic and applied sciences and mathematics were organized into the National Science Consortium (NSC). Implementation of the NSC scholarship program under the DOST-SEI started in school year 2010-2011. "*Before the Consortium was organized, the chosen colleges produced an average total of 74.7 PhD and 247.4 MS graduates per school year ... The formation of the Consortium is expected to increase collective production to around 250 PhD and 350 MS graduates per year....*" [27] CHED 3-year data from SY 2009-2010 to AY 2011-2012 show that there are 15 PhD programs in the natural sciences and that 275 students were enrolled during that time period. [28]

RA No. 7687 was amended by **RA No. 8248**, which provides for the creation of a Science and Technology Human Development Council chaired by the DOST Secretary and composed of the CHED Chairman, DepED Secretary, TESDA Director-General, DBM Secretary and the President of the Philippine Association of State Universities and Colleges (PASUC). The Council performs the following functions: 1) coordinate science and technology human resource development programs; 2) formulate a medium and long term science and technology human resource development plan in accordance with the national medium- term plan; 3) formulate policies for the allocations of science and technology scholarships; 4) formulate broad policies on advanced degree programs for science and technology; 5) formulate a career system for technologists and technicians to complement the scientific career system; and 6) formulate programs to train and retrain scientists, engineers, researchers and technologists and encourage them, through various incentives, to return and practice their professions in the Philippines, to enhance and accelerate the technological development of the country. Apparently the potential of this Council has not been adequately tapped.

In 1982, the government institutionalized a Scientific Career System (SCS) trough ***Executive Order No. 784.*** Jointly administered by the DOST and the Civil Service Commission, this system provided an incentive system for R&D personnel in government service through career advancement, progression and rewards. ***The Magna Carta for Scientist, Engineers, Researchers and S&T Personnel in the Government*** (RA No. 8439) reinforced this existing SCS through the exemption from the salary standardization law, honorarium, share in royalties, allowances (hazard, subsistence, housing and quarters), longevity pay, medical examination, scholarships and grants and other exclusive rights and privileges.

Box 5. THE SCIENTIFIC CAREER SYSTEM

From 1982 to 2010, the Scientific Career System awarded a total of 111 scientist ranks. There were 30 active members as of June 2010. [29,30]

In 2009 there were 2,009 researchers with PhDs in government, 1,910 of them in public HEIs. There were 2,677 with master's degrees, 1,912 of them in public HEIs. Combined there were 4,686 researchers with advanced degrees in government, 3,822 of them in public HEIs. [31]

It may be noted that the number of those who have availed themselves of the SCS benefits is 2 orders of magnitude lower than those who may be eligible! A review is apparently in order.

Box 6. RESEARCH SCIENTISTS AND ENGINEERS

Based on DOST data, the Philippines had 90 research scientists and engineers (RSE) per million population in 2002. [31] This number is very low compared to the UNESCO benchmark of 340 per million population. With a current population of about 100 million, we need to have 34,000 RSEs. According to DOST data, as of 2009 we had, 13,091 researchers. [31] In 2002, the number of researchers was 7,203. Assuming a linear growth rate, the increase in the number of researchers per year is 841. Extrapolating from 2009 figures, the number of researchers by 2012 would be about 15,600. The current shortfall from the required 34,000 is, therefore, 18,400.

Assuming a constant annual increase of 841 and an annual popuation growth rate of 2%, the UNESCO benchmark will never, ever be attained. A major surge is called for. Vietnamese professors visited Mapua a few years back and said that their plan was to have 2,000 new PhDs every year for 10 years in a row. If we did the same, *i.e.*, have 2,000 newly-minted PhDs every year, it would take us 15 years to reach the benchmark. If we want to do it in 10 years we have to produce 2,600 PhDs every year. Please see Table 5 below. This assumes that we want only PhDs as researchers, for which there could be good reason.

To get these numbers we can turn to the three national science high schools systems (see Box 3 above), which together graduate about 12,700 students every year! We can filter these and get additional talent from other high schools, especially the city/municipal science high schools and the private science high schools.

As of 2006, there were 50 higher education institutes offering master's degree programs in engineering and the sciences. [32] There are only 7 Philippine schools offering PhD programs in engineering. As mentioned in Box 4, as of 2009 there were only 10 colleges and schools from seven universities with established Ph.D. programs in the basic and applied sciences and mathematics. These colleges and schools are organized into the National Science Consortium (NSC). [27] The numbers of graduates produced by the ESEP and ERDT and the NSC combined, which are an order of magnitude less than required, concretely demonstrate the inadequacy of local resources. (See Box 4 above) This means that if wanted to attain the UNESCO benchmark we have to depend heavily on sending scholars to schools abroad. The expenses would increase considerably. However, we should be able to plan for it if we mean to do it.

RA 8248 provides for the creation of a Science and Technology Human Development Council, a ready-made vehicle that is currently inactive. If it could be reactivated, clearly, it would be its job to shepherd the young talents from the high schools to the graduate schools.

Table 5. Required Number of New RSEs per Year
to Satisfy UNESCO Benchmark

Assumptions: UNESCO Benchmark Of 340 RSEs Per Million
and 2% Annual Population Growth

Year	Population	Required RSEs	Additional Requirement from a Base Of 15,600 In 2012	Required Number of New RSEs per year
0	100,000,000	34,000	18,400	
1	102,000,000	34,680	19,080	19,080
2	104,040,000	35,374	19,774	9,887
3	106,120,800	36,081	20,481	6,827
4	108,243,216	36,803	21,203	5,301
5	110,408,080	37,539	21,939	4,388
6	112,616,242	38,290	22,690	3,782
7	114,868,567	39,055	23,455	3,351
8	117,165,938	39,836	24,236	3,030
9	119,509,257	40,633	25,033	2,781
10	121,899,442	41,446	25,846	2,585
11	124,337,431	42,275	26,675	2,425
12	126,824,179	43,120	27,520	2,293
13	129,360,663	43,983	28,383	2,183
14	131,947,876	44,862	29,262	2,090
15	134,586,834	45,760	30,160	2,011
16	137,278,571	46,675	31,075	1,942
17	140,024,142	47,608	32,008	1,883
18	142,824,625	48,560	32,960	1,831
19	145,681,117	49,532	33,932	1,786
20	148,594,740	50,522	34,922	1,746

The *Magna Carta* allows engineers, researchers, technologists, technicians and other Science and Technology personnel to render consultancy services to the private sector and entitles them to receive such honorarium that may be paid to them by the private entity concerned. Such payments shall be over and above their salary from the government during the period of consultancy and shall not be considered double compensation. Furthermore, they are allowed to be seconded to any private entity whenever such services are required.

These provisions directly enable industry-academe collaboration for research.

R&D Funding

It may be noted that several Philippine laws provide for public funding of R&D in a number of areas, namely, agriculture and fisheries, renewable energy and air and water pollution. The SUCs and private HEIs can access the funds.

The Agriculture and Fisheries Modernization Act of 1997 *(RA 8435)* provides for the funding of basic and applied research in SUCs. It states that "*The budget for agriculture and fisheries research and development shall be at least one percent (1%) of the gross value added (GVA) by year 2001 allocating at least one percent (1%) of the total amount by 1999. The Department of Finance (DOF) in consultation with the Department shall formulate revenue enhancement measures to fund this facility."* Further, *"At least twenty percent (20%) shall be spent in support of basic research and not more than eighty percent (80%) shall be used for applied research and technology packaging and transfer activities."*

The Renewable Energy Act of 2008 (RA 9513) provides for the funding of studies jointly undertaken by the public and private sectors. It establishes a DOE-administered Renewable Energy Trust Fund "*to enhance the development and greater utilization of renewable energy*." Among the exclusive uses of the fund is the financing of "*research, development, demonstration, and promotion of the widespread and productive use of Renewable Energy (RE) systems for power and non-power applications, as well as to provide funding for R & D institutions engaged in renewable energy studies undertaken jointly through public-private sector partnership, including provision for scholarship and fellowship for energy studies.*"

The Philippine Clean Water Act of 1999 (RA 8749) mandates the DENR, in coordination with the DOST, other agencies, the private sector, the academe, NGO's and PO's, to "*establish a National Research and Development Program for the prevention and control of air pollution.*" Emphasis shall be given to research on and "*the development of improved methods having industry-wide application for the prevention and control of air pollution.*" The R & D program shall "*develop air quality guideline values and standards in addition to internationally-accepted standards. It shall also consider the socio-cultural, political and economic implications of air quality management and pollution control.*"

The Philippine Clean Water Act of 2004 (RA 9275) mandates the DENR, in coordination with the DOST, other concerned agencies and academic research institutions, to "*establish a national research and development program for the prevention and control of water pollution. As part of said program, the DOST shall conduct and promote the coordination and acceleration of research, investigation, experiments, training, survey and studies relating to the causes, extent, prevention and control of pollution among concerned government agencies and research institutions.*"

The Gross Domestic Expenditure on R&D (GERD)

A country's gross expenditure on R&D (GERD) is an indicator of relative public and private support given to R&D by various countries. Table 7 of Annex D gives the values for various economies over a number of years.

While making comparisons may be useful to a degree, what is important is that R&D spending is well thought out to keep outlay for R&D from being a mindless exercise of keeping up with the Joneses, more so for precious public funds which can have plenty of other competing uses for the benefit of the public.

Table. 6 Philippine R&D Expenditures by Sector [based on Reference 31]

SECTOR	R&D EXPENDITURE (In Million Pesos)					% of Total (2009)
	2002	2003	2005	2007	2009	
All Sectors	5,769.80	5,909.70	6,326.74	7,556.36	8,779.16	100
Government	975.60	1,129.60	1,175.53	1,333.94	1,392.69	16
Higher Education	762.40	657.40	1,350.10	1,756.91	2,112.66	24
Public HEIs	640.00	455.00	1,092.87	1,326.45	1,745.32	20
Private HEIs	122.40	202.40	257.23	430.46	367.33	4
Private Non-Profit	121.70	104.60	96.21	162.17	28.45	3
Private Industry	3,910.10	4,018.10	3,705.10	4,303.35	5,045.37	57

Looking at the 2009 figures of Table 6, it may be observed that, at 57%, private industry spent more in R&D than all other sectors combined. Corroboration of this figure from other sources has not been found.

The combined spending of public HEIs and government is 36%.

Private HEIs' share is very small at 4% and shows no definite trend over the years. Public HEIs have spent more than private HEIs. Their spending has also consistently increased from 2003 onwards.

The small share of private HEIs may be appreciated in the light of their income being almost exclusively derived from tuition fees. These are mostly and spent on tuition, too.

A small part of the spending of private industry is in collaborating with or in commissioning HEIs. The box below shows the figures and compares them with those of other Asian countries.

Box 7. AMOUNT OF PRIVATE FUNDS IN R&D EXPENDITURES OF PHILIPPINE HEIs AND ASIAN SCHOOLS

The amount of R&D expenditures of HEIs that are sourced from private sources may be used as an indicator of the extent of industry-academe contract/collaborative research. The following rounded-off figures in millions of pesos are taken from Reference 31:

YEAR	Public HEIs	Private HEIs	As a percentage of Total Industry R&D Spending
2002	17.6	15.9	0.8
2003	25.7	14.5	1.0
2005	218.7	17.1	6.4
2007	316.4	40.8	8.3
2009	130.8	37.1	3.3

As a percentage of its total industry R&D spending shown on the Table 6 above, the portion that industry gives to academe in terms of collaborative/commissioned research is very small (see last column above).

There was a significant increase after 2003, but there was a lapse in both absolute amount and percentage in 2009.

More industry funds have gone to public HEIs than to private HEIs. From Dr. Mendoza's paper (Annex C), UPLB obtained P 31.1 M in research funds from industry from 2002 to 2011, the largest yearly amount being in P 12.7 M in 2012.

Based on Tables 1 and 2 of the previous section of this report on International Experience, the following were the contract/collaborative expenditures in millions of USD of select universities in Asia in 2006 [2]: Kyushu U: 28.7; Tohoku U: 65.3; Tokyo U: 296.2; NUS: 4.9; IIT Bombay: 10.4; IIT Madras: 14.8; Mahidol U: 4.35.

It is not known what the split in funding is between industry and these Asian schools, but, roughly, if the split were even, it appears that the private R&D spending in collaborating with each of NUS, IIT Bombay, IIT Madras and Mahidol already would be in the same order of magnitude as the entire expenditure of Philippine industry in collaborative R&D across all Philippine schools. The spending of UPLB would be at least an order of magnitude less than the single-school spending of said Asian schools.

In September 2012, the DBM announced its intention to provide a budget of PhP 1.7 B (since cut to P 1.2 B by the Senate) in the CHED 2013 budget to develop the capability of selected HEIs to "*undertake high-end collaborative research and to capture the potential of next generation of ICT and biotechnology in the development of products and services that government and private enterprises can deploy.*" This program has been dubbed as the Philippine-California Advanced Research Institutes (PCARI). It seeks to build research institutes in ICT and Biotechnology where, in collaboration with the University of California at Berkeley and the University of California at San Francisco professors and researchers, the professors and researchers of select Philippine schools will do industry-relevant research in an effort to move "*from supply-driven R and D to the systematic linking of research supply and demand.*" [33] The industry partners have yet to be identified. This initiative is representative of an academe-industry R&D Center.

It should be mentioned that the Board of Investments (BOI) registers and approves R&D Projects for purposes of giving them incentives. From 1978 to 2012, it registered a total of 23 projects with a total value of PhP 820 M.

Small and medium Enterprises

The Magna Carta for Small Enterprises of 1991 [RA 6077 as amended by RA 8289] provides for the creation of the Small and Medium Enterprise Development (SMED) Council which has, among its duties: "*the promotion of the productivity and viability of small and medium enterprises by way of directing and/or assisting relevant government agencies and institutions at the national, regional and provincial levels towards the ... provision of support for product experimentation and research and development (R&D) activities as well as access to information on commercialized technologies.*"

Box 8. A PREFERENCE OF SMEs FOR COMMISSIONED RESEARCH

In the case of Hongkong, Dr. Salvacion states in Annex D that "*some SMEs prefer to gain access to university knowledge by hiring highly skilled graduates rather than collaborating with universities in research*." If the SMEs do not want to do their own R&D but nevertheless feel the need for new technologies and knowledge that their highly-skilled graduates cannot provide, their alternative would be to license university-developed technologies or to commission research by the universities. In the previous section of this report on *International Experience*, it is stated that in the newly industrialized economies of Asia SMEs have a preference for owning their own patents through commissioned research rather than licensing. If Filipino SMEs behave in the same way then specific provisions and incentives must be given to SMEs that want to commission schools to serve their R&D needs.

Reference 34 surveyed 474 business establishments to determine the number of firms that considered government support programs to be important for innovation. Of these firms, 258 (54%) establishments were considered "innovation active." And of these 258, 118 (46%) stated that Universities or other education institutions are their partners in innovation activities. Table 7 below shows the components of government support programs and the number of firms, by size that considered each component important to them. It may be noted that it is in the areas of *training* and *technical support and advice* where they consider government support to be most important. These are also areas in which academe can participate. The later area could come in the form of consultancy and secondment. It may be observed that it is the micro and large industries that consider support for R&D as important. SMEs do not consider such support important at all!

Table 7. Number of Firms that Considered Government Support Programs That they Received Highly Important for Innovation, by Establishment Size [based on Reference 34]

Government Support Programs	Micro 104	Small 109	Medium 81	Large 180	All Firms 474
R & D funding	34	0	0	31	65
Training	34	55	14	63	166
Subsidies	0	0	0	31	31
Tax rebates	34	0	14	63	111
Technical support & advice	34	55	0	78	167
Infrastructure support	34	0	0	47	81
Loans and grants	34	0	0	31	65

Technology commercialization

The Technology Transfer Act of 2009 (RA 10055) provides the framework and support system for the ownership, management, use, and commercialization of intellectual property generated from R & D funded by government.

In the preamble of this Act, there is acknowledgment "*that the successful transfer of government-funded R&D results depend on the proper management of intellectual property, development of capacity by RDIs (Research and Development Institutes which include HEIs by definition) to become self-sustaining and competitive, and on enhancing interaction and cooperation with the private sector, particularly small and medium enterprises through collaborative and contract research based on equitable, fair access, and mutual benefit for all involved partners.*"

This Act will encourage public HEIs to conduct R&D by being vested, in general, "*the ownership of IPs and IPRs derived and generated from research funded by the a GFA (Government Funding Agency), whether such funding is in whole or in part.*"

The Public HEIs shall "*identify, protect, and manage the IPs generated from R&D funded by the GFA and pursue commercial exploitation diligently as a required performance stipulated in the research funding agreement...*" They shall "*be allowed to directly negotiate agreements for the commercialization of IPs...*"

To be able to do the above the public HEIs are mandated to "*ensure that they have access to the skills and management capability to effectively perform their responsibilities of owning, managing, and exploiting the IP or IPRs.*"

They must also "*accord their staff with incentives ... to sustain efforts in identifying valuable IP and in pursuing IP commercialization....*"

Under this act, the RDIs, including public HEIs, can, "*when necessary, create and establish spin-off companies to pursue commercialization.*"

"*In meritorious cases and to help ensure successful commercialization, an RDI shall allow its researcher-employee to commercialize or pursue commercialization of the IP and/or IPRs generated from R&D funded by the GFA by creating, owning, controlling, or managing a company or spin-off firm undertaking commercialization, or accepting employment as an officer, employee, or consultant in a spin-off firm undertaking such commercialization.*"

As an incentive to the RDIs themselves, "*Public RDIs undertaking technology transfer shall be vested with the authority to use its share of the revenues derived from commercialization of IP generated from R&D funded by GFAs. All income generated from commercialization of IPs and/or IPRs from R&D funded by public funds shall be constituted as a revolving fund for use of the RDI undertaking technology transfer, deposited in an authorized government depository bank subject to accounting and auditing rules and regulations: Provided, That said income shall be used to defray intellectual property management costs and expenses and to fund R&D, science and technology capability building, and technology transfer activities, including operation of technology licensing offices.*"

The law is clear on the mechanisms to effect technology transfer. Among the provisions are:

- *All RDIs are to establish their own Technology Licensing Offices and to adopt their own IPR management and technology transfer policies;* and

- *The DOST and the DTI and its Intellectual Property Office (IPO), in consultation with, CHED, DA, DOH, DOE, DENR and DND, shall help build the capacity of GFAs and RDIs to commercialize IPs.*

The Technology Transfer Act should release a lot of potential and energy among HEIs. It still remains to be seen, however, how effective it will be.

