

Future of U.S. Research Universities in a Globalized World: A Chemical Engineer's View from Singapore

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Introduction

The forces of globalization have been with us for a sufficiently long time so that eyebrows are no longer raised when statements such as, "Globalization is the 21st century equivalent of the Industrial Revolution" are made. Nearly every human endeavor has been affected by forces described in Thomas Friedman's "The World is Flat"¹. Examples include the response we get to toll-free help calls as well as factory closings caused by the need for a corporation to manufacture components abroad in order to remain competitive.

In contrast to the tectonic-plate scale of rearrangements seen in the manufacturing and service industries, operation of the major U.S. research universities has proceeded without corresponding upheavals. Why is this? Should we expect something different? What does the future hold for us? In this article, I shall provide some opinions regarding these and other questions. Because my own international interests in recent years have been focused on Asia my comments are Asia-centric, and they reflect my experiences as senior advisor to the president of the National University of Singapore (NUS).

Anomalous Culture of the Research University. Audacious Discoveries Emanating from Citadels of Conservatism

Those research universities generally acknowledged to be among the best in the world, house faculties whose professional reputations are garnered by upsetting conventional wisdom in order to make new discoveries or to establish new paradigms. Yet corporately they belong to a group considered to be resistant to structural change at a level possibly comparable to most organized religions. Indeed, a case can be made

that such resistance to change is a factor supporting the longevity of these institutions. However, permanence is not synonymous with excellence. The purpose of this article is to ask whether that resistance to change will hold the universities largely impervious to globalization and, if so, whether U.S. universities will retain their positions of prominence. My opinion is that unless U.S. universities embrace globalization as a new opportunity, they will, within a generation, find themselves among the also-rans of the world's research universities.

Context

In 2003 Goldman Sachs² published a scenario in which, by the year 2050, Asia could dominate the world's economic landscape. China would have the highest gross domestic product (GDP) among all nations, followed by the U.S. and India, respectively (Figure 1). Evidence that the stirring Asian giants are already affecting the academic research landscape is not hard to find. An example is found in our own flagship research publication, the *AIChE Journal*. Table 1 shows the origin of articles published during the first five months, respectively, of 1990, 1995, 2000, 2005, and 2006. Two interesting results emerge from this simple sampling. First, *AIChE Journal* has been a truly international journal for a long time, and it is now dominated by articles from abroad. Second, the number of articles from China and India is growing rapidly, both in absolute terms and relative to the total number of articles published.

Is the Pipeline of Talent to the U.S. Likely to Run Dry?

It is well known that graduate research in engineering and science in the U.S. is fueled by students from abroad, with well over 50% of our graduate students coming from other countries. Is this flow of talent likely to cease? I do not think so. However, I do believe that, barring major political upheavals, our ability to attract top students from abroad will be severely tested within the next decade, and I offer several observations to support that claim.

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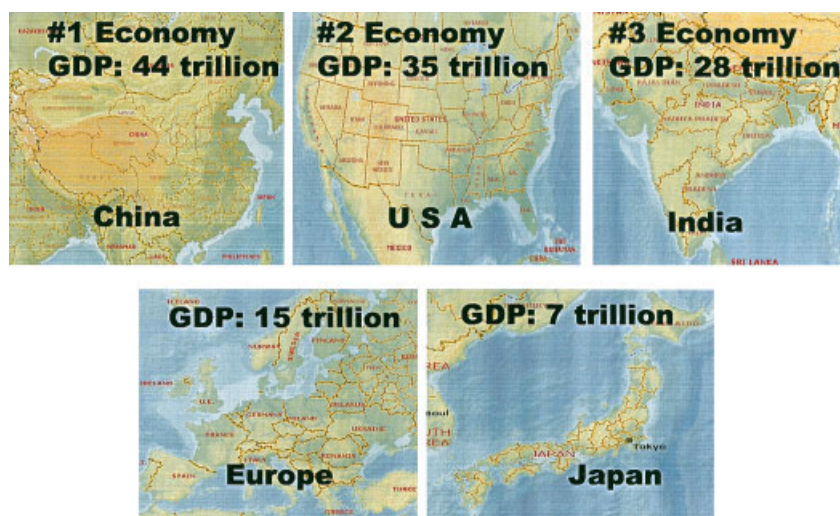


Figure 1. Goldman Sachs² scenario of countries with the largest Gross Domestic Products (GDP) in 2050 (courtesy National University of Singapore)

History

Well into the 20th century, it was common for American scientists to spend time under the tutelage of a mentor in Europe. This was also true for several of the early giants of the chemical engineering profession.³ That trend abated, and following World War II the center of the academic universe became the U.S. We have enjoyed that hegemony for so long that most of us have known no other condition. To us, it is “normal”. However, with the flattening force of globalization at work, it is important to recognize that our present state is as abnormal as it is for the world’s automobile appetite to be satisfied by three manufacturers headquartered in Detroit.