Box 9. THE I.T.S.O.

One project of the DTI-IPOHIL in helping build the capacity to commercialize IPs is the establishment of a network of Innovation & Technology Support Offices (I.T.S.O.) or "patent libraries" to strengthen institutional capacity of universities and research-related institutions to access patent information and make use of the patent system**.** To date it has trained one hundred seventy-eight (178) professionals in patent searching and patent drafting and has built a network of 47 host institutions nationwide, 38 of which are academic institutions. Of these 38, 23 are SUCs and 15 are private. It is only very recently that the project has been implemented and it has to be seen how useful it is going to be to the HEIs.

It may be noted in the previous section on *International Experience* that Taiwan considers the lack of qualified professionals in technology transfer and licensing a big issue. The ITSO project is a good start but has a long way to go.

Summary

The legal environment in which to do R&D work, including collaborative projects, is, in general, enabling. However, the promise of certain laws has not been realized. The country is orders of magnitude off in S&T manpower build-up and in industry-academe collaborative R&D funding.

AN R&D INVESTMENT CALCULUS AND THE ROLES OF ACADEME, INDUSTRY AND GOVERNMENT

An investment calculus

An investment calculus for R&D has been worked out in the US by Thurow [5]. See box 10 below. The enabling of industry-academe collaborative R&D in the Philippines should be based on the appreciation of such a calculus as applied to Philippine conditions.

Box 10. PRIVATE AND SOCIAL RATES OF RETURN ON R & D

"Private rates of return on R&D spending average about 24 percent. Since firms are not rapidly expanding their R&D budgets, this indicates that something like this level of returns is probably necessary to cover the capital costs (6 percent) and the inevitable risks and uncertainties. By subtraction, private firms seem to think that the right risk factor is about 18 percent...

At the same time, social returns (total economic returns to the whole society) on R&D spending (averaging the results of eight different studies) were 66 percent, with a range from 50 to 105 percent – or almost three times as high as those 24 percent private financial returns. This means that $2 of every $3 in net benefits generated did not accrue to those paying for the R&D. There are huge positive social spillovers from research and development spending...

This difference between private and social rates of returns is the primary reason why governments must support R&D funding. Societies can take spillover effects into account. They can focus on that 66 percent social rate of return and not the 24 percent private rate of return. They don't have to worry about which particular firms benefit. If governments don't support R&D spending, much too little R&D will be done...

Because of the investment calculus used by business firms, a good R&D project expected to pay off in five years or less is almost sure to find private funding. If payoffs lie ten or more years in the future, the project clearly requires government financing. For projects within a five- to ten-year time perspective, there is a case for cost-sharing..." [5]

With the above calculus, there should be a "sweet spot" for industry-government collaboration. In the US this is located in the 5 to 10 year payoff period range. Research on lithium-ion batteries fell within this range in the US [5]. The equivalent range for the Philippines should be the subject of a study.

The above calculus implies on the one hand that industry may not be expected to do basic research, which, because of its very nature, has a long pay-off period. With but few exceptions this has indeed been the case. Since industry is always under the pressure of business necessity "*satisfactory progress in basic science seldom occurs under conditions prevailing in the normal industrial laboratory.*" [4]

The above calculus implies on the other hand that, for the very same reason of the long pay-off period associated with basic research, it would make sense to support basic research in the publicly-funded SUCs. That the *Agriculture and Fisheries Modernization Act* requires that at least 20% of the total R&D funds used by SUCs be placed in basic research is well-guided in this sense. Another reason why it is natural for SUCs to engage in basic research is that, by their very nature as academic institutions, their faculty members, as compared to industry personnel, have wider latitude of academic and individual intellectual freedom, which is essential to the discovery of new knowledge, a process that could challenge existing beliefs and practices.

The above calculus implies that, private HEIs, by their very nature, can justify investments only for R&D projects with relatively very short pay-off periods. Although they also foster academic freedom private HEIs are nonetheless subject to commercial pressure. They cannot deploy much resources towards R&D and should thus concentrate on the development end of the R&D spectrum, and leave basic and much of applied research to the SUCs. Nonetheless the acceptable pay-off periods for R&D investments for private HEIs may in fact not be much different from that of private firms so that the areas for collaborative R&D, on the "D" end, should be considerable.

Of US experience on government R&D institutions, Reference 4 has this to say, "*Much of the scientific research done by Government agencies is intermediate in character between the two types of work commonly referred to as basic and applied research. Almost all Government scientific work has ultimate practical objectives but, in many fields of broad national concern, it commonly involves long-term investigation of a fundamental nature. Generally speaking, the scientific agencies of Government are not so concerned with immediate practical objectives as are the laboratories of industry nor, on the other hand, are they as free to explore any natural phenomena without regard to possible economic applications as are the educational and private research*

Assuming that pay-off periods are the same as those determined by Thurow [5] for the US, the pay-off periods where collaborative R&D are logical would be the areas of overlap shown in the Figure 1 below:

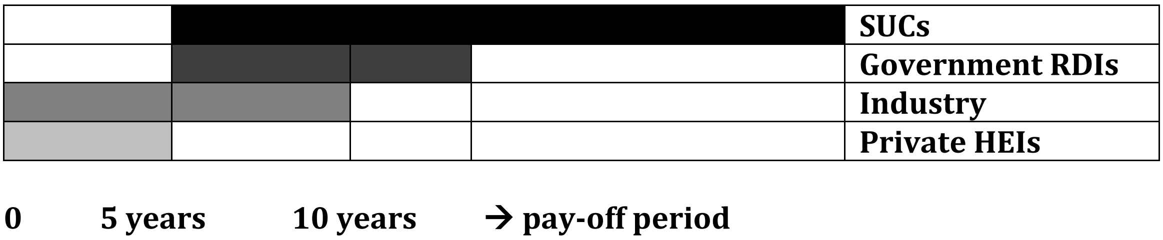

Figure 1. Areas of Collaborative R&D Defined by R&D Pay-Off Periods

That SUCs and government RDIs should not touch the less-than-5-years payoff period should be a matter of public policy. Why deploy public resources to areas that can supposedly easily get private funding?

The above should not mean that SUCs cannot take on short-term research commissioned by industry nor technology business incubation. Given the present paucity of resources, the SUCs should engage in these forms of technology commercialization activities to augment their revenues.

The above should not also mean that private HEIs should be restricted to the less-than-5-years period for collaborative research. In fact, they cannot be. If they so choose they can engage in the longer pay-off period areas although it probably will not make business sense to them in most cases.

The interaction between government and the university may be noted. Salvacion in Annex D states that until the 1990's Korean industry preferred working with government RDIs rather than universities. He also states that in China in the 1950's both academe and industry did not do any R&D, which was the exclusive province of RDIs under the central guidance of the China Academy of Sciences. At present the Chinese universities are considered to be the main institutions for the generation and application of knowledge. In the Philippines, there are calls for government to just become R&D funding institutions and not be competitors of HEIs in R&D projects.

The Research University

The WEF Global Competitiveness Report of 2012-2013 [1] categorizes the Philippines as being in transition from the factor-driven stage of competitiveness to the efficiency-driven stage (investment-driven stage, in Michael Porter's [35] terminology). The country's ultimate goal should be to reach the innovation-driven stage. To reach that goal, among the items that it has to do is to vastly improve its R&D innovation system, in which it is currently ranked 94th in a field of 144 economies. [1] See Table 8 below.

Table 8. WEF Ranking for R&D innovation [1] (Field of 144 economies)

2012-2013 World Competitiveness Indicators for R&D Innovation	Chin	Indo	Mal	Phl	Sing	Thai	Viet
Capacity for Innovation	23	30	17	86	20	79	78
Quality of Scientific Research Institutions	44	56	28	102	12	68	87
Government Procurement of Advanced Tech Products	16	29	4	107	2	98	39
University-Industry Collaboration in R&D	35	40	18	79	5	46	97
Availability of Engineers and Scientists	46	51	20	91	13	57	70
Patent applications/millions population	38	101	34	83	13	72	97

Does a country need to develop basic research capabilities if it wants to eventually join the ranks of innovation-driven economies or is there an alternative path?

Thurow states that there is reason why countries may just want to get a free ride on the results of the basic science done by other countries. He observes, *"Knowledge is slippery stuff. Studies show that research done in other countries or in other companies is about half as productive as research done for oneself. That is a tremendous loss for those who are pioneers and a tremendous incentive for many to be free riders, invest little in R&D, and simply use what has been invented. If a lot of knowledge is lost, those paying to develop that new knowledge cannot get the full benefits when they sell their knowledge – either directly as patent rights or indirectly as products – and they quit paying... Those thinking about investing in research and development have an incentive to wait and see what they can get for free – skip the risky phases of investment and jump in when the development path is clear."* [5]

Bush himself acknowledges that even the United States rode on European scientific capital before the Second World War, "*In the nineteenth century, Yankee mechanical ingenuity, building largely upon the basic discoveries of European scientists, could greatly advance the technical arts*." [4]

"To free-ride or not to free-ride?", that is the question.

Porter states that in the investment-driven stage, *"firms...compete in the relatively standardized, price-sensitive segments of the market, and product designs often reflect foreign market needs. Product designs are at least* ***one generation behind*** *the world's most advanced ones. Process technologies are near the state of the art but do not advance it....*" In the next stage, innovation-driven stage, "*... firms not only appropriate and improve technology and methods from other nations but* ***create*** *them. A nation's indigenous firms push the state of the art in product and process technology...*" [35]

In less modern but no-less-forceful language, Bush argues for the development of basic research capabilities for the US right after World War II thus, *" ... A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill. ...*" [4]

This author agrees that if one were to depend on the scientific capital of other countries, one would always be a step behind. The answer to the question, "To free-ride or not?", simply depends the level of our curiosity as a people, our appetite for competition, and our national ambitions.

If the answer is not to free-ride, then we must develop credible basic research capabilities and, based on the above R&D investment calculus, to let such capability reside in some of our SUCs, which would then be considered what in international academic circles would be called "research universities."

Box 11. FUNDING FOR RESEARCH UNIVERSITIES

"Research universities, with few exceptions, are government-funded public institutions. Only in the United States and to some extent Japan do private research universities exist...Tuition-dependent private institutions can seldom fund expensive research universities..." [36]

In the United Sates, around 150 out of more than 3,000 institutions are research universities. They are awarded 80% of competitive government research funds. The UK and Japan have about 20 research universities each. China is aiming to establish more than 20. Brazil has fewer than 6. [36]

The creation of research universities is an expensive proposition. Prioritization of resources would be necessary for developing countries. The World Bank came to the conclusion that, "*The creation of a differentiated academic system is ... a prerequisite for research universities and is a necessity for developing countries.*" [37]

CHED's current efforts at implementing a typology of schools will lead to a new way of differentiating Philippine HEIs. With the proper typing of schools and the incentives for them to be excellent within their type, CHED could more rationally deploy government resources. It should provide an actively supportive environment in which internationally competitive research universities could be arise and flourish. Such universities should ultimately not only look at Philippine-based companies but also foreign-based companies as possible R&D collaborators. Such cross-border collaboration is in the realm of experience. Branscomb, for example, mentions that Japanese companies go to US universities for collaborative research. [21]

RECOMMENDATIONS

"---Enterprise for the Filipino is a small stall: the sari-sari. Industry and production for the Filipino are the small immediate scratchings of each day: isang kahig, isang tuka. And commerce for the Filipino is the very smallest degree of retail: the tingi...."

-Nick Joaquin [38]

The recommendations discussed below support portions of the Philippine Development Plan (PDP) 2011-2016. For easy reference, boxes quoting relevant portions of the PDP are interspersed within the text.

The first two recommendations are meant to assure the flow of knowledge and scientific talent from academe to industry in sufficient volume. The first is meant to build the capacity to create a bank of scientific capital as a resource that can spell competitive edge for the country. The second is meant to build a sufficiently large pool of high-level scientific talent to capacitate both academe and industry so that they can productively do R&D work on their own and in collaboration with each other. The second recommendation supports the first.

RECOMMENDATION No. 1: <u>Build a number of research universities from among the existing SUCs.</u>

- **Employ the framework of CHED's current initiative on typology and amalgamation of SUCs**
- **Harmonize with the development of industry clusters**

There can be no substantial collaborative R&D between industry and academe without substantial R&D capability in the school system. Such R&D capability cannot be built mainly out of income from collaborative activities with industry, which, in the first place, is hesitant to work with academe because of the perceived lack of capability in the schools. The vicious circle has to be broken. The government will have to invest heavily in R&D capacity-building in schools. Like other countries it should marshal and deploy massive resources to build basic research capability, from whence the basic science comes for applied research and development. As explained in the body of this study, the public universities, the SUCs, are the logical vehicles for such a long-pay-off-period investment. Such basic research capability will translate into serious capability for industry-academe collaborative work in applied research and development. Eventually these SUCs should be capable of basic

Box 12. ADVANCING THROUGH SCIENCE, TECHNOLOGY AND INNOVATION (STI)

PDP 2011-2016 [39]

A "whole-of-government" approach will be pursued to achieve competitiveness. Thus, the government will strengthen vital factors that highly contribute to the advancement, distinction, satisfaction and demands in the domestic and international markets "Science, Technology and Innovation" (STI), and "Quality".

The government shall continue to implement the national innovation strategy called Filipinnovation. This will enable the country to achieve

(a) a competitive and multidisciplinary work force competent in producing value-added knowledge-based services of global standards;

(b) competitive local firms driven by or borne out of constant innovations brought about by increased R&D; and

(c) a public policy environment that ensures continuous innovation not only through executive, legislative and judicial initiatives but through local government programs.

It will promote the usage of Information and Communications Technology (ICT) in enterprises. Filipinnovation focuses on:

(a) strengthening human capital investments for STI;

(b) stimulating STI;

(c) enhancing management of the STI system; and

(d) upgrading the Filipino mindset in S&T.

Since the strategy/policy imperatives are interconnected, it shall be coordinated and harmonized to create necessary conditions to deepen and consolidate STI capacity.

STI, a crucial factor for productivity, competitiveness, job creation, sustainable development and poverty alleviation will also pursue R&D initiatives:

Address opportunities for STI professionals;

Address structural gaps in the STI and R&D sectors such as inefficiencies in the structure of incentives and allocation of R&D resources that are obstacles to new programs and activities which could help attain STI and R&D goals;

Facilitate new STI policies needed to boost productivity, economic growth and job creation through increased knowledge-intensive economic activities while maintaining social cohesion;

Foster tie-ups between industry and the higher education institutions to strengthen the effective transfer of appropriate technology and advanced skills needed by the industry and for the production of higher value goods and services;

Facilitate and utilize sufficient information on the scientific and technological experiences and know-how of other countries;

Establish e-centers to enhance access to knowledge and technology, particularly in rural and remote areas;

Box 13. CLUSTER DEVELOPMENT

PDP 2011-2016 [39]

In developing identified industries, government shall pursue an industry cluster program to foster inter-enterprise linkages among MSMEs and strengthen collaborative networks.

Industry Clusters are geographic concentrations of competing, collaborating and interdependent businesses, working on a similar regional infrastructure and creating wealth of regions through exports. It fosters the transfer and adoption of new technologies, creates risk capital, and attracts foreign investment

It breaks down organizational, geographical and sector boundaries, all needed for creating a cycle of sustainable economic growth. The industry clustering strategy is vital for linking manufacturing with other sectors (e.g. mining, agriculture, tourism, construction, etc.), particularly as these affect raw material needs of manufacturing and the manufactured-product requirements of other sectors.

Industry clusters provide benefits such as:

Maximizes capacity through shared hard and soft infrastructure, human resources, R&D and safety standards;

Provides access to all players, attracting expertise and local suppliers;

Ensures that top export products or revenue streams are sustained through the development of its value chains down to the provinces and municipalities;

Offers a focus to attract new investments, encourage local expansion and stimulate start-up of new companies;

Promotes horizontal collaboration and strategic partnership;

Enhances productivity by providing firms access to specialized inputs and skills, as well as unique information, knowledge and technology; and

For IT-enabled clusters such as technology business incubators, technology parks and clusters of knowledge-based industries, the creation of shared infrastructure and the provision of business support services for innovators and developing entrepreneurs shall be promoted. The establishment of technology business incubators across the country will be pursued, taking into consideration commercial sustainability, careful matching of target markets with the strengths and ambitions of potential firms, and proximity and linkages to research institutes and universities. The provision of business support services shall be private sector-led and demand- driven. The clustering of knowledge-based industries through science and technology parks shall be stimulated research of a level that can compete globally for collaborative R&D projects and of a scale that will satisfy national requirements for competitiveness, productivity, and poverty alleviation.

Eventually all other HEIs, public and private, should benefit by way of faculty development and collaborative activities with these research universities.