Knowledge is (economic) power

There is ample evidence to show that just as iron, coal, and oil have been central to manufacturing prowess, knowledge — and its application — are raw materials for growth in the late 20th and early 21st centuries. The special edition of *Newsweek*⁴ coinciding with the 2006 World Economic Forum in Davos, Switzerland, was titled “The Knowledge Revolution. Why Victory Will Go to the Smartest Nations and Companies”. Articles by Bill Gates, Tony Blair, and others have titles, such as “Ideas Matter”, “Failing Europe” and “Where America Stands”.

The issue is a chilling read for those who believe the United States (or Europe) will house the world’s engines of growth through the 21st century.

Rise of Asia.

I have already referred to the expected rise of Asia to economic primacy within the next few decades. Alongside these figures is the less quantifiable, but equally important expectation among Asians that they are the wave of the future. In Shanghai, Singapore, and parts of Bangalore, the expectation is evident. It is a different environment than one senses in the U.S. or Europe. One way to convey the Asian sense of resolve and anticipation is to quote from an article written by Singapore’s prime minister, Lee Hsien Loong, in the aforementioned *Newsweek* edition. He wrote, “On an intelligent island, every pair of hands has to be a pair of thinking hands”, and “Globalization will force nations to reallocate resources, restructure their economies and reorient their societies for the future. Singapore accepts this as a given”.

Timescale of change

Another characteristic of modern civilization about which much has been written is the shrinking timescale over which significant change occurs. One instructive way to illustrate this is to note the rank-ordered list of the largest corporations at five-year intervals during the past 30 years. The increasing volatility of that list is apparent. Applying that exercise to the academic scene and using some measure of graduate-study quality in engineering and science, the corresponding list will show far less volatility. However, perceptions of research quality do change, and I believe they are now changing more

Table 1. Papers Published in *AIChE Journal* During the First Five Months of Selected Years*

Year	1990	1995	2000	2005	2006
% Foreign Papers	36	36	51	56	65
% from China and India	5	3	4	9	9
% from China and India among Foreign Papers	12	8	8	17	13
Number of papers from China & India	4	4	4	13	16
Total Number of Papers	88	139	103	137	184

* In cases where coauthors were from the U.S. and from abroad, assignment was based on some combination of the location at which the work was performed and the source of its support.

A Hub of Global Players



Figure 2. Recent occupants of Jurong Island (courtesy Singapore Economic Development Board).

rapidly than at any time in memory. Does this spell the demise of U.S. research universities? I do not think it does. What I believe will change in the next decade is the near-monopoly the U.S. has had in recruiting the best students for PhD and post-PhD education. Graduate students and post-docs will have more options. There will be more universities competing in the global talent reservoir, and the U.S. will face more than token competition, particularly from Asian universities. The increased competition will occur not only at the student level, but also for talented faculty members — at all levels. This change is, in my opinion, inevitable. It would be both unrealistic and unwise to ignore it or to attempt to prevent it. The balance of this article will focus on how we, and indeed the global academic research enterprise, can profit from these trends.

Some Observations

Increasing global talent base

Both China and India have ambitious plans to upgrade advanced education in engineering and science. This includes making those curricula available to a larger fraction of the population. Given a huge population base of over two billion people, a small increase in the fraction of talented young people pursuing research careers will result in very large changes in the global talent pool. It will be important to U.S. universities to have access to this pool, and to provide competitively attractive means to do so. The waning interest and performance of U.S. students in quantitative subjects is well known. With more than half of our country's graduate-student population already coming from abroad, an even greater disconnect is likely between U.S. graduate education in science and engineering and the U.S. population as a whole.