The new CHED typology and amalgamation initiative can provide a framework for this purpose. The areas for basic research of the universities can be based on the cluster development program under the PDP 2011-2016.

There are already Philippine universities that are poised to become research universities. However, gauging from data from world university ranking studies, the road is still long and arduous.

RECOMMENDATION No. 2: Scale up the government programs of developing and harnessing S&T manpower by at least an order of magnitude

- **Implement a massive PhD scholarship program; include technology commercialization considerations in the planning of the thesis/dissertation of the scholars**
- **Strengthen the three national systems of science high schools and the city/municipal science high schools**
- **Funnel and shepherd selected graduates of the three national science high school systems and the city/municipal science high schools through college and graduate school by special arrangements with public and private HEIs. Should the total capacity of existing public and private HEIs prove inadequate, establish a university of science and technology**
- **Increase the benefits of the Scientific Career System to match the stringent requirements**
- **Reactivate the Science and Technology Human Development Council and administer all of the above through said Council**

The most important element in building R&D capability is human resource. It has been shown in the body of this report that by adding 2,600 RSEs every year, the country can reach the UNESCO benchmark in 10 years. A good proportion of these should be PhD graduates. Since there are not enough PhD programs in science and engineering in local colleges and universities, the government will have to send scholars to schools abroad. The dependence should decline over the years as the PhD graduates join local schools in delivering PhD programs.

After a selection process, the streams of graduates from the three national systems of science high schools, numbering 12,700 every year, should be funneled and shepherded through college and graduate school. Capable graduates of the city/municipal science high schools, private science high schools and other high schools can be added to the cohort. Special academic arrangements with select SUCs and private HEIs must be made and, if the total capacity of existing public and private HEIs is found to be inadequate, a university of science and technology should be established. The huge number of students in the existing science high school systems is an argument for the strengthening of the science high school systems as an already existing means for the marshaling of young scientific talents.

Needless to say, such an S&T manpower-building program must be underpinned by an overall socio-economic development plan. Among other things, it must in the end make both academe and industry globally competitive in R&D work and technology commercialization to attain the objectives of greater productivity, enhanced competitiveness and poverty alleviation.

Box 14. TALENT POOL OF MS AND PhD DEGREE HOLDERS

PDP 2011-2016

"...*To show the reliability of Philippine electronics and increase exports, country image branding and investment are significant. Likewise, this would entail aggressive promotion by: targeting emerging markets; conduct of high-level investment missions; integration of the electronics industry; establishment of human competencies throughout the value chain such* ***as continuously growing talent pools in MS and PhD levels as long term strategy****; and attract new players in potentially competitive sub-industries such as solar cells, growing capacity in IC design and the country's collaboration with Taiwan*...." [39]

The lateral entry into the talent pool of Fil-Am RSEs who will relocate back to the Philippines will be helpful but cannot be expected to produce the same impact as it did in India, Taiwan or Korea. There are simply much fewer Fil-Am scientists and engineers and a critical mass cannot be achieved. There are, for example, comparatively very few Fil-Ams who have reached the top technical and management position in Silicon Valley, unlike the Indians and the Chinese. [40] The Indians in Silicon valley returned home to Bangalore, with their expertise and, just as importantly, their American business connections, to successfully put up India's version of a Silicon Valley. Recruiting foreigners, as Singapore does, is a possibility, but an expensive one. In our case, therefore, we have to basically pull ourselves up by our bootstraps with home-grown talent.

RECOMMENDATION NO. 3: Provide incentives to firms that engage academe in R&D work

- **Give incentives to domestic firms that partner with academe in collaborative R&D**
- **Give additional incentives to R&D-registered PEZA locators that partner with academe in collaborative R&D**

It is mentioned in the body of this study that SMEs would rather commission academe to do research, than license university-generated technology, in order that they can own the intellectual property arising from the research.

The body of this study also showed also that it is in the areas of training and technical support and advice where SMEs consider government support to be most important and they do not at all consider government support for R&D important! It is the micro and large industries that consider support for R&D as important. The apparent reason is the low capacity of the SMEs for R&D. Even in other Asian countries, with the exception of Japan and Korea, there is a lack of companies that have the capabilities to commercialize upstream technologies from the universities. [2] This is why, on the other side, schools, noting the low absorptive capacity of SMEs, prefer to create spin-offs instead. But even spin-offs may encounter the lack of "*sophisticated lead-users in the domestic economy as customers*." [2]

Obviously, the first thing that ought to be done is to capacitate SMEs. The massive scholarship program of Recommendation No. 2 can support this. An incentive system for commissioned research, as a preference of SMEs, and for collaborative R&D should also be put in place.

Box 15. THE LOW PRODUCTIVITY OF MSMEs

The low productivity of MSMEs can be attributed to the sector's lack of access to new technology, weak technological capabilities, and its failure to engage in innovation and research and development (R&D) activities. The result is wasteful duplication and nonoptimal use of limited resources. Furthermore, lack of awareness for science and technology (S&T) and scarcity of S&T human resources are limits to production optimization. [39]

BOI considers R & D activities in PEZA zones as a priority program and that fiscal and non-fiscal incentives are offered to those foreign companies that practice such activities. As shown in the body of this report from 1978 to 2012 the BOI registered a total of 23 projects with a total value of PhP 820 M.

A reason why there are very few registered projects is that the DTI-BOI only offers incentives to income generating activities and that only a few of the companies register their R&D activities as such. Furthermore, many companies consider their current R&D activities as in-house and do not register or declare them as a separate activity. [35]

Recommendations 1 and 2 are complemented by Recommendation 3. The greater investment in universities in R&D capacity building, which will eventually lead to heightened technology commercialization activities, is matched by greater absorptive capacity of industry. Incentives for commissioned and collaborative R&D will stimulate the interaction between industry and academe. What remains, for the other forms of technology commercialization, will be to provide other support systems such as venture capital and the facilitation, by way of reduction of cost of regulation, of the formation of spin-off companies.

RECOMMENDATION No. 4: Change regulations that stymie R&D activities

- **Allow the appointment of foreigners as full-time professors in SUCs**

- **Facilitate procurement of scientific equipment to be used for R&D**

- **Remove taxes on donation of equipment from PEZA locators**

While the legal environment provided by government is in general enabling as explained in the body of this report, certain government regulations could discourage, hinder or even stymie R&D activities.

The appointment of foreigners as full-time professors in SUCs as regular employees will help upgrade R&D capabilities. This has not been allowed because professors of SUCs are considered as government employees and, therefore, have to be Filipino citizens. This prevents the hiring of the best talents in the world, regardless of citizenship, into Philippine SUCs. At best they can be given part-time positions and visiting professorships. [41]

RECOMMENDATION No. 5: Place bets

- **An initial, tentative recommendation: Concentrate on software engineering, agriculture and fisheries, manufacturing, climate change and the environment (including renewable energy), the internet-of-things and bio-engineering**

- **Let the National Academy of Science and Technology (NAST) take the lead in determining the priority areas.**

Given limited resources, the country must place bets in funding R&D in the different areas of science and technology. In addition, the funding mix among basic research, applied research and development must be calibrated.

The first question to be answered is how the priority areas should be chosen. Should it be based on the magnitude of resource requirements with "less" being better? In this case, IT would fit the bill. Should it be based on the share of sectors in the GDP or on levels of investments in the sector? Service sector-related research would then be favored. Should it be a bet based on a race against other countries towards the future? Biological engineering would be the wave of the future. Or should all criteria be used? In any case, there has to be a way of doing a cost-benefit analysis over an extended period for the various technologies and their combinations.

Box 16. PLACING BETS

"An economy as big as the United States can afford to place reasonable bets in all areas where it looks as if technology can be pushed forward. In contrast, a country as small as Israel cannot. The U.S. research and development budget is three times the entire GDP of Israel. Israel has to focus, concentrate its money, and place its bets on very limited number of technologies if it is to spend enough money on any one technology to have any chance of success. If it spends very small sums in all areas, it will end up wasting all of its resources. But if it must focus its bets, in what areas should it focus? No one knows. Since small countries and companies have to bet in what is an intrinsically riskier, more uncertain environment, they not surprisingly tend to bet less.

Within Western Europe, a lot of money is wasted by countries betting small amounts on different technologies but not betting enough on any one technology to make a difference. If the European Economic Community could pool its research and development spending, there is every reason to believe that the payoffs could be substantially enhanced for everyone ... R&D spending in an integrated Europe ought to be more productive than the same R&D spending in individual countries." [5]

Information technology, specifically software engineering, needs little physical resources. Furthermore, it enables the existence of our BPO sector. It can help secure our dominance with the development of high-level proprietary technologies that can make for superior outsourced services.

Agriculture and fisheries should continue to be supported as they relate to food security and livelihood for the majority of the population. Competitiveness in world trade in these areas, borne of increased productivity, should also be considered.

Box 17. AGRICULTURE AND FISHERIES

PDP 2011-2016 [39]

A Competitive & Sustainable Agriculture & Fisheries Sector

Strengthen Research, Development and Extension (RD&E):

Update databases and information systems for the formulation of a reliable and responsive National RD&E agenda;

Increase investments in integrated RD&E programs that promote productivity enhancement, develop environment-friendly and efficient technologies throughout the value chain, in partnership with selected higher education institutions, LGUs, private and business sector;

Harmonize all agricultural and fisheries mechanization programs and projects of all concerned national government agencies, LGUs, and higher education institutions;

Rationalize and strengthen the extension system to improve complementation of national, local and private sector entities along the value chain in the provision of extension services;

Expand and sustain the sector's human resource base; and

Encourage the participation of farmers, fisherfolk and their organizations in research and promotion activities;

For industry, R&D in manufacturing, including the semiconductor sector, may be necessary to help reverse what some have observed to be a decline in the sector and to support inclusive growth.

Box 18. MANUFACTURING

"*Among private business firms, (R&D) spending differences are also large. In the United States, manufacturing firms contribute 81 percent of total private R&D spending. Most firms outside of manufacturing spend almost nothing on R&D. The need to maintain an R&D base is in fact one of the principal reasons for a country to worry about losing its manufacturing base. The reason manufacturing does most of the R&D spending is that historically it has been impossible to make money on innovations unless one made and sold the products that were the fruits of that new knowledge. Selling knowledge so that others could make the products that came from it has never been a profitable strategy*." [5]

Thematic areas like climate change and the environment, including renewable energy, make good social and business sense.

The internet-of-things (smart grid, intelligent cities, other smart technologies) and bio-engineering (including biomedical) are among the waves of the 21st century.

Panels can be created to deal with this issue under the guidance of the National Academy of Science and Technology (NAST)

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ANNEX A

INDUSTRY-ACADEME COLLABORATION FOR RESEARCH: The MSU-IIT Experience

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Introduction

The Mindanao State University-Iligan Institute of Technology **(**MSU-IIT**)** is an external unit and one of the ten campuses of the Mindanao State University System. Established on July 12, 1968 as provided for by **Republic Act (RA) 5363**, the institute has continually provided quality education to thousands of students from almost everywhere in the Philippines. MSU-IIT envisions itself as *a world-class institution of higher learning renowned for its excellence in science and technology and for its commitment to the holistic development of the individual and society (www.msuiit.edu.ph/about/index.php).*

To live with its commitment, MSU-IIT offers its students a wide array of more than *115 academic programs*, which include *43 graduate programs* in a variety of fields including education, business, arts and humanities, engineering, information technology, the natural sciences, and mathematics. Students are given opportunities to collaborate with more than 400 distinguished full-time faculty members passionate about teaching, research, extension, and community development. The current (2012) student population of MSU-IIT is around 12,000.

MSU-IIT is also known as the Information and Communication Technology Learning Hub for Northern Mindanao and the Virtual Center for Technology Innovation - Microelectronics based on the standards of the Department of Science and Technology (DOST).

Many believed that MSU-IIT has achieved this far because of the powerful combination of big-university opportunities and a friendly, small-community campus setting. It is a public, non-residential, mid-sized, comprehensive university with a special emphasis on *science and technology* located in downtown Iligan City, Philippines - a small, safe, and vibrant city that is a regional hub of culture and commerce. Students not only enjoy an intensely personalized academic experience but also participate in an extensive array of extracurricular activities that include more than *60 student organizations* and a highly successful internationally-respected music and performing arts program. Not surprisingly, MSU-IIT graduates become well-rounded leaders in every field one can think of.

Undergraduate programs are offered under the following academic cost centers:

1. College of Arts and Social Sciences
2. College of Business Administration and Accountancy
3. College of Education
4. College of Engineering
5. College of Science and Mathematics
6. School of Computer Studies
7. School of Engineering Technology
8. College of Nursing

Except for the College of Nursing and School of Engineering Technology, all academic cost centers are offering graduate programs. With this focus on graduate programs, research has become a very important component in the learning processes. In both the College of Engineering and College of Science and Mathematics, graduate students enjoy the support of various scholarships like the Engineering Research and Development for Technology (ERDT) and the National Science Consortium (NSC) where research grants are part of the whole scholarship package. There are also a good number of CHED scholars with similar research support. However, to be significant to society and being able to contribute to economic advancement, research outputs should find their way to industry applications and commercialization.

Recent development has put more pressure on the institution to really work extra hard in the area of research and industry collaboration. The MSU-IIT has just recently been accepted as member of the ASEAN University Network/Southeast Asian Engineering Education Network (AUN/SEED-Net). As new member institution (MI) MSU-IIT has to collaborate with 25 other MIs in the region and with 14 Japanese Supporting Universities in research and human resource development. In addition, MSU-IIT's membership with the phase III of AUN/SEED-Net demands active participation and involvement in the advancement and globalization of the industry in the ASEAN region through promotion of university-industry collaborative activities.

MSU-IIT in its present state is committed to the advancement of industry-academe collaboration.

Industry-Academe Collaborations in MSU-IIT:

A survey questionnaire was distributed to the different academic cost centers to identify the different agencies by which they have collaborative activities (see Appendix A.). There were 13 respondents from different academic cost centers. The answers were summarized in Table 1. As shown, the most common activities by which MSU-IIT engages with the industries are: On-the-Job-Trainings (OJT) and plant visits. Most of the research collaborations with industry were done by the College of Engineering. Although most of these are covered by MOA, no specific IP provisions are incorporated in it except for non-disclosure of results/data as required by most industry partners. In the case of PHINMA (Bacnotan Steel Corp.), MOA specified that IP belonged to them and disclosure of results like publications needed their permission. However, there were few instances that informal engagements with industry in research were done. An example was the case of Mr. Roberto Sala, a Doctor of Engineering student who worked his dissertation at the Philippine International Development, Inc., in Zamboanga City. A company insider was made an external panel member. The company shouldered all the costs, and MSU-IIT through Mr Sala, was able to solve the pestering problem of coal dust fumes emitted during boiler firing. No MOA was signed for the particular engagement. Dr. Roberto Sala earned his doctoral degree.

Table 1. Entities with which MSU-IIT has active partnership.

Agency	Nature of Collaboration	With MOA? (Y/N)
LGUs	OJT, Extension Services	Y
GOs	OJT, Tours and Visits	50% Y
NGOs	OJT	60% Y
Hospitals	OJT, Extension Services, Tours and Visits	Y
Hotels	OJT, tours and visits	Y
Industries	OJT, Tours and Visits, Scholarships, Research	90% Y

*3 listed LGUs, 7 GOs, 8 NGOs, 4 hospitals, 11 Hotels, and 58 industries

Factors that Enable and Hinder Collaborative Research with Industry

The following are considered enabling factors:

a. Agreements like MOA, MOU, etc
b. Provision of enough research budget
c. Acquisition of relevant research equipment
d. Faculty development
e. Graduate programs

The following are considered hindering factors:

a. Difference in research goals between academe and industry
b. IP ownership
c. Issues on trust and interest in the research topic
d. Inadequate funds
e. In the case of research funds given as trust funds to the institute, government procurement and auditing rules are beyond the comforts of the researcher
f. For multinational companies, R&D are usually done and are provided by their mother companies, and hence, they are not too willing to engage with the local universities

Recommendations to Enhance and Foster Strong Industry-Academe Research Collaboration

1. Universities should provide faculty researchers with incentives to attract them to do research
2. Faculty immersion in industries
3. Professorial chairs offered by industries
4. For state universities, government should pour in more money to enhance research capability and faculty development, provide more faculty items to reduce their teaching loads in order to give them more time for research,
5. Interventions to develop the culture of research in both academe and industry
6. Industry should allocate a portion of their income for research, like the concept of social responsibility budget, and be used for research even in areas different from industry interest.

CONCLUSION

Industry-academe collaboration in the country is still wanting. Industries are always focused in their own research agenda and interests which oftentimes are not compatible with that of the academic. Some industries though are open to funding research but they can not commit large budget in a not so sure investment. Academics on the other hand, cannot deliver quick solutions to company problems. Academics have credibility problem, we still need to show them that we are capable and can deliver. The government should come in and provide an environment conducive for industry-academe partnership in the area of research. Requiring industries to set aside a research fund with a corresponding tax incentive is not a bad idea.

ACKNOWLEDGEMENT

The author is thankful to all Deans and Department Heads of MSU-IIT who responded and provided answers to the questionnaire despite the very short time given.

Appendix A. Survey Questionaire

Name;_____________________
Office/Department/College:_______________
Position:___________________________

Industry-Academe Collaborative Activities in the Office/Department/College:
Name of Industry Nature of Collaboration Inclusive Period With MOA?(Y/N)

Kindly answer the following questions and feel free to use other sheets:

1. What do you consider to be the enabling and hindering factors for industry-academe collaboration in research in MSU-IIT?
2. The IP provisions in the contracts, if any; and
3. What do you think are the specific measures that government, academe and the industry can undertake to improve research outputs through academe-industry collaboration?