Stay close to the customer

There is every reason to expect that along with Asia's increasing capacity for producing a technically educated work force, jobs requiring such skills will also increase. In the chemical and petroleum industries this has already happened in

manufacturing. The position on the value chain of biotechnology and some areas of electronics is rising, and research and development (R&D) opportunities are expanding. A few years ago a major U.S. pharmaceutical company opened a research laboratory in Singapore. One of the executives associated with the decision said, "Why should we bring people from Asia to the U.S., train them, and then go through the requirements necessary to keep them here? We should provide jobs for them near their homeland so they do not have to leave it." If this seems obvious to the corporate sector, should it be any less so for academe? The customers of a research university are, on the one hand, students; on the other, they are the corporations and universities to which our students are attracted after termination of their formal study. Should we not serve both of these customer bases by being in close proximity to them?

Singapore approach

As the major countries of the world attempt to cope with globalization, they may find instructive the approach of the tiny city-state that is Singapore. An island of less than 300 square miles with a population of four million, Singapore has contended with "globalization" since its founding as a trading port. The notion of adding value to goods that pass through it has now been extended to the flow of ideas. Singapore's location and size define a unique set of conditions, and to the extent that there is a "Singapore story" it will not serve as a template transferable to other nations. Nonetheless, there are important lessons to be learned from the Singapore experience.

In the 1980s Singapore determined that the chemical and petroleum industries were key drivers of its economy. To anchor the industry already present in the form of several refineries and manufacturing plants, and to attract others, the country embarked on a bold (\$4 billion) project to co-locate components of that sector together on the fusion of several islands into one 12-square-mile complex known as Jurong Island. Utility and other infrastructure support were supplied centrally to Jurong Island's tenants. Recent corporate occupants are shown in Figure 2.



Figure 3. Two buildings of the Biopolis complex (photo courtesy of Singapore A*STAR).

It was recognized early on that R&D support should be available to this sector, providing means for companies to undertake, jointly or singly, R&D projects without encumbering the home R&D facilities. On the Singapore side this translated into a move toward an indigenous knowledge-based activity, an ingredient necessary to thrive in a globalized environment. Thus, in 2004, a government-sponsored Institute of Chemical and Engineering Sciences (ICES) was established on Jurong Island, with 34,000 square feet of laboratory space, and a current staff of more than 120 research scientists and engineers.

With Jurong Island a reality, the government, through its Agency for Science Technology and Research (A*STAR) expanded this model to the life sciences, but now with a larger emphasis on R&D, although still connected with present or perceived future manufacturing capacity. The result is a huge complex known as Biopolis (Figure 3). With the emphasis on ideas and research, Biopolis is a collection of A*STAR-sponsored research institutes (RI's) designed to resonate with the biotech and pharmaceutical industries. Nestled with these RI's are several corporate pharmaceutical laboratories, including firms such as Novartis and GlaxoSmithKline. Investment in the construction of Biopolis exceeded \$300 million. However, the plan is not complete. The next phase is construction of a neighboring Fusionpolis, which will collect in contiguous space most of the RI's focused on physical science and engineering. This plan recognizes that the life and physical sciences form a continuum and must be synergistic⁵.

Biopolis and Fusionpolis are in close proximity to the NUS campus in order to facilitate the link that should exist between advanced (PhD and post-PhD) education and the needs of the Singapore economy. For example, the research of several NUS PhD chemical engineering candidates takes place in ICES labo-

ratories, and is conducted under the direction of chemical engineering faculty members who also hold ICES appointments.

What are the exportable lessons to be learned from the Singapore story that will help other countries to cope with globalization? Three are particularly important:

1. National resolve is a requirement.
2. Ideas are as much a raw material as are coal and iron. One can profit by adding value to ideas.
3. Ideas come from people, and those people are a valuable asset. They must be acquired by successful competition in an increasingly global marketplace.

Using Globalization to Enrich Research Universities

It should be understood that I am referring to institutional, not individual, responses to globalization. Individual faculty members have collaborated with like-minded colleagues abroad for as long as means of travel and communication have existed. However, the globalized environment in which we now find ourselves argues for institutional strategies that will not only prevent damage to U.S. and other western universities, but will allow them to thrive in a globalized society.

One can codify institutional responses into three broad categories, each with its advantages and pitfalls. Although each may, at first blush, appear self-evident, there are important policy questions that for the most part have not yet been satisfactorily addressed.