Thank you very much.

FB Alagao, Ph.D.

ANNEX B

INDUSTRY-ACADEME COLLABORATION FOR RESEARCH: THE CLSU EXPERIENCE

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INTRODUCTION

The importance of research in higher education is widely recognized. It plays a vital role in expanding the frontiers of knowledge. Higher educational institutions such as the Central Luzon State University (CLSU) should be at the forefront in the continuing search and utilization of information especially those that contribute to the solution of society's everyday problems. The ultimate measure of the credibility of an institution of higher learning is based not only on the quality of its curricular programs but also on its vital contribution to the advancement of science and technology, its discoveries, research breakthroughs, and patented inventions. Hence, tertiary institutions are schools of education and schools of research.

At CLSU, research is given further impetus through one of its major goals, Discovery of Knowledge, as embodied in its University Strategic Plan. In its expanded form, this goal envisions CLSU "to lead in the pursuit of knowledge not only in the established areas of inquiry but also in the rapidly expanding advanced frontiers of science and technology.." One of the strategies identified under this goal is for the university "to progressively move towards greater emphasis on strategic research for development of new and emerging knowledge".

But just like most if not all state universities and colleges (SUC) in the country, CLSU suffers from the problem of lack of research funding. While CLSU maybe one among a few SUCs with dedicated funds for research out of its institutional budget, the allocation for research activities is greatly supplemented by funds from external sources as well as money generated from its research and development activities.

This report presents CLSU's experiences on its partnership with industry for research. Specifically, a brief history and status on its academe-industry collaboration is presented highlighting the important milestones that have been accomplished. A general profile of its industry partners is described including an enumeration of the type or nature of research activities that have been conducted. The report also identifies the particular intellectual property (IP) provisions that have been agreed between the university and its partners as embodied in the research contract. Another component of this report of is a presentation of the enabling and hindering factors prevailing at CLSU which affect the collaboration; and finally, what can the government, industry and the academe undertake to improve research through academe-industry collaboration.

BRIEF HISTORY AND CURRENT STATUS

Evolution of the University Research Program

Industry collaboration on research at CLSU evolved hand in hand with the growth and development of the university research program as enumerated in the chronology of events presented in Table 1. The official start of research in the university coincided with the creation of the Graduate Research Department in 1950, indicating that research was initiated as a component of the academic and instruction program, in particular, graduate education.

Table 1. Chronology of events and milestones in the growth and development of the CLSU Research Program

1950	:	Official start of research with the creation of the Graduate Research Department
1963	: :	Creation of the Division of Research and Extension First research partnership with the private sector was recorded through a grant of P2,000.00 from the Philippine Association of Flour Millers to conduct wheat research
1967	:	The Research and Extension (R & E) Division was split into separate divisions
1978	: :	The R & E Divisions were transformed into a unified directorate as Research and Development Center (R & DC) CLSU was designated as base and coordinating agency of the Central Luzon Agricultural Resources Research and Development Consortium
1980	:	The R & DC underwent structural change with the creation of three divisions (ATR, RDS, and TDUS)
1987	:	The R & D Center was transformed into a major program known as Research, Extension and Training (RET) headed by a Vice-President.

		Under the RET is the Research Office headed by a Director.
1992	:	Start of recorded research partnership with industry
2007	: : :	The Intellectual Property (IP) Office was established The IP policies and guidelines were approved by the Board of Regents The University Linkage Committee was created to review and evaluate research and other forms of partnerships with the private sector (and government agencies/institutions)
2010	:	A project for the establishment of an Agricultural Food Technology Business Incubator (AFTBI) was implemented with support from PCAARRD-DOST
2011	:	The CLSU AFTBI was institutionalized

It can be noted from the foregoing table that the first research partnership with the private sector was recorded in 1963 through a grant of P2,000.00 from the Philippine Association of Flour Millers to conduct wheat research. However, there are no available data and information on succeeding collaborations with the private sector until 1992 when records were kept more systematically. Although there are no documentary evidences that are available, interviews with concerned researchers with direct knowledge of such activities attest with certainty that there were industry- commissioned researches within this period.

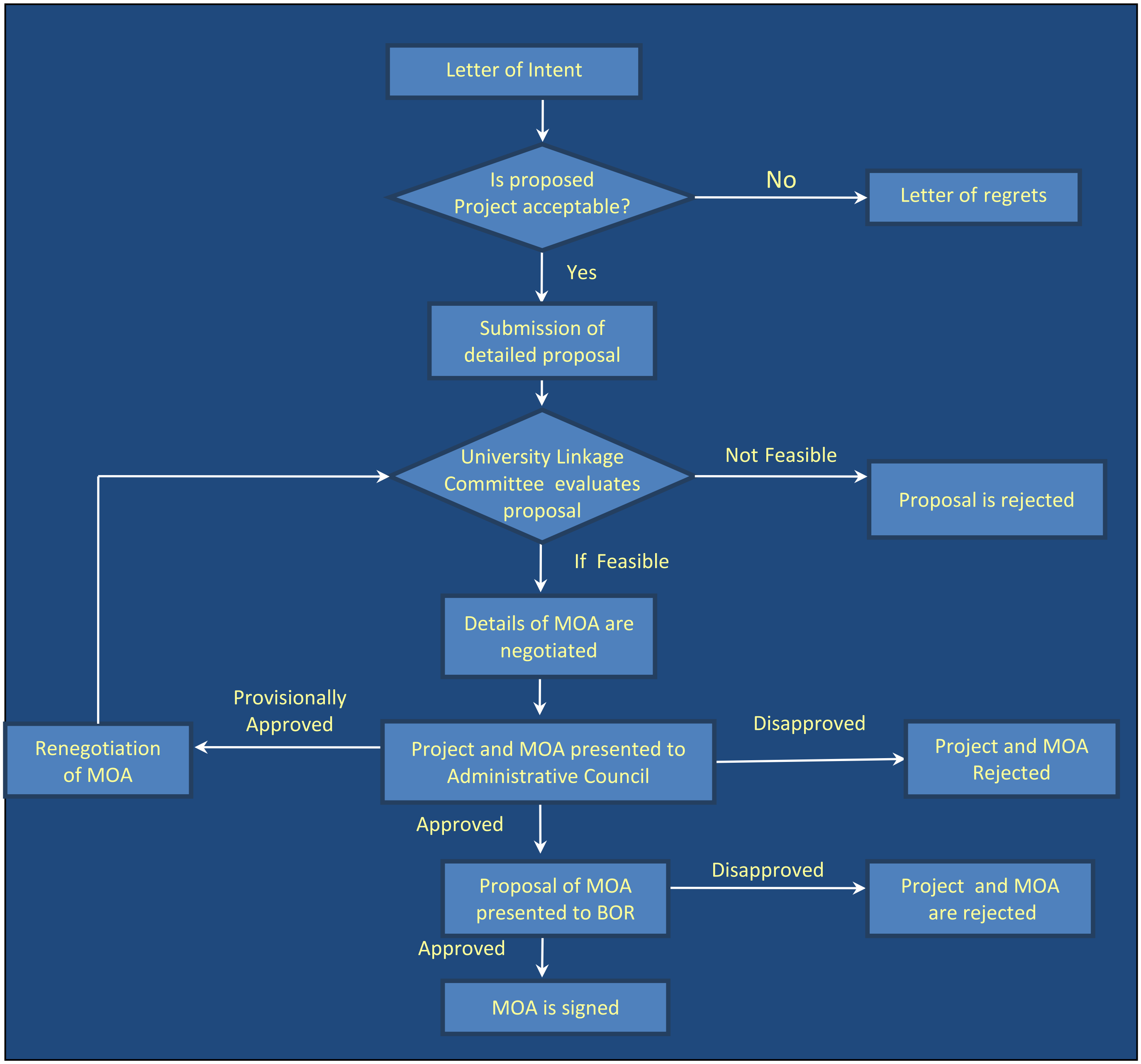
One of the major positive developments favoring university-industry partnership on research was the establishment of the Intellectual Property Office (IPO) in 2007 together with the approval by the CLSU Board of Regents of the university IP policies and guidelines. Because of the growing interest by the private sector to enlist the university's services for commissioned researches, a University Linkage Committee was created to screen, review and evaluate proposals.

In 2010, a project for the establishment of an Agriculture and Food Technology Incubator (AFTBI) was initiated with support from the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) of the Department of Science and Technology. This project was initiated a complement to the research program. It was envisioned to speed up the dissemination and commercialization of products of research by providing technical, financial and marketing assistance to micro, small and medium enterprises to start their businesses using CLSU developed technologies and products. The AFTBI was eventually institutionalized in 2011 becoming an important service platform under the university business affairs program that is closely linked to the IP Office.

Evaluation and Approval of Partnership Projects with the Private Sector

Figure 1 illustrates the process by which collaboration projects with industry are reviewed, evaluated and approved. The process normally starts with a letter intent from a potential industry partner, followed by the submission of a detailed proposal should the project be found to be acceptable. A detailed review and evaluation is then conducted by the Linkage Committee which performs a major and vital role being bestowed with the responsibility of determining whether projects are feasible and consistent with the universities goals and objectives. The Committee is also involved in the initial discussions and negotiations regarding the terms and conditions of the partnership agreements. After the screening and evaluation by the Linkage Committee, proposals are further examined by the Administrative Council which decides if projects are beneficial to the university after which, these are endorsed to the Board of Regents for final approval.

Figure 1. Process Flow in the evaluation and approval of private (industry) and public partnership projects



Industry Partners

Records show that the university had a total of 43 industry research partners with varied business interests. Fourteen (14) or 32.5% are chemical companies, followed by feed companies (8 or 18.5%) and veterinary or pharmaceutical companies (7 or 16.2%). Among the partners were an NGO and an advanced scientific institution (ASI).

The names of the industry partners are shown in Appendix Table 1. The list shows that many of the chemical, feed and veterinary companies are multinational companies engaged in the manufacture of products used in crop, livestock and fish production. The lone ASI is a Norwegian-based company involved in tilapia production specializing in the application of molecular biology tools and techniques.

Table 2. Profile of industry partners

Type of Business	Number	%
Chemical companies	14	32.5
Feed companies	8	18.5
Veterinary/Pharmaceutical companies	7	16.2
Companies with:		
Diversified interests	3	7.0
Specialized interests	5	12.0
NGO	1	2.3
Advanced Scientific Institution (ASI)	1	2.3
Interest Groups/Associations	2	4.6
Foundations	2	4.6
TOTAL	**43**	**100.0**

Type and Nature of Research Activity

Researches commissioned by the industry partners are classified into different types or nature of activities. Product evaluation trials which constitute more than half of the projects (58.2%) are those involving materials that are used in production activities such as pesticides and livestock or fish feeds. Normally, the duration is one production cycle and the data parameters collected are growth rates and yields. In most cases, the experimental protocol is provided by the company. Another type of activity belongs to the efficacy and bioassay tests category which comprised 21.8% of the total projects. These collaborative projects are very similar with product evaluation trials but require more in-depth analysis. Adaptability trials (7.3%) refer to those projects requiring the evaluation of products such as improved or hybrid seeds or improved breeds of livestock. Among the 55 projects were two evaluation trials of prototype models: one trial allowing for modifications in the product design while the other involved a straightforward demonstration project.

Table 3. Number of projects by nature or type of activity

Nature/Type	Number of Projects	%
Product evaluation	32	58.2
Efficacy and bioassay tests	12	21.8
Adaptability trials	4	7.3
Product design, testing and evaluation	1	1.8
Evaluation and demonstration of prototype model	1	1.8
Basic research	5	9.1
TOTAL	**55**	**100.0**

Of special interest are those collaborations involving the conduct of basic researches designed to generate new knowledge. Such activities are conducted through partnerships which are longer term in nature with a reasonable degree of sustainability. (One project was a commissioned research with one-year duration).

However, these activities are presently confined within the units of the university involved in the aquaculture field, in particular, the genetic improvement of tilapias. These projects were initially funded by the government and the public sector (international development agencies) through grants. When this support was terminated, there was a need to generate funds in order to sustain the genetics and breeding work, to continue the conduct of researches, and to retain the trained personnel.

Collaboration with industry partners in this area is well entrenched involving distribution and commercialization of the products of research. In other words, the collaboration has expanded into both a research and business partnership with the latter designed to generate income to fund research and other related activities. These partnership arrangements resulted in the establishment of mechanisms which allowed the generation of funds which are allocated for longer term research activities. Generated funds are in the form of license fees, R&D fees, membership contributions, direct sales (from fingerlings and broodstock), and charges for services. These mechanisms include the organization of a non-stock, non-profit foundation with a legal personality to enter into business arrangements and contracts with private entities; an income-generating project (IGP) with generated revenues managed and administered by the university thorough a trust fund; and a joint venture arrangement where a business entity was created with the university assuming an administrative and oversight responsibility.

The research projects conducted though these partnerships are mainly in the areas of biotechnology, genetics and breeding as shown in Annex Table 2.

Benefits Derived from the Partnerships

There are numerous benefits which are derived from these partnerships. A brief discussion and presentation follows:

Availability of funds for research

One of the major benefits is the generation of research funds. CLSU, just like other state universities and colleges in the country, suffers from the constant problem of fund availability for research. However, with industry participation, funds become available from commissioned researches. Highlighted is the contribution of the private sector in the generation of funds to sustain research in the aquaculture field. Without industry support, the breeding work for tilapia may have stopped and research on tilapia genetics and the application of biotechnology would not have been sustained.

Human resource development

The benefits on human resource development come mainly in the form of: acquisition of knowledge and skills; and travel grants (international and domestic). Industry partners have specialized knowledge and skills which are not possessed by university researchers. Through interaction and direct contact, the expertise is transferred thereby benefitting the university in general. Exposure to international and national meetings, conferences and forums is also a big boost to the morale and confidence of researches made possible through travel support granted by industry partners.

Improvement of research facilities

Most of the partnership arrangements allow the donation by the industry partners of equipment purchased out of the research grants. Moreover, laboratories are upgraded and experimental fields are developed. Support of private sector partners made it possible to initiate modest improvement in research facilities.

Opportunities for students

Significant benefits arising from these partnerships accrue to students in the form of research exposure; thesis support; scholarship grants; industry-related on-the job training experiences; and possibilities for employment in partner companies.

Strengthened linkage with the private sector

In the University Strategic Plan, one of the major goals is Proactive Engagement where more intensive efforts is devoted to engage various sectors of society to advance the mission, goals and objectives of the university. Promoting academe-industry collaboration for research is considered an important strategy to strengthen linkage with the private sector because of the numerous advantages and benefits that the university can derive.

Build-up of institutional credibility and stature

Having successful collaborative research activities with the private sector enhances institutional stature. This builds up a credible tract record and validates the university's capability to deliver successful results inspiring confidence among potential industry partners.

INTELLECTUAL PROPERTY (IP) ARRANGEMENTS

The most important and sensitive aspect concerning research partnership with industry is in the area of intellectual property (IP) issues and concerns. The terms covering this area are specified in the contract as contained in a memorandum of agreement (MOA) signed between the university and the private sector partner.

As shown in Table 4, there are ten (10) specific IP provisions that were identified and contained in the various MOA signed by the university with its private sector partners. Of the ten, exclusive ownership of data by the industry partner and joint publication rights appeared the most frequent at 30.3 and 28.3%, respectively. Guarantee of confidentiality by CLSU was next with 9.1% frequency rate. Use of data and publication rights with permission by CLSU recorded frequency rates of 8.1% while sole publication right by the industry partner with CLSU given credit likewise recorded the same frequency rate. Joint ownership of data appeared in the contracts at a 4.0% rate.

The foregoing IP provisions indicate a significant bias in favor of the industry partners. This is expected considering that the nature of the research partnerships is in the form of commissioned research involving "for profit" activities. Moreover, the dominating objective of the private sector is the promotion of their business interests which comes naturally to them. Be that as it may, there are significant benefits that accrue to the university as discussed in preceding section.

There are two (2) more IP provisions appearing in the contracts which warrant further explanation. One concerns the open access nature of the data and information generated by the joint research activity. This provision appeared in the project with an NGO where the objective of the partnership is to improve the design of a prototype model and promote its adoption by users or consumers. In effect, the collaboration involved the distribution of a product (which assumes the nature of a public good) for the benefit of the general public.

The other provision concerns royalty and income sharing from the sales of genetically improved tilapia fingerlings by accredited hatcheries licensed as producers and distributors. Based on CLSU's experience, this arrangement was problematic because it required accurate monitoring of the volume of sales which was very difficult to implement. Eventually, the royalty payment was replaced by a fixed annual development fee of which a significant portion was allocated to fund research activities.