Branch campuses abroad

In the engineering arena perhaps the most visible example of this approach has been the experience of Georgia Tech in France (<http://www.georgiatech-metz.fr>). Since 1990 Georgia Tech has maintained a campus in Metz, in the Lorraine region of France. Established originally as a base for undergraduates wishing a study-abroad experience, the program has grown to the point where graduate degrees are offered in selected engineering disciplines, and collaborative research programs have been formed with several European Union universities. Georgia Tech Lorraine now has aspects of all three models described here.

A clear advantage of the branch campus model is the degree of control maintained by the home institution. However, this very fact implies a lack of parity with organizations and individuals in the host country. It is difficult to avoid perceptions of colonialism; and competition rather than collaboration with local institutions can occur.

Alliances

These are bilateral (or perhaps larger) memoranda of understanding (MOU's) between institutions, where each party perceives a clear advantage to collaboration. Typically, both instruction and research collaboration are incorporated into the MOU. The files of university presidents are filled with MOU's, but because of unrealistic expectations and insufficient mutual commitment, only a small fraction of these agreements has had a meaningful impact on the participating institutions.

An alliance of special interest to readers of this journal is the joint PhD program between the departments of chemical and biomolecular engineering at the University of Illinois at Urbana-Champaign (UIUC), and NUS (http://www.chee.nus.edu.sg/educational_program/AnnOnNewIntake.html). Although institutional in terms of its structure, the program relies on self-generated collaborations between faculty members in the two departments. Graduate students from both institutions are co-supervised, and are in residence in both countries over the course of their study and research.

Perhaps the most ambitious example of an alliance has been the Singapore MIT Alliance (SMA-1) (<http://web.mit.edu/sma/index.htm>), which was initiated in 1998 and has recently been extended and broadened (SMA-2) to include the possibility of dual graduate degrees between MIT and NUS or Nanyang Technological University (NTU). Primary themes in SMA-2 include materials, computational engineering, manufacturing, systems biology, and chemical and pharmaceutical engineering.⁶

SMA has been in existence long enough to provide several clues about the ingredients essential to a successful alliance. I would list them as follows:

- a. A long-term commitment from the top of both organizations.
- b. Clearly defined financial and other contributions from both institutions.
- c. Buy-in from a significant fraction of the faculty in those departments involved in the alliance.
- d. Clearly defined milestones and assessment criteria.
- e. Sufficient authority vested in individuals designated at each institution as responsible for the alliance. Those involved in the alliance should perceive they are dealing with “one-stop shopping”, not the complex bureaucracy that is the default structure of most alliances.

SMA-1 developed means for porting graduate courses at MIT to Singapore students. Much of the teaching was done in real-time, meaning that one group attended class in the evening and the other in early morning. This mode of instruction continues in SMA-2, but a strong emphasis has been placed on research collaboration. Based on white papers composed by MIT-Singapore faculty teams a few large projects have been selected that will lead to collaborative research with students working in Singapore and at MIT laboratories interchangeably. Ideally, each participant brings expertise to bear on a common problem that the other could not supply with equal ease.

All of this may appear to be a logical and efficient way to optimize research capability, but what does it have to do with globalization?

I return to the statement made earlier about the need to be where the customer is. If we are committed participants in research projects, some portion of which is conducted in parts of the world where an increasing number of talented engineers and scientists will be available, that allows a connection with those who might be unable or unwilling to enroll at a U.S. university. It also provides an important means to leverage on the strengths of partner institutions. If additionally we are working directly with indigenous institutions, those organizations should not feel threatened, and can indeed benefit from the long experience with graduate education and research associated with many Western universities.

Networks

Here I refer to a particular type of multilateral arrangement. Given the nontrivial administrative hurdles posed by binary alliances, one can rightly ask what motivating force prompts one to undertake the obviously greater challenges inherent in multi-institutional MOU's. There is no question that the administrative hurdles can be intimidating. On the other hand, certain economies of scale exist, and if one balances the administrative time devoted to, say, six binary MOU's, it probably exceeds that associated with a network of seven schools. However, the driving force for a network is far more substantive than that. If a network is properly focused at its inception, the possible rewards in terms of research accomplishment and education can be impressive.