Table 4. Intellectual Property provisions contained in the partnership agreements

Specific IP Provisions	Frequency	%
Exclusive ownership of data by industry partner	30	30.3
Joint ownership of data	4	4.0
CLSU can use data, with permission	8	8.1
Joint publication rights	28	28.3
Sole publication rights by industry partner, with CLSU given credit	8	8.1
CLSU can publish results, with permission	8	8.1
Guarantee of confidentiality by CLSU	9	9.1
Open access to data and information	1	1.0
Exclusive ownership of trademark and brand name by industry partner	2	2.0
Royalty and income sharing	1	1.0
Total	**99**	**100.0**

ENABLING FACTORS

For academe-industry research collaboration to develop and prosper, CLSU recognized the need to create an enabling environment to insure success and foster partnership growth. These enabling factors are closely intertwined and complementary to each other such that the absence of one makes it difficult for the partnership to be established and operate successfully. The identified enabling factors include the following:

1. Institutional Support
2. Active and credible research program
3. Strong educational and research infrastructure

4. Dedicated research personnel (researchers, administrative and support staff
5. Proper procedural, regulatory and organizational mechanism

HINDERING FACTORS

There are also factors which have been identified as hindering not necessarily the establishment of partnership with the private sector but impede the expansion of such. At CLSU, efforts continue to be exerted to overcome these factors which are as follows:

1. Lack of an effective marketing mechanism to promote institutional research capability
2. Government and institutional regulatory impediments affecting fund disbursements and procurement
3. No specific and clear-cut guidelines under which the institution will collaborate with the private sector
4. Conflict between sharing and protecting, specially regarding equity and access to the research products
5. Limited expertise and capacity for legal arrangements, particularly in the management of IPR

MEASURES TO IMPROVE ACADEME-INDUSTRY PARTNERSHIP IN RESEARCH

Based from our experiences, much remains to be done in order for academe-industry collaboration in research will be developed and improved. There are specific roles that the government, industry and the academe must do or perform to provide a better enabling environment and possibly eliminate the hindering factors.

The following measures are hereby recommended:

For Government:

1. Increase investment in research to enhance the capability of academic institutions

2. Provide a more conducive and better enabling environment to encourage private sector investments in the academe
3. Help universities to establish spin-off companies to commercialize products of research

For Industry:

1. Enlist more academic institutions for commissioned research
2. Include academic research partnership as part of CSR
3. More openness in sharing information, transfer of knowledge/expertise, and benefits

For the Academe:

1. Develop research (and entrepreneurial) culture
2. Strengthen research capability and infrastructure
3. Aggressively search out industry partners (including venture capitalists)
4. Establish IP office and develop IP policies and guidelines (in particular, develop strong IP disclosures, contract arrangements and license agreements)
5. Establish research parks and TBIs

CONCLUSION

Research collaboration with industry has resulted in many significant benefits to CLSU. Foremost of these is a better appreciation of the service component and commercial aspect of conducting research. Specifically, researchers conduct scientific investigations not only for the singular purpose of discovering new knowledge but also mindful of the potential financial rewards arising from their intellectual efforts. As a result, the institutional mechanism has been put in place with the establishment of the Intellectual Property (IP) Office and the crafting of the university IP policies and guidelines to serve as platform for this development.

The research-development-extension-commercialization continuum was found to have been enhanced with academe-industry partnerships. This is vital in sustaining research endeavors through the generation of funds from the business aspect of the research collaboration. Additionally, industry partners play a unique role in the dissemination and uptake of products and technologies developed from research.

There are important lessons that have been learned from CLSU's research partnership with industry. However, much work remains to be done in order to take more advantage of the opportunities and maximize the benefits that academe-industry collaboration for research provides.

Annex 1. List of partner-companies by type/nature of business

I. **Chemical Companies**

1. Aldiz
2. Allied Botanical Corporation
3. BAYER Philippines
4. Biostadt Company
5. Chemical Industries of the Philippines
6. Chemrez Technologies, Inc.
7. Dynafarm
8. Harvenson Enterprises
9. Hexaphil Agriventures, Inc.
10. Jardine Davies
11. Norsk Hydro Philippines, Inc.
12. Ramgo International
13. Khone Poulenc Agrochemicals Philippines Inc.
14. Zetryl

II. **Feed Companies**

15. Adiseeo Asia Pacific Pte. Ltd.
16. CJ Philippines Inc.
17. Diasham Resources Pte. Ltd. thru Agrimate Inc.
18. Delacan Biotechnil
19. Easy Bio Philippines
20. Feedmix Specialist Inc.
21. Nutriquest International
22. Santeh Feeds Corporation

III. Pharmaceutical/Veterinary Companies

23. Univet
24. Robichem
25. Fujisawa Pharmaceutical
26. BAYER (Animal Health)
27. Merial
28. Agresource Inc.
29. SMPTC, TRYCO

IV. Companies with:

Diversified interest

30. Dupont
31. Syngenta Philippines Inc.
32. General Bureau of Land Reclamation, Heilongjiang, PROC.

Specialized interest

33. East-West Seed Company
34. Federation of Handmade Paper Makers and Converters Inc.
35. Longping High-Tech
36. Fishgen Ltd.
37. Suncare Philippines

V. NGO

38. Center for Rice Husk Energy Technology

VI. Advanced Scientific Institution

39. GenoMar As, Norway

VII. Interest Group/Association

40. American Soybean Association - International Marketing
41. Philippine Association of Flour Millers

VIII. Foundation

42. GIFT Foundation International, Inc.
43. LISI Agricultural Foundation, Inc.

Annex 2. List of basic, developmental and applied researches in aquaculture conducted under academe-industry partnerships

1. Genetic improvement of tilapia through DNA marker-assisted selection for improved growth, fillet yield, survival, and other economic traits

2. Gene expression analysis in *Litopenaeus vannamei* and *Oreochromis niloticus* provided acidifier in the diet

3. Influence of varying levels of 17-alpha methyltestorterone in the performance of Nile tilapia (GenoMar strain)

4. The influence of the duration of behavioral stress response on social dominance in Nile tilapia (*Oreochromis niloticus* L.)

5. The influence of social stress on bile retention and gall bladder-live weight index in Nile tilapia (*Oreochromis niloticus* L.)

6. Sex reversal of tilapia using phyto androgen

7. Feminization of genotypically YY-*Oreochromis niloticus* (L.) fry by oral administration of diethylstilbestrol (DES)

8. Fingerling production and sex ration of genetically male tilapia (GMT) from crosses of YY males with different maternal strains

9. Intra-specific predation in genetically male tilapia (*Oreochromis niloticus* L.)

10. Masculinization of genotypically XX-Nile tilapia (*Oreochromis niloticus* L.) by dietary administration of 17α-methyltestosterone in agar-boound feed

11. Influence of varying levels of 17α-methyltestosterone in the performance of Nile tilapia (GenoMar strain)

12. Comparison of generation 10 and 18 GenoMar Supreme Tilapia strain: growth, survival, fillet yield and reproduction

13. Reproductive performance of GenoMar strain of Nile tilapia (*O. niloticus*) with INVE maturation supplement as additive on daily feeds

14. Revolving tilapia grow-out production: a model of best farming practice

15. Breeding of FAC selected tilapia (FaST) using within family selection

ANNEX C

ACADEME-INDUSTRY COLLABORATION:
THE UNIVERSITY OF THE PHILIPPINES LOS BAÑOS EXPERIENCE

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The University of the Philippines (UP) Los Baños has had a long history and tradition of research since 1909 when the College of Agriculture, the first college of UP was established in the town of Los Baños. In 1972, the UP campus at Los Baños was elevated to university status by Presidential Decree No. 58. The technologies that have been released by the original two colleges at UP Los Baños, Agriculture and Forestry, and UPLB to the public are mostly agriculture-based such as improved crop varieties, forestry management technologies, soil management technologies including biofertilizers, soil diagnosis kits, pest management protocols, propagation technologies including tissue culture techniques, poultry and livestock nutrition and management technologies, food processing technologies and the like.

As a National University as declared in Republic Act 9500, the University of the Philippines is tasked to "serve as a research university in various fields of expertise and specialization by conducting basic and applied research and development, and promoting research in various colleges and universities, and contributing to the dissemination and application of knowledge" (UP Charter 2008, RA 9500).

A recent study showed that UPLB satisfies the minimum requirements of being a research university in terms of number of doctoral programs offered (Tecson-Mendoza 2010). However, the profile (number of professors and associate professors), number of faculty, substantial research funds and income from generated technologies, high number and quality of intellectual property and quality publications are the lowest among several universities UPLB was compared with, including Universiti Putra Malaysia which was chosen because of its agricultural background.

There is now increased emphasis on and awareness for UPLB to fulfill its mandate of being a research university. As mentioned above, one criterion — substantial research funds and income from generated technologies, especially the latter, depends a lot on strong academe and industry collaboration.

This paper attempts to analyze the extent of UPLB and industry collaboration in research and factors that contribute to its current state. This paper will cover (a) profile of agencies or institutions that fund researches at UPLB; (b) nature/stage of researches funded by industry; (e) intellectual property provisions in research contracts; (f) problems/hindering and enabling factors; and (e) how these problems or hindering factors have been addressed by the university to improve academe-industry research collaboration.

Profile of Agencies Funding Researches at UPLB

Before the 1960s, the funds for researches at the College of Agriculture (CA) came mostly from the university itself. In the 1960s, the rice breeding program of CA under Dean Dioscoro L. Umali and the rice breeder Dr. Pedro B. Escuro, obtained a grant of P200,000 ($100,000) from the National Rice and Corn Corporation. This represents the first big grant given to the College for research. Thereafter, CA researchers obtained grants from government agencies. When the author joined the Institute of Plant Breeding (IPB) at UPLB in 1976, the research money of IPB came primarily from the budget allocated by government to IPB. However, with increasing activities and the availability of external grants, researchers sought funding from government agencies such as the Department of Agriculture and Department of Science and Technology and those from foreign countries, such as USAID and other US granting institutions (BOSTID, US Science Program, CDR, etc), ACIAR, CIDA, JSPS, JICA, etc.

UPLB received more than PhP 1 billion research grants for the period of 2005-2009 (Table 1) (OVCRE 2010). A review of the list of completed researches from 1992 to 2007 (OVCRE 2010) shows that only six private companies provided grants to UPLB researches through central administration (Table 2). However, many more private companies (48) from industry provided grants through the UPLB Foundation Inc. (UPLB FI) (Table 3). Grants provided by industry ranged from PhP 50,000 to 4 M and totaled PhP 51 M from 2002 to 2011 (Table 4). This represents a small percentage of the total research funds obtained by UPLB (Table 1) and the total research funds channeled through UPLB FI . The choice of the UPLB FI by private companies and other funding agencies as well as administrator of their grants is understandable because of the bureaucracy of the procedures when grants are administered by the UPLB central administration. The number and amount of grants given by private companies have also increased by six-fold from 2002 to 2011 (Table 4).

Table 1. Research funds of UPLB from 2005 to 2009.

	Research funds amount in PHP'000		
Year	**UPLB**	**UPLB FI**	**TOTAL**
2005	45,999	126,049	172,048
2006	36,208	142,485	178,693
2007	52,483	127,830	180,313
2008	65,420	153,635	219,055
2009	100,648	151,094	251,742
	300,758	701,093	1,001,851

Data from: UPLB OVCRE (2010)

Table 2. Funding agencies and institutions that provided grants to UPLB from 1992-2007.

Government agencies/institutions	**International agencies**	**Private sector/Industry**
CHED, CHED ZRZ DA (BAR, BAI, NAFC, BFAR, BPRE FIDA) PhilRice DAR DENR DOST (PAGASA, PCIERD, PCAMRD RRDP-PCARRD, PCARRD [PCARRD-STARRDEC, PCARRD/PARRFI, PCARRD-IFS; PCARRD/ SAPPRAD; PCARRD-AVNET; PCARRD-RRDP; PCARRD- ACIAR; PCARRD-ASSP PCARRD/ ISAAA; PCARRD-Rockefeller Found. Inc.; PCARRD/ ADB/ AVRDC], PCASTRD, NRCP] PCA UPLB Basic Res. Trust Fund Landbank TLRC	Australian Centre for International Agricultural Research (ACIAR)/ SEARCA AVRDC ICRISAT IDRC IAEA WWF CIMMYT/ PCARRD SEAFDEC UNESCO/ TOYOTA USAID/ ICDRP USAID KUL-Belgium IFS	TF-Palico FEACO/MPC/; BMDDC East-West Seed Co., Inc. Marsman-Drysdale LAKPUE Procter and Gamble Distributing Phil. Inc.

Data from: UPLB OVCRE (2010)

Table 3. Private companies which provided funds to UPLB researches through the UPLB Foundation Inc. from 2002 to 2011.

Ayala Property	Terra Concepts	Natural Health Matters
Management Corp.	Crew Minerals Inc.	Vaigu Inc.
Absolut Chemicals Inc., and	Asian Alcohol Corp.	AP Renewables, Inc
Consolidated Distillers of	Chevron Geothermal	Trevenodd Crop.
the Far East Inc.	Philippine Holdings	Grainpro Philippines Inc.
Legaspi Oil Co. Inc.	Monsanto Phil	Trevenodd Corp.
First Philippine	GRANEX Mfg Corp.	International
Conservation Inc.	SUMIFRU Philippines Corp	Pharmaceuticals Inc.
First Generation Holdings	BASF	AgriSpecialist Inc
Corp.	Del Monte Philippines	Green Cross Inc.
OPTA	Monsanto Philippines Inc.	BOSTIK Philippines
Pilipinas Shell Foundation	Pilipinas Shell Foundation	Reckitt Benckiser Singapore
Lactobacillus Pafi Techno	Inc.	PTE
Resources Corp.	Energy Development Corp.	Trevenodd Corp
Tribio Technologies Corp.	Syngenta Crop Protection	Pioneer Overseas Corp./
Pioneer Hi-Bred	AG	LPR Enterprise
International Inc.	Pioneer Hi-bred	ZAGRO Singapore Pte Ltd
Dow AgroSciences LLC	International Inc.	Aurora Pacific Fruits
AGRO K	Energy Development Corp.	MICRO-PLUS Konsente
ANE Agric Corp.	San Migue Yamamura	GmbH
CropLife Phil	Packaging Corp.	Marketpoint Enterprises Inc
Filinvest Land Inc.	Splash Corp.	Henkel Philippines
Grain Pro Inc	Bayer Crop Science.	Herbiotics Inc.
New Guinea Fruit Co.	Clarkchem Inc.	Jollibee Foundation Inc
APT Vet Link	Monde Nissen Corp	Negros Holdings Drydock
LAPUE	Primera Agro Development	Corp.
	Corp.	Pharmaceia Jimenez

Data from: UPLB Foundation Inc. (2012)

Table 4. Summary of research grants to UPLB researches from industry (2002-2011)

			Number of grants				
Year	**Total, PhP**	**Range, PhP**	**<200,000**	**201,000-499,000**	**500,000-999,000**	**1,000,000-1,999,000**	**>2 M**
2011	12,735,169	40000-3,772,000	14	8	2	2	1
2010	7,338,041	97,800-2,520,000	4	3	2	1	1
2009	6,774,269	300,000-2,790,000	0	2	3	0	1
2008	4,767,262	50,000-1,430,000	1	1	1	3	0
2007	6,133,182	450,000-4,123,000	0	3	1	0	1
2006	7,084,772	221,000-3,000,000	0	2	2	0	2
2005	2,196,841	200,000-741,000	1	2	2	0	0
2004	1,052,200	215,000-837,000	0	1	1	0	0
2003	1,106,231	1,106,000	0	0	0	1	0
2002	1,992,812	276,000-1,717,000	0	1	0	1	0
	51,180,779						

Data from: UPLB Foundation Inc. (2012)

Nature and Stages of Researches Funded by Private Institutions

Funding for R & D can be at any of the following points on the R & D process: (a) at the start of the project, fund is given based on scientific merit, importance and potential success of concept; (b) at proof of concept; (c) at stage when technology is near maturity; (d) when technology is fully mature and ready to be commercialized.

Most of the researches funded by private industry sector are applied and are at the end of the research spectrum. Efficacy and toxicity testing of finished products, socio economic studies on impact of products or technologies, and field evaluation of finished products such as insecticides, are some of the researches (Table 5). A few are basic such as developing systems to rejuvenate very old fruit orchards and conducting the terrestrial flora and fauna of selected areas in Oriental Mindoro (Table 5). Several projects were commissioned to UPLB researchers by multinational companies to study effects of genetically modified crops on local nontarget organisms. Several projects required the development of prototypes of dryers and use of distillery effluents as fertilizers.

Many basic researches can be related to industry or have future applications. This is a common way that project leaders justify to funding agencies their basic research proposals. There are also basic researches which do not have any relation to industry or whose application is quite remote. Examples are taxonomic and systematic studies of organisms, gene sequencing and characterization, and the like.

While the number of projects funded by private sector as well as the amount has increased, their relative importance and magnitude pale in comparison with researches funded by government and international funding agencies.

IP Provisions in Contracts

The IP provisions in the contracts between UPLB and industry companies can be described as ranging from strict, medium and liberal or no restrictions. A few examples are given in Table 6. Strict IP provisions include funding agency's sole ownership of data, technology and product resulting from the project, strict confidentiality, use of data by project implementer only with consent from funding agency and will not be for commercial gain. Medium strictness of IP provision entails joint ownership of records and data, joint ownership of project outputs, publications or any discoveries or inventions.

Table 5. Nature of UPLB researches funded by private sector.

Nature/type	Examples	Range of grants (PhP)
1. **Basic research**	studying diversity of non target organisms in regulated field trial sites, developing appropriate nursery and plantation designs, protocols for mass rearing insects, terrestrial flora and faunal inventory of selected areas in Occidental Mindoro	0.3 M to 2.7 M
Applied		
2. Toxicity testing	Chemical pesticides, dermal toxicity of products,	100,000 to 800,000
3. Socio economic studies	Feasibility, socio economic impact of products, socio economic and health survey in geothermal areas, feasibility of dry dock facility in Negros	120,000 to 1.27 M
4. Field evaluation, epidemiology	Insecticides, prevalence of swine disease, monitoring of key non arthropods in transgenic maize,	3.7 M
5. Survey, assessment, planning	Rubber plantation management and tapping on Mt. Makiling, upland agricultural master plan for Casiguran, Aurora, environmental baseline study for a nickel mining project,	0.75 M to 2.5 M
Development		
Product development	Developing a prototype and process for commercial wood plastic composite pallets using rice hull, use of distillery effluent as fertilizer, developing mechanical tray-type dryer, Developing systems to rejuvenate mango orchards.	0.725 M to 1.13 M

Data from: UPLB Foundation Inc. (2012)

Problems or Hindering Factors of Industry-Academe Collaboration in Research at UPLB

1. Bureaucratic processes are just too slow and complex.

a) Slow processing of papers — preparation and signing of contracts, purchase and payment of equipment and supplies, payment of salaries, preparation of financial reports, auditing.
b) Too many signatories on papers; some papers need to go to the Board of Regents for approval.
c) Lack of one office that will take care of most of the needed papers

Table 6. Intellectual property provisions in UPLB research contracts with industry companies.

Strict	Funding agency as sole owner of project's data, technology, product (e.g., Splash, Bayer Crop Science, Monsanto); data from experimental work can be used by UPLB FI through implementing unit for advancement of scientific research with prior written consent from funding agency, will not be used for commercial gain; Strict confidentiality (Syngenta); Funding agency retains exclusive ownership of all rights, title and interest in materials and information provided to UPLB FI through the implementing unit for the purpose of project implementation, the funding agency has the right to use and disclose results for any research or commercial purpose, and notify and assign patents, IPR to funding agency;
Medium	Joint ownership of records and data, results can be published by UPLB FI through the implementing unit in consultation with funding agency; joint ownership of records and data, funding agency has the right to publish results with prior written consent from project leader; data and information cannot be used by third parties without prior consent from both funding agency and project leader; joint ownership of any idea, invention, etc, funding agency has exclusive use worldwide of project invention for three years from project completion, invention cannot be shared with third parties without mutual consent of both parties; joint ownership of all project outputs, publications, discoveries, inventions;
No restrictions	No IPR clause in contract

Data from: UPLB Foundation Inc. (2012)

2. Facilities and utilities may be the best in the country but constantly need upgrading.

In the 1960s, UP College of Agriculture undertook a campus development plan which brought it out of the rubbles of the second world war and pushed it to be the top agricultural school in Asia. Since then, and since it became an autonomous university in

1972, few additional buildings were added, like the Animal Science and Veterinary Medicine complex, the Electrical Engineering building and the new gymnasium. However, UPLB still lacks good research facilities for many of its colleges. There are patches of very good to excellent facilities but only a few. Notably,the Institute of Plant Breeding under the College of Agriculture has very good facilities. BIOTECH Institute recently obtained grants to upgrade its facilities.

Electricity and water are not reliable, especially the voltage of electrical power is fluctuating.

3. Lack of appropriate manpower

In the 1970s, the number of faculty members of UPLB was about 800 for its 3200 students. Now the number of students is about 12,000 and its faculty numbers about 880. While there is a clamor to further increase research activities, the number of faculty and researchers and the expertise needed is wanting.

4. IP issues

Traditionally, technologies and products resulting from UPLB researches had been freely given to the endusers. Crop varieties, livestock and poultry nutrition technologies and management techniques had been freely shared not only with the endusers in the country but in foreign countries as well. Since funding for their researches had come from government, the prevailing belief was that any research product or technology should be given back freely to the people from whose taxes government gets its budget!

There has also been a lack of awareness and appreciation for intellectual property rights and its management by University personnel. Case in point is the mango flowering induction technology invented by Dr. Ramon C. Barba at UP CA. The technology was patented in the Philippines and in the US. However, Dr. Barba nor UP CA did not protect the technology and allowed the free use of the technology by others. No royalties were received by UP or by Dr. Barba for the use of the technology. In another case, after Dr. Barba and his team developed the micropropagation technique for bananas, they immediately conducted a workshop inviting both private and government entities to transfer the technology. The transfer was indeed successful as the technology was used by private sector for the rapid multiplication of banana for the plantations.

Since funding has primarily come from government, the earlier version of the UP IP rules does not provide for exclusivity in contract with private sector for the licensing of its products. This could be a deterrent in private sector’s willingness to provide substantial grants to the university as this lack of exclusivity will not ensure that its investment can be recovered in a reasonable period of time or at all.

5. Lack of rapport between business and academe

It is commonly acknowledged that the academic and business people have different ways of looking at and doing things. This could just be perception but it has prevailed.

Enabling Factors or How Problems Have Been Addressed

Factors that contributed to universities to change their policy from doing pure science to doing science that can produce technologies and income for the university are primarily the dwindling financial support from government for the University's operations and the successful commercialization of technologies emanating from faculty research which brought hundreds of millions of dollars in royalties to the University.

The UP System and constituent universities including UPLB have realized the importance of technology commercialization and have addressed problems or weaknesses that hinder this.

1. **Enabling policies**

    a. Technology Transfer Act of 2009

    The Technology Transfer Act of 2009 (Republic Act No. 10055) "An Act Providing the Framework and Support System for the Ownership, Management, Use, and Commercialization of Intellectual Property Generated from Research and Development funded by Government and For Other Purposes" (Appendix A) was approved in 2009. Its objective is "to promote and facilitate the transfer, dissemination and effective use, management, and commercialization of intellectual property, technology and knowledge, resulting from R &D funded by the government for the benefit of national economy and taxpayers.

    A key provision in this Act for RDI (research and development institutions, including universities) is that the ownership of IPs and IPRs derived from research funded by the government funding agencies (GFAs) shall "in general, be vested in the RDI that actually performed the research," with a few exceptions cited in the Act. Further, the Act provides that all revenues from commercializing IPs and IPRs from R & D funded by GFAs shall be for the credit of the RDI, unless the contract between them has a revenue sharing provision. The sharing of revenues from royalties, upfront fees, sales of IP, licensing etc will be governed by an employer-employee contract, without prejudice to the rights of researchers uneer RA No. 8439 or the "Magna Carta for Scientists, Engineers, Researchers and other S & T Personnel in Government."

    The law which is patterned after the Bayh-Dole Act of the US that has been cited as a positive influence in the commercialization of technologies from researches funded by the US government, is a milestone as it also encourages RDI researchers to pursue commercialization of the IP or IPRs by "creating, owning, controlling, or managing a company or spin-off firm…or accepting employment as an officer, employee, or consultant in a spin-off."

This law is important in promoting and strengthening industry-academe collaboration as it encourages technology commercialization and formation of spin-off companies which necessitate interaction and collaboration with industry.

b. Revised UP System IP Policies 2011

The "Revised Intellectual Property Rights (IPR) Policy of the University of the Philippines System" was approved in 2011 (Appendix B). The revised UPS IP policies cover all types of IPRs recognized by Philippine laws such as the amended Intellectual Property Code, the Plant Variety Protection Act "as well as applicable laws of other states." It also has aligned with the provisions of the Technology Transfer Act of 2009.

Two important provisions of the revised UPS IPR policies are on royalty sharing and exclusivity. On the former, UP will provide 100% of the first PhP200,000 (or less) of the royalty the University receives from commercializing the IP. In addition, the inventor will get at least 40% of the royalty. Of the remainder, the UP system gets 25% of the remaining 60%, and 75% goes to the constituent university to be divided among the CU, the college, the institute/unit, the IP office, as will be decided by the CU constituents and leaders. Sharing of other payments for upfront, milestone and others shall be governed by appropriate agreements covered by the Technology Transfer Act.

On exclusivity, unlike the previous approved IP policies, the 2011 IP policies allow granting exclusive licensing "in some cases, as when significant investments of time and resources are needed to bring the technology to market,". This will provide an incentive to private institutions to bear the risks of further development as in drug development (Article 8, number 5).

2. Addressing slow bureaucratic processes

a. Establishment of the UPLB Foundation Inc.

The UPLB Foundation Inc. started as GIRD (Generator of Integrated Resources Development) Foundation Inc. which was established in May 1977 to institutionalize the service done by UPLB experts in their consultation and expanded to assisting UPLB increase and utilize its resources —human, financial and material, in a more focused thrust in the key programs of UPLB, namely, agriculture, biotechnology, engineering and environmental sciences and other related programs (www.uplbfi.org). In addition to consultancies, UPLB FI has since rendered other services: fund management, conduct of researches, policy studies and surveys, project conceptualization, design and implementation, design and implementation of project benefit, monitoring and evaluation systems, manpower training, statistical design and analysis cum computer applications and electronic data processing. From a small equity of PhP5,500 in 1977, UPLB FI's equity is now worth PhP 375 M. Since 1977, UPLB FI has completed more than 2000 projects. UPLB FI signed a Memorandum of Agreement with UPLB FI which formalises the arrangement and allows the foundation to use the facilities of UPLB and its experts needed by projects. The 1977 MOA has been superseded by a MOA signed in October 2009 by the UP President and the President of UPLBFI.

Because of the relative ease which accompanies official transactions with UPLBFI, many projects have been administered by UPLBFI. As Table 1 shows, from 2005 to 2009, UPLBFI administered research funds totaling PhP 700 M compared with PhP 300 M for central administration. UPLB FI also provides bridging funds of PhP 100,000 to 200,000 to projects whose fund release has been delayed; each request has to be endorsed by the funding agency to ensure that indeed the project fund has been approved.

b. CTTE established in 2007

The Center for Technology Transfer and Entrepreneurship (CTTE) was established in 2007. It is tasked to "integrate all policies, programs and activities for the successful disposition of UPLB technologies to the private and public sectors through technology licensing and technology business incubator." The CTTE is directly under the Vice Chancellor for Research and Extension and presently has three entities under it—the Science and Technology Park/Technology Business Incubator. Intellectual Property Office (IPO), and the Center for Technology Exchange and Training for Small and Medium Enterprises (ACTETSME). The UPLB STP/TBI was established in 1992 with an infrastructure grant from the Department of Science and Technology. It initially had four buildings, 1 pilot plant, 2 food and feeds buildings, and 1 tissue culture building on a 22 hectare lot. The ACTETSME building was built in 1996 in the STP as a joint project between the UPLB College of Economics and Management and the Department of Trade and Industry. It is tasked to strengthen and promote technology exchange among SMEs at the national and regional levels.

In 1997, the Intellectual Property Office was instituted under the Office of the Vice Chancellor for Research and Extension. Its main functions are to assist personnel and students in the "protection, promotion, valuation and commercialization of technologies and other intellectual properties created and developed at UPLB." The UPLB IP Office has conducted regular seminars and training on IP for UPLB personnel. Several UP personnel have also successfully passed the IP tests given by the Department of Trade Industry.

In June 2010, CTTE got a PhP 10 M grant from PCIERRD-DOST to renovate the CTTE building, by adding more office spaces, obtain computers and training equipment.

Presently, six technologies of UPLB are being commercialized (Table 7) (Supangco 2012).

A technology which has been commercialized by UPLB since the early 2000s is the Sinta hybrid papaya developed by Dr. Violeta N. Villegas. Sinta was franchised to East West Seed Co. and has earned royalties which increased from PhP 278,000 to PhP 1,822,000 from 2005 to 2010. The export component is about 60% of total sales for 2010. However, even earlier in 1995, 5 inbred lines of maize were licensed to Ayala for PhP 2.32 M for use in breeding.

The first spin-off company of UPLB is O'Mark Enterprises owned by Dr. Teresita M. Espino, inventor of the enzyme catalyzed virgin coconut oil (VCO). BIOTECH used to produce and market it while Dr. Espino was still connected a faculty of UPLB. Upon her retirement, she licensed the technology from UPLB, founded the spin off company and got the approval from UP in 2007. O'Mark is presently located in the UPLB STP.

The promotion of entrepreneurship has increased in the recent years in the University.

Three UPLB Technologies were finalists during the past three PESO (Philippine Emerging Startup Open) Challenges where two won the Grand Prize.

- Enhanced Solo (Papaya with long shelf life and ring spot virus resistance) (Grand Prize 2005) (IPB CA UPLB)
- SNAP Nutrients (Finalist 2006) (IPB CA UPLB)
- BIO N (Grand Prize 2007 BIOTECH)

A new GE course on entrepreneurship (Unleashing the Entrepreneurial Spirit) was institutedby the College of Economics and Management in 2011 and is now being offered.

Table 7. Six UPLB technologies commercialized with revenues for UPLB.

Technology	**Unit**	**Type of Protection**	**Vehicle of commercialization**	**Licensee**	**Location**
Sinta hybrid papaya	Institute of Plant Breeding	NSIC registration	Franchising	East-West Seed Philippines	Off campus
Trichoderma	CAS	Patent (IP Philippines)	Licensing	Bio-Spark Corp	UPLB-STP
Virgin coconut oil	BIOTECH	Patent (IP Philippines)	Licensing	O'Mark Enterprises	UPLB-STP
Mykovam	BIOTECH	Patent (IP Philippines	Marketing agree-ment/licensing	Adam Farms and	BIOTECH

		)		Agr. Resource Mgt Services Inc	
Bio-N	BIOTECH	Patent (IP Philippines)	Marketing agree-ment/licensing	Nationwide (DA-RFUs, Coops and private investors)	BIOTECH
Probiotics	BIOTECH	Patent (IP Philippines)	Marketing agree-ment/licensing	APT Vet Link Inc.	BIOTECH

From: Supangco (2012)

3. Manpower and Infrastructure readiness

UPLB has in the past years commissioned faculty members to critically study and make plans for university to fulfill its mandate as a research university and to address the new emerging concerns through the centennial professorial lectures. UPLB also had the staffing pattern of the manpower and expertise of colleges reviewed and recommendations to improve the faculty profile and number.

Plans for building a central laboratory which will have the more sophisticated equipment that can be used by University personnel and students are in advanced stage.

4. Improving rapport between industry and academe

Attempts to improve the relationship and rapport between industry and academe have been made in the past. Among these are the holding of *kapihan* to provide an informal atmosphere for the exchange of information and ideas among industry and academic people and holding of business forums where researchers present their pitches for their technologies.

Concluding Remarks

This study shows that UPLB has in place the needed policies (UP Revised policies, Technology Transfer Act of 2009), infrastructure and programs (UPLBFI, CTTE, IPO, science park/technology incubator), manpower and research expertise for improved industry-academe research collaboration. UPLB continues to strengthen its manpower and facilities for research. What needs to be further strengthened is the dialog and interactions between industry and academe to promote this collaboration.

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Comparative Study of the Determinants of Industry-Academe Linkage in Selected Countries*

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1 Introduction

Industry-academe linkage or collaboration remains an elusive goal for many countries. This is true especially in the so-called emerging economies, although it is also a problem for some developed countries. The reason for this elusiveness is probably multifaceted and likely to vary from country to country. This is because the factors which determine the relationship between higher education institutes (HEI's) and business enterprises are themselves outcrops of an overall framework. In the case of some emerging economies, the problem is lack of funding for research and development (R&D), predominance of small and medium enterprises (SMEs) in the economic landscape, and lack of human resources that appreciate and can articulate technological requirements [1]. In some of the more developed countries, the reason(s) may lie in the nature of the participating sectors.

1.1 Objectives

In this work, the author basically seeks to validate the list determinants of linkage that were presented in the preceding section. This goal breaks down into the following objectives:

1. prepare a list of determinants of academe-industry linkage
2. find indicators of these factors
3. describe how these factors influence the level of industry-academe link- age

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4. show how these factors interact

5. describe the roles and actions of government, industry and academe in the framework of linkage

1.2 Scope and Limitations

Limitations on time and availablity of data constrained this work to only a small group of countries. However, care was taken to select representatives from the high-, middle- and low-income countries or groups of countries (**Ta- ble 1**). Another criterion made was the history of a country's economic order as well as its political system. Thus, China and Poland were selected for study because these countries transitioned from a totally planned economy to a market economy. The author also contributes his observations during visits to countries as participant in the technology benchmarking program of the Engineering R&D for Technology (ERDT) consortium between 2006 and 2011. It is hoped that the selection of countries will provide enough diversity of economic environments to highlight the effect of each factor and also their interaction.

Table 1: List of Countries Covered by this Study

High-Income	Middle-Income	Low-Income
Hongkong Ireland Republic of Korea Sweden	Brazil China Poland Russia	India Pakistan Vietnam

Data is obtained from documents such as articles that treat the subject of academe-industry linkage and institutional reports on innovation and economic development, and the data that is freely accessible in the website of the World Bank. These sources painted a picture of the situation in the countries listed in **Table 1** between 2000 up to 2011.

A limitation that arises from the use of data from the documents cited is the reliance on data pertaining to formal research and development (R&D). As pointed out in [2], this approach excludes other important contributions such as the introduction of new machineries, investment in education, and non-technical innovations.

This work also limits itself to "vertical" collaboration between universities and industy but excludes non-academic R&D institutions (RDI's), and neglects "horizontal" collaboration between similar players.

Finally, this work makes no attempt either to quantify its empirical observation or to create an empirical model out of its finding.

2 Framework and Methodology for Research

This author believes this framework for academe-industry linkage to unfold through levels or stages which are shown schematically in **Fig. 1**.

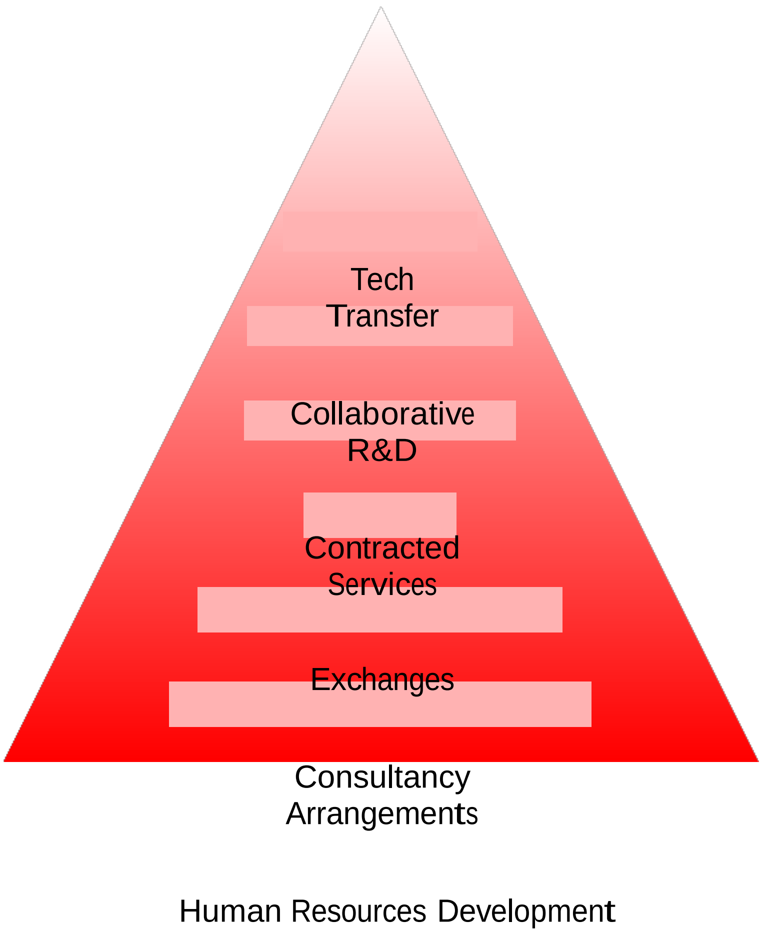

Figure 1: Hierarchy of frameworks for linkage

As seen in **Fig. 1**, the framework of human resources development is the lowest form of all. Here, there is really little or no partnership between academe and industry. The former simply serves as a provider of skilled manpower or of additional training to personnel from industry. Such a framework arises in a setting where there is no capacity or need for R&D in both HEI's and companies.

The framework of "consultancy arrangements" occurs when there is at least informal or faculty-level arrangements in which industry calls on experts in the university to solve its technical problems. It is possible also that academe may obtain information from companies about how to structure curricula to suit the needs of industry better. This framework occurs in an economic environment where enterprises are relatively low-tech but are aware of their needs to some extent. The need for R&D is not urgent as most of the technology is imported on a turn-key basis. This is also true when industry is dominated by small and medium enterprises (SME's) with more need for manpower than technology.

Exchanges of manpower and some knowhow can become formal in a low-tech environment where large-scale technology-dependent companies dominate. There may also be a need to access certain specialized equipment or facility which exist either in the academe or in industry. Formal agreements may be made to cover such programs as internships, on-the-job trainng, student placement, use of equipment or facilities, adjunct professor arrangements and the like.

As industry uses more advanced technology and feels the need to develop its capabilities without relying on imported solutions, it may turn increasingly to academe for help. This can take the form of contracted services such as testing and even short-term research. The object of such projects, which is the solution of some specific technical problems, may be non-trivial from the point of view of industry but still not the material of rigorous academic pursuits.

In a setting where there is full awareness of long-term or persistent problems and needs of society, more strategic thinking and innovative approaches may be sought by both industry and academe. Such a situation can give rise to collaborations in R&D. These cooperative projects require cost-sharing but also bring about benefits. For industry, these projects promise value-add to their products, and thus market competitiveness that manifests itself as increased profits and bigger market share. On the part of academe, advantages include extra income for the faculty and even for the institution, enhanced experience of the faculty, and an improved institutional image.

Near the apex of the hierarchy is the framework of tech-transfer. Its fundamental basis is the conscious organization of all R&D around the generation of intellectual property (IP). This IP-based thinking implies the commercialization of R&D outputs and enforcement of IP rights (IPR). Moreover, it suggests that environments be created in order to nurture nascent commercialization schemes. Such environments include incubation centers, business/technology parks, commercialization units, and the like.

Given the above hierarchy, one should see that the public good nature of linkages decreases as one goes up the hierarchy. This public good nature arises from the nature of knowledge, namely that it is inexhaustible and accessible to all. As one moves up the hierarchy, however, these characteristics are reduced mainly because of the requirements of industry which has a natural tendency to seek monopoly.

The reader should also see that shifting from the HR framework to technology transfer also parallels movement up the value chain. Thus, it is seen that knowledge is converted to value for society to enjoy. Development in this direction is therefore a shift towards a knowledge-based economy.

At this point, the reader should be warned that the simplistic scheme shown in **Fig. 1** is no more than a visual aid designed to help show how
the framework for academe-industry linkage may evolve. In truth, in any setting, it is possible to see the various frameworks in coexistence. In a large university, for example, some departments may be in the stage of incubating technologies while others may just be providing consulting services. In the manifold national setting, even more combinations are likely to be observed.

One advantage of this hierarchy of frameworks, at least as far as this author is concerned, is that it reveals some of the factors that determine academe-industry linkage in any country. These were already suggested in the preceding description of the frameworks for linkage and are listed in **Table 2**. Indicators or descriptors were added based only on the author's understanding of the factors. Hence, these enumerations are not exhaustive and merely suggestive.

Table 2: Factors that Affect Academe-Industry Linkage and Indicators Predicted by this Author

Factors or Determinants	**Description or indicator**
Nature and maturity of HEIs	• Technological orientation • Age • Size • Graduate programs
Nature of Industry	• Composition • Needs

Research activity in academe and industry	• Expenditure for R&D • Scientific publications • Number of patents
	Continued next page

Table 2 – continued from previous page

Factors or Determinants	Description or indicator
Management of IP	• Policies for protecting IP's • Incentives • Infrastructure
Economic environment	• RSE's per million population • Per capita income

The development of any framework for academe-industry linkage must be seen not only as a function of the above-mentioned factors but also in the context of the evolving intellectual property landscape, globalization, new platforms for collaboration and other global trends. This multifaceted environment may be characterized [2] by:

- unprecedent investment in the creation of intangible assets
- innovation-driven growth
- invention becoming international, collaborative and open in nature
- the central role of knowledge markets in the innovation process

As a sort of looking glass, the hypothesis of the hierarchy of linkage frameworks proposed by the author was used in examining the experience of other countries. The object was not so much to validate **it** but more to show the exceptions to it. **It** is believed that the exceptions more than the "theory" of this author will shed more light on the nature of the factors affecting linkage.

The methodology used in this work is simple: examination of institutional and national reports that were available online. From this reports, a listing of factors which condition university-enterprise linkage was prepared. These factors were then analyzed qualitatively to find out how their impact varied, whether and how they interacted, and what sectors or institutions were involved in these interactions. It was hoped that presenting diverse national conditions would compensate for lack of mathematical rigor in the analysis.

3 Results

3.1 Nature and Maturity of HEI Sector

Because the HEI sector is an essential player in all linkages, its nature plays a crucial part in enabling this linkage. This "nature" refers more to its structure rather than its capacity for R&D, which is regarded as a component of the determinant called "R&D activity" in this work. This structure is best described by the composition of the sector, especially the proportion of technology-oriented institutions with R&D capability.

At the outset, it is declared that the age and size of an institution are not determining factors as far as academe-industry linkage is concerned [3], contradicting the initial hypothesis of this author. It follows then that the size and age of the HEI sector in a given country should not determine whether it enables or hinders linkage. Rather it is the components listed in **Table 3**. Indicators that were found by other researchers to influence academe-industry linkage are shown in **Table 3**.

Table 3: Indicators of the Nature of HEI Sector Used in the Literature

Indicator	
Composition	[1, 3, 5]
Technology orientation	[1, 3, 5]
HEI attitude towards linkage with industry	[4]

The experience of European countries, which have many of the oldest HEIs in the world but generally lag behind the US in terms of academe-industry linkage, is very instructive. In these countries, it is found that the nature of the HEI sector is enabling under the following circumstances:

- **Technology Orientation of HEIs.** In Ireland, the HEI sector comprises 7 comprehensive universities and 14 institutes of technologies. The universities get a bigger share of R&D funds, receiving 461.3M Euros in 2004. By comparison, the institutes of technlogy received only 30.4M Euros in the same year. Moreover, R&D funding increased over 1998–2004, with the greater increase occurring for the universities [5]. Thus, it is seen that the capacity of the HEI sector for linkage was present. Despite this, linkage level is regarded as low [5]. Only 16.9% of the 1,370 R&D-active firms were reported to be collaborating with an HEI. It appears that attitudinal reasons on both sides of the gap were responsible for this. On the part of industry, there were priorities other than research. In the HEIs, interest in collaboration was "limited".

- **Strong University Sector.** Sweden has a university system which, in relation to its small population, is said to be the largest in the world [5]. Through R&D, this university system supports the economy which is dominated by a small number of very large multinationals. An indication of the high R&D in the HEI sector is the fact that it absorbed 42% of public financing for research in 2006 [5]. The Swedish universities are supplemented in their work by "virtual research institutes with industrial participation on their boards to support the development of solar technologies, instrumentation and measurements; a Swedish partnership to develop low energy light emitting diode lamps; and experience with European Framework Programmes for Research and Technological Development" [6].

On the other hand, the influence of the HEI sector is hindering in the following:

- **Prevalence of Instruction-Based HEIs.** In Poland, according to [1], the focus of HEIs is largely teaching and very few institutions dedicated to R&D are found. The meager research in academe is reportedly very basic and little connected to any commercial purpose.
  This is probably due to the former centralized economy which did not encourage much initiative among the various sectors, particularly in the area of research.

- **Duality of HEI Sector.** France provides an example of how both attitudes and composition of the HEI sector influence the formation of industry linkages. The dual nature of its HEI sector was seen to hinder the development of academe-industry linkage [4]. The research-based universities performed the bulk of high-quality research but had little contact with industry. The technical and engineering schools. on the other hand, worked closely with industry but did very little R&D.

- **Attitudes and Notions.** It was found by a Canadian study [4] that attitudes and notions deeply entrenched in the HEI

> sector of European countries have prevented the development of strong academe-industry linkage. Rooted in nineteenth-century traditions in academe, these attitudes and notions exerted such an influence that, according to the study, it was not broken until the 1980s when reforms began to promote academe-industry linkage. One such hindrance is reportedly the "professional soul" of universities which viewed collaboration with industry with ambivalence, disregard or even hostility. Another notion is that engaging in industry-related work distracted from academic work. Thus, according to the study, Greek and Spanish university staff were formerly forbidden to work with industry. This is corroborated by [7]. The one notable exception to the European pattern was the United
> Kingdom, reportedly because of political pressure to forge industry collaborations, shortage of funds because of decreasing government allocations, traditions of collaboration in the "civic" universities and close relationships with US HEIs.

It should be mentioned that from earlier times the US attitude towards academic linkage with industry is the opposite of that of Europe. American universities saw working with enterprises as natural. Partly for this reason, the US leads the world in academe-industry collaboration.

The case of India is also worthy of mention. India has an HEI sector which is truly capable of R&D and has a large and growing talent pool and number of R&D centers. Indeed, there is a considerable patenting and publishing of research outputs. Yet, research in the academic sector is largely the basic kind and lacks application [8].

3.2 Nature of Industry

The nature of industry is just as important as the nature of the HEI sector as a determinant for academe-industry linkage. Attitudes towards linkage are conditioned by company strategies for gaining competitiveness and considerations of the cost of R&D among others. These are in turn a function of the size and nature of the company.

In the case of Hongkong, for instance, some SMEs prefer to gain access to university knowledge by hiring highly skilled graduates rather than collaborating with universities in research. Competitive advantage is obtained also by locating in less expensive environments, e.g. the Pearl Delta Region in China.

In contrast, Sweden's industry is dominated by a few but very large multinationals which account for 70% of all expenditures for research. Linkage remains a priority of the government and this appears to take the form of 42% of public funds for R&D going into basic research ("curiosity research") in the HEI sector [5].

The case of India needs to be elaborated here. India, as already noted, has an HEI sector which has a high capacity for research. Its industry includes a big number of multinational companies (MNCs) as well as large domestic enterprises. However, rather than link with HEIs for research, the MNCs have their own research centers to address their R&D needs while the domestic enterprises would rather "go for quick acquisition of technology" [8]. Other examples are seen in **Table 4**. It can be seen that the ability of enterprises to link with universities for R&D is determined by their level of technological sophistication and the degree that their needs are or may be addressed by R& D in the academe. It also appears that when industry is composed largely of SMEs, the driving force for linkage is weak or that linkage will be kept to the lower forms. This implies that the capacity for R&D or absorption of R&D output should be strengthened among SMEs.

Table 4: The Experience of Some Countries with the Effect of the Nature of Industry Sector on Academe-Industry Linkage

Country	Composition of Industry	Needs of Industry	Source
Hongkong	98% SME (2008)	Highly-qualified labor trained by HEIs	[9]
	Effect on linkage: SME's do not feel need		
India	• Growing number of MNCs which perform research • Large num- berof domestic enterprises also	Participation of academe in applied R&D	[8]
	Effect on linkage: Low linkage activity		
Ireland	• Dominated by SMEs • Only 100 out of 1,025 Irish-owned	capacity-building for R&D	[5]
	Effect on linkage: Low linkage activity		

Continued next page

Table 4 – continued from previous page

Country	Composition of Needs of Industry Industry	Source
Sweden	Dominated by R&D a small number of mutinationals which are active in research (provides 70% Effect on linkage: High priority for it	[5]
Poland	99.86% SME funds for conducting in- Effect on linkage: Low interaction between academe and industry	[1, 3]
Turkey	Situation in 2000: no R&D; low-skill personnel. • SMEs 99.6% of all enterprises • only 27.3% of value-add from SMEs • average of 3 Effect on linkage: Low level of linkage	[3]
Uganda	In 2000, • largely agricultural, only 8.4% manufacturing • largely SME • Unskilled labor • Guidance on identifying technical neeeds Effect on linkage: Reduced to technical assistance from HEI on identifying technical needs	[3]

3.3 Research Activity

The hypothesis of this author that R&D activity in industry and academe is an important factor for linkage is validated by other works [1, 3, 5, 8]. This determinant of linkage is referred to as "basic S&T indicators" by [1] or "S&T development" by [3]). A sampling of specific indicators used in other works is given in **Table 5**.

Table 5: Indicators of the R&D Activity Used in the Literature

Indicator	
GERD by financial source	[1]
GERD by performer	[1]
Total number of researchers	[1]
Number of researchers per million population	[3, 8]
Number of patent applications filed by residents	[3, 8]
Number of patent applications by enterprises	[1]
Number of patent applications by HEI's	[1]
High-technology exports as % of manufacturing exports	[3, 5]

A remarkable example of the effect of R&D activity on linkage is the experience of China as cited in [1].

In the 1950s when China's economy was centralized, the government emphasized the teaching function of universities over research. Meanwhile, industry also did not take up resposnibilities to perform R&D, this function having been largely centralized in a network of R&D institutes (RDIs) led by the Chinese Academy of Science (CAS). Hence, in the 1950's the role of the universities was mainly to provide talents to other sector, including industry. This was therefore the core of the framework for linkage.

In 1979, however, the Chinese government declared universities as centers not only of teaching but also of scientific research, marking a transitional period in the role of HEI's in linkage. In 1985, the RDIs received more autonomy in certain areas which in 1992 included "contract responsibility" according to which the director of a public RDI could sign a contract with the state and take responsibility for achieving goals in research, among others. By the end of this transitional period in 2004, HEI's were collaborating closely with industry and RDI's and the framework for linkage evolved to include joint research, human resource training and personnel exchange.

At present, HEIs are recognized as the main institutions for the production and application of knowledge in China. Moreover, the line between the functions of HEIs and industry has become blurred with HEIs setting up their own enterprises and industry establishing private universities.

3.3.1 RSE's per Million of Population

The number of research scientists and engineers in absolute terms or relative to the population of country can be interpreted as a measure of its capacity for research. Alternatively, it can be used as an indicator for research activity if used with another indicator such as the number of scientific publications or applications for patent. For example, the rapid increase in RSE's in China is correlated with the increase in the number of Chinese scientific publications. The latter is itself an indicator of not only the intensity of research activity but also its quality if the number of publication in international cited journals is accounted for.

In **Table 6**, the number of researchers, including Ph.D. students engaged in research, are presented for each country in this study. The high-income economies have between 2,000 and 5,500 RSEs per million population in 2009. These countries, in particular the United States, are known to have a good tradition of industry-academe linkage because of high R&D activity. In the present decade, three members of the BRIC group of countries, saw their RSE's increasing steadily. Russia's number already compares very well with those of the high-income group while China's is begining to enter the range.

From the table it is clear that this number decreases from the group of high-income economies to the lower-income groups, suggesting a correlation with level of economic development.

3.3.2 R&D Expenditure

The gross expenditure on R&D (GERD) reflects the actual support given to R&D by both public and private institutions. Therefore, it paints a picture of how much the capacity for R&D indicated by the number of RSEs is converted to actual R&D activity.

Table 7 shows the sum of public and private expenditures in R&D in the selected countries. As an indicator of R&D activity, GERD shows that the high-income group again leads the others. What is remarkable is the steady rise of China's GERD and the observation that the GERDs of the so-called BRIC countries Brazil, Russia and China already compare well with those of the high-income economies. This is no accident. For example, in Brazil and China, accounts of which are given in [3] and [1], repectively, the increase is part of a national strategy. In China, this strategy sees an increase in industry support for university research and a

Table 6: Comparison of Researchers per Million Population (Data taken from [10] except for India which were obtained from [8].)

Country	Researchers per Million Population by Year							
	2002	2003	2004	2005	2006	2007	2008	2009
Germany	3,225	3,265	3,274	3,287	3,390	3,525	3,667	3,780
Hongkong	1,556	1,978	2,144	2,647	2,682	2,845	2,664	2,759
Ireland	2,382	2,503	2,695	2,787	2,883	2,952	3,342	3,373
Japan	4,943	5,170	5,176	5,385	5,416	5,409	5,189	–
Republic of Korea	3,057	3,244	3,336	3,822	4,231	4,672	4,947	–
Sweden	–	5,393	5,434	6,101	6,130	4,979	5,220	5,018
United States	4,654	4,911	4,708	4,633	4,721	4,673	–	–
Brazil	459	496	535	588	621	658	696	–
China	630	667	712	856	931	1,077	1,199	
Philippines	–	71	–	81	–	78	–	–
Poland	1,484	1,534	1,586	1,629	1,561	1,608	1,618	1,598
Russian Federation	3,381	3,365	3,310	3,230	3,236	3,274	3,152	3,091
India	–	–	103	260	346	421	459	479
Pakistan	–	–	–	80	–	160	–	162
Vietnam	116	–	–	80	–	–	–	–

slight drop in government appropriation. According to [1], this steadily increased from about 17% in 2000 to nearly 38% in 2004. Government contributions dropped from 58% to 54% in the same period. This appears to reflect the Chinese government's policy of giving more autonomy to academe-industry linkages. India's GERD is reported to be 0.9% and is planned to increase to
2% in a few years [8]. Hongkong's situation is remarkable considering that it is a high-income country despite its low GERD. A possible explanation for this is the strategy of its SME-dominated industry to gain competitiveness by locating in cheap environments.

3.3.3 Patent Applications by Residents

In **Table 8**, the number of number of patent applications filed by residents is presented for selected countries. This number may be used as an indicator of real innovation activity. If patents are viewed also as a basis for academe-industry linkage, the number of patent applications can also serve as an indicator of potential for linkage. The obvious caveat, however, is that this number does not indicate the fraction filed by universities.

From **Table 8**, it is clear that with the exception of Hongkong and Ireland, the representatives of the high-income group of countries show

Table 7: Comparison of the GERD of Selected Countries [10]

	R&D Expenditure (% of GDP) by Year							
Country	2002	2003	2004	2005	2006	2007	2008	2009
Germany	2.49	2.52	2.49	2.49	2.53	2.53	2.68	2.82
Hongkong	0.59	0.69	0.74	0.79	0.81	0.77	0.73	0.79
Ireland	1.10	1.17	1.23	1.25	1.25	1.29	1.45	1.77
Japan	3.17	3.20	3.17	3.32	3.40	3.44	3.45	–
Republic of Korea	2.40	2.49	2.68	2.79	3.01	3.21	3.26	–
Sweden	–	3.80	3.58	3.56	3.68	3.40	3.70	3.62
United States	2.62	2.61	2.54	2.57	2.61	2.67	2.79	–
Brazil	0.98	0.96	0.90	0.97	1.00	1.07	1.08	–
China	1.07	1.13	1.23	1.32	1.39	1.40	1.47	
Philippines	0.14	0.13	–	0.11	–	0.11	–	–
Poland	0.56	0.54	0.56	0.57	0.56	0.57	0.60	0.68
Russian Federation	1.25	1.29	1.15	1.07	1.07	1.12	1.04	1.25
India	0.74	0.73	0.74	0.78	0.77	0.76	–	–
Pakistan	0.22	–	–	0.44	–	0.67	–	0.46
Vietnam	0.19	–	–	–	–	–	–	–

much higher patent applications than many of the countries in the low-income group. However, it is seen that the BRIC economies, in particular China, already show comparable numbers of patent applications. Thus, in 2010, the output of China just slightly surpassed that of Japan and was well above the number for the US. Brazil's number for the same year is comparable to Sweden's.

3.4 The Role of Government

The factor or determinant which is not obvious from cursory inspection of the hierarchy of frameworks for linkages is the role of government. The documents reviewed by this author clearly point to the facilitating role of the government to bring about effective academe-industry collaboration. References [3, 5], for instance, agree on the facilitative role of government:

- Specific support schemes:
  - incentives such as tax cuts or exemptions in return for for R&D expenditure in joint ventures
  - matching grants made available on competitive basis for joint R&D ventures
  - the creation of technology centers or science parks
- facilitative framework conditions
  - regulations, particularly on IPR
  - policies, especially those in education; labor; public procurment; regional and urban planning; and competition

It is found that the term "government" is not limited to national government. As reported in [4], government may be supranational (e.g., EU) or regional (e.g., the Basque Autonomous Community).

It should be noted that not all government facilitative measures are aimed at joint ventures and R&D. The case study of Makerere University in Uganda reported also in [3] documents government efforts in support of exchanges.

Given the exception of Uganda and possibly other countries not examined in this work, it may still be asserted that the role of government as a determinant for academe-industry linkage is to shift the framework of linkage from the loose HR model towards tech-transfer. This is visualized in **Fig. 2**, which resembles the so-called Sàbato Triangle which was first pub- lished in 1968. In this new schematic, the lines connecting two corners of the triangle represents collaboration between two sectors. Thus, the horizontal base represents academe-industry linkage. Any point within the triangle represents such a linkage with some government participation.

Finally, it is noted that **Fig. 2** does not completely portray the relationship between government, academe and industry. Because this model was constructed from limited information, it shows government, academe and industry as independent institutions, such as the case in the US [11]. In this set-up each institution can be the starting point for collaboration. What the picture does not capture is the situation where government dominance is a salient feature. This was the situation in the former Soviet Union and in some Latin American countries [11], and also in China and probably the Warsaw Pact countries if the example of Poland can be used as a guide. In this situation, the government dominates both academe and industry and, hence, government has the initiative for starting academe-industry linkage. This was the case of China when it decided to introduce reforms in the
1980s. It is suggested in [11] that the world is moving towards increasing overlaps in the roles of government, universities and industry.

The regulatory role of government is examined in a later publication of UNESCO (Reference [1]).

Examples of national government intervention are shown in **Table 9** while examples of regional interventions are presented in **Table 11**.

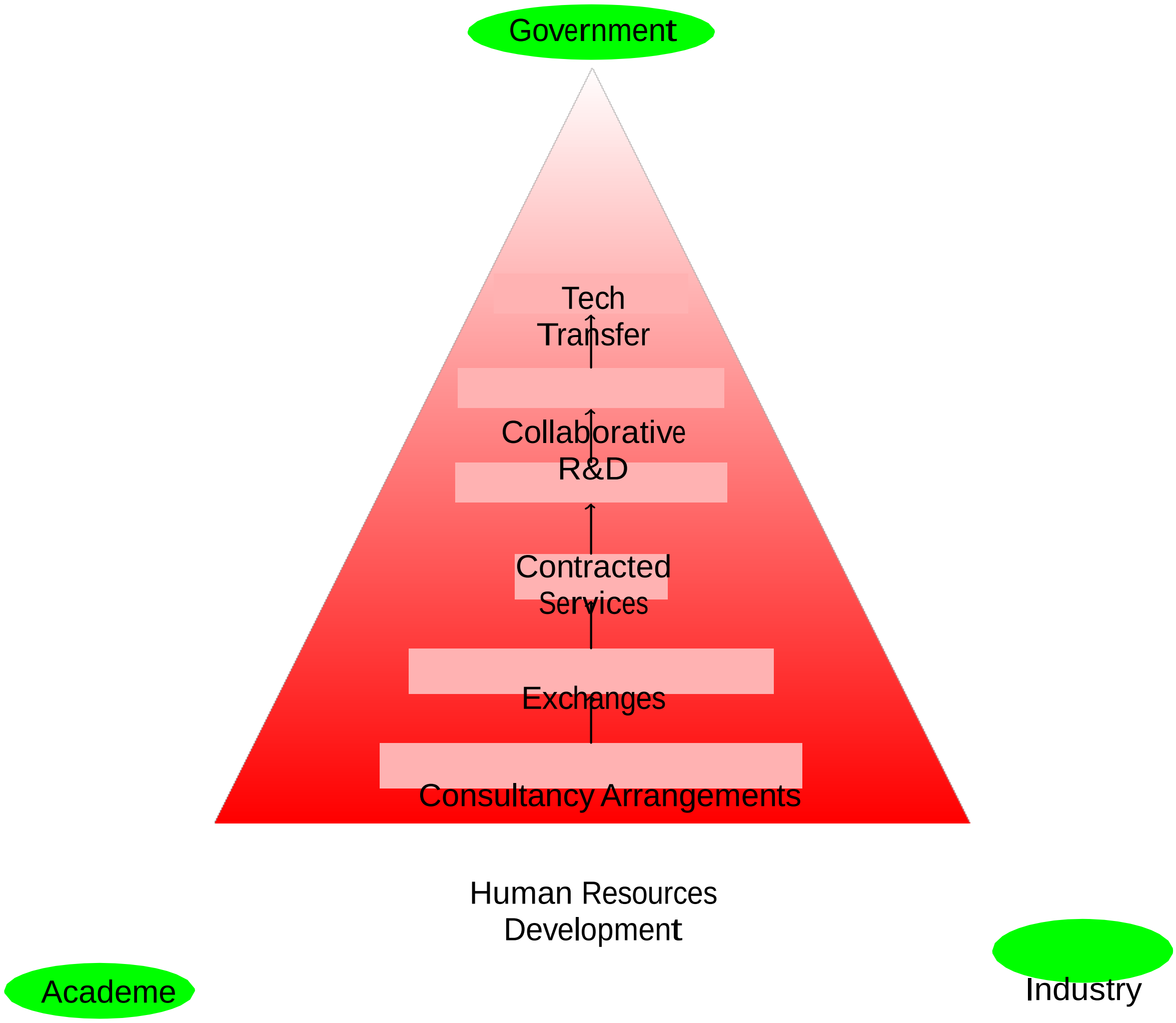

Figure 2: The role of government in the context of the development of a framework for academe-industry linkage

Table 9: Examples of National Government Measures to Facilitate Academe-Industry Linkage

Country	Facilitative Measures	Source
Brazil gen-	• enactment of a law in 1991 providing erous tax incentives for the information technology industrial sector, and requiring companies to spend at least 5% of their revenue in R&D • special programs for supporting R&D and collaboration: – FINEP-TEC:soft loans to enterprises 17 for R&D, provided that at least 15% of the expenditure was made by industry – PRODENGE/RECOPE: promotion of research networks – OMEGA :promotion of cooperative R&D between a university and at	[3]

Table 9 – continued from previous page

Country	Facilitative Measures	Source
China	• economic reforms, which included decentralization and grant of autonomy to HEIs and RDIs • declaration of HEIs as centers of education and research in 1979 • restructuring of HEIs and RDIs for integration and application of knowledge and greater cooperation with industry • creation of the various programs for the pooling of financial and human resources for R&D and for diffusion, application and commercialization of knowledge	[1]
Turkey	creation of a revolving fund of which 81% is used to pay for laboratory-based research, 5% to support faculty travel to conferences, 3% is for administrative us, 1% is for another special fund and 10% is deducted as tax	[3]
Israel	National program conducted by the Office of the Chief Scientist of the Ministry of Commerce and Industry for developing generic technologies through the creation of consortia between univerisities and industry.	[3]
Poland	• Creation of the State Committee for Scientific Research (KNB) which, among other functions, manages funds for the stimulation of academe-industry linkage • Creation of the State Technology Agency (ATT) in 1997 which offers soft loans to support innovation particularly in the SME sector	[3]

Continued next page

Table 9 – continued from previous page

Country	Facilitative Measures	Source
Morocco	• A new financial mechanism called the *hors compte* budget which allows HEI's to autonomously manage funds for collaborative projects with industry • Creation in 1997 of the *Pôles de Compétences Qualité* which creates a network of technology-oriented HEI's and a cluster of industry	[3]
Spain	promulgation of the Law for University Reform in 1984 which allowed publicly-funded universities to engage in contract research	[4]
Sweden	• launched in 2004 of a new strategy for innovation policy, *Innovative Sweden* • passage in 2005 of a new government bill on research, *Research for a Better Life*, which calls for linkage, change in IPR on university research, and technology transfer and commercialization, among others • establishment of competence centers in 1995 where industry and academe may collaborate	[5]

Table 10: Examples of Supranational Government Measures to Facilitate Academe-Industry Linkage

Supranational Government	Facilitative Measures	Source
European Commission (IMI),	• the Innovative Medicines Initiative a joint undertaking with the pharmaceutical industry to develop better and safer antibiotics • establishment of the European Institute of Technolog to promote interactions between research institutions and industry as well as knowledge transfer • EC Framework Programmes ("FP) for R&D which encourage transnational knowledge transfer through research projects that involve a international participants from the public and private sectors • Competitiveness and Innovation Pro- gramme to support all forms of innovation, public-private partnerships and measures to iimprove access to finance and fund novel ways to facilitate knowledge sharing between research institutions and companies, in particular SME • European Regional Development Fund (ERDF) which were created to support incubators and science parks deemed to be effective means to spinout knowledge and create better SMEs university links"	[6, 7]

Table 11: Examples of Regional Government Measures to Facilitate Academe-Industry Linkage

Regional Government Source	**Facilitative Measures**	
Regional Government of Flanders (Belgium)	establishment of the Inter-University Microelectronics Centre (IMEC) in Leuven in 1984	[4]
Basque Autonomous Community (Spain)	funding of regional research centers which act as clearing house and venue for academe-industry collaboration	[4]

3.5 The Economic Environment

According to [3], the economic environment affects R&D collaboration more than the conduct of joint education. In the more industrialized market- driven environment, the institutional players appear to be independent of each other and the role of government is more facilitative. In the more agricultural economies, the role of government in bringing academe and industry to work together is the same, but the framework for linkage is more towards HR development and much less of joint R&D.

In a planned economy, the independence of industry and academe is lost and government has the dominant role in conditioning linkage.

3.6 The Interrelationship of Factors

Figure 1 should not be interpreted to mean that the route to higher forms of innovation-based linkage is linear or that it can be planned. In fact, it has been found that the opposite is true [6]. Just as there are many routes to innovation, there are possibly many ways of achieving high-level linkage.

The overall economic environment affects the way that the other factors operate on academe-industry linkage. The experience of the formerly planned economies of China, Poland and Russia are proofs of this. It was already seen that in these economies there was little incentive for industry and academe to undertake industrially-useful research or to collaborate with each other. In Uganda. for instance, the economic environment allows mostly small-scale industries to flourish and therefore there is no need for R&D. In Sub-Saharan Africa, the economic environment is such that there is insufficient capacity in both academia and industry [6]: "The higher education sector is recovering from decades of neglect and underfunding, resources are often inadequate to provide core education functions, and the knowledge production capacity needed to drive new interactions is not available. The industrial sector primarily focuses on small and medium scale operations that target immediate and local needs. Where we find high technology producers and export-oriented manufacturers, their research and development infrastructure is often located elsewhere, without the geographical proximity that seems to be an essential ingredient for successful partnerships."

Of course, it was possible for the economic order to be transformed by the other factors, notably government and the evolution of the industry sector. In the case of China again, it was a deliberate decision of government to shift from a centrally planned economy to one that is at least partly market-driven and where academe and industry have more autonomy.

The nature of industry also interacts with the nature of the HEI sector and R&D activity. Where SMEs predominate, the tendency is for R&D activity to be low both in industry and academe, and for the academic sector to focus on instruction. Certainly, receptiveness of the HEI sector to the needs of industry is conditioned by the presence or absence of a technological orientation. Indeed, case studies of linkages involve only HEIs with science and engineering departments.

3.7 Summary of Findings

The age of an institution is an important factor but not a determining one when it comes to new modes of operation, such as joint ventures [3].

The size of an institution which could affect the degree of decentralization as well as scientific potential did not appear to be important [3].

Facilitating mechanisms by government were found to be important to nearly all countries reported in [3]. Government incentives include tax cuts for R&D expenditure in joint ventures, matching grants made available on competitive basis for joint R&D ventures or the creation of technology centers or science parks in close proximity to the universities. It should be noted, however, that the 12 HEI's in this study were public with the exception of only one.

4 Conclusions

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Table 8: Comparison of Patent Applications by Residents

	Number of Patent Applications per Year								
Country	2002	2003	2004	2005	2006	2007	2008	2009	2010
Germany	47,598	47,818	48,448	48,367	48,012	47,853	49,240	47,859	47,047
Hongkong	112	107	127	156	172	160	173	149	133
Ireland	914	862	787	789	838	847	931	908	733
Japan	365,20	358,18	368,41	367,96	347,06	333,49	330,11	295,31	290,08
Republic of Korea	76,570	90,313	105,25	122,18	125,47	128,70	127,11	127,31	131,80
Sweden	3,358	3,025	2,768	2,522	2,446	2,527	2,549	2,186	2,186
United States	184,24	188,94	189,53	207,86	221,78	241,34	231,58	224,91	241,97
Brazil	3,365	3,689	3,958	3,905	3,810	4,023	4,084	3,921	2,705
China	39,806	56,769	65,786	93,485	122,31	153,06	194,57	229,09	293,06
Philippines	149	141	158	210	223	225	216	172	166
Poland	2,313	2,268	2,381	2,028	2,157	2,392	2,488	2,899	3,203
Russian	23,712	24,969	22,985	23,644	27,884	27,505	27,712	25,598	28,722
India	2,693	3,425	4,014	4,721	5,686	6,296	6,425	7,262	–
Pakistan	55	57	73	143	91	109	170	–	–
Vietnam	134	149	206	362	196	339	320	391	306