One example of a network with which I am familiar is the Global Enterprise for Micromechanics in Molecular Medicine (GEM4) (<http://www.gem4.org/>). GEM4 grew out of the experience of Professor Subra Suresh, former head of the Dept. of Materials Science and Engineering at MIT. Professor Suresh was interested in the effects of disease states on the physical properties of biological cells, and he began a collaboration with colleagues at Institut Pasteur in Paris, and at the National University of Singapore. The Paris group had perfected techniques for gene disruption of specific cells, and in Singapore one could use optical tweezers to study the mechanical behavior of cells. Through this collaboration they have studied the deformability and adherence of red blood cells infected with malaria parasites. It is unlikely that these results would have been forthcoming from any one of the three institutions. Professor Suresh surmised that his experience was just one example of a situation likely to exist in overlaying the simultaneous needs for expertise in engineering, biology, and medicine. His vision was to create an entity that “belonged” to no single university, but had financial and in-kind buy-in from all members. GEM4 was officially launched in October of 2005. It already has 13 member institutions from five countries, and is attracting funding from government and philanthropic agencies. In the summer of 2006 GEM4 organized a two-week oversubscribed summer school aimed at interweaving relevant subjects from its three disciplinary origins.

I believe that GEM4 is a model with many of the features that can mesh research universities with the fast pace of a globalized society. However, the administrative, structural, and cultural challenges associated with alliances, such as SMA and networks such as GEM4 should not be underestimated.

Moving from Vision to Execution

Accepting the vision of global networks as desirable for research universities of the 21st century causes little controversy. However, turning that vision into a meaningful reality requires adjustment of some deeply rooted policies that in the past have often served as essential means for differentiating universities and providing relative competitive advantages. In the extreme they go to the very heart of the core competences and core values of a university. Some of these vexing issues are taken up below.

Intellectual property (IP)

Development of a satisfactory and robust IP policy has been an elusive goal for universities ever since enactment of the Bayh-Dole Act of 1980 that gave IP rights to universities for inventions growing out of federally funded research. During the past two decades universities have become increasingly possessive of IP as a means for revenue generation. Given the current level of satisfaction between faculty members and their administrations with respect to IP policy, the task of broadening it to a larger number of interested parties is daunting. Yet that is exactly the challenge that must be addressed when dealing with alliances or networks. There is no magic formula here, and negotiation between parties will be the rule. Assuming the IP evolves from a shared effort, the arrangement will probably reflect the best judgment of relative effort by people and institutions involved. The method of division of royalties among co-authors of a book should be a reasonable first-order model. As with this model, willingness to compromise and absence of greed are necessary conditions for a successful outcome.

Standards

A jealously held prerogative of our universities is the gate-keeping function of departments, university senates, and, ultimately, boards of trustees and perhaps state legislatures. What constitutes an acceptable dissertation? Who is responsible for a credit-bearing course? Who can confer a degree? Answering these questions translates globalization rhetoric into actionable programs. Anyone who has sat through a university senate meeting or listened to deliberations of boards of trustees can vouch for the contentiousness of these issues. Yet one cannot help but wonder if much of the concern about erosion of standards amounts to each university protecting the same, or nearly the same, crown jewels. I believe the real fear — and it is justifiable — is fear of loss of sovereignty, not loss of standards. Just as national sovereignty is impacted by multinational alliances, any meaningful international (or intranational!) arrangement cannot be accomplished without enough mutual trust and confidence between participants to allow some decisions affecting an institution to occur outside that institution's customary sphere of influence. Indeed, this may be a useful litmus test of the desirability of entering a multi-institutional arrangement.

Students

A predoctoral student from University *x* in, say, China is doing a portion of her dissertation research in the U.S. at University *y*. She is co-advised by faculty members from each location. What is her status while in residence at *y*? Presumably she is still enrolled at *x*. However, if she has a stipend, is that paid by *x*? Does she owe “rent” to *y* because of the time and space occupied there? Suppose there is a laboratory accident in which the student is involved. By whose insurance is she covered? If covered by the home country, is there a question of parity of safety requirements for the insurance to be valid? All of these questions may sound bureaucratic and boring to the two dissertation supervisors, but they are necessarily of great import to the universities, funding agencies, and certainly the individual students involved.

Faculty

Essentially all of the questions brought up for students apply also to faculty, along with additional issues. Some of them are similar to those associated with sabbatical leave policies, which, in fact, vary widely among U.S. universities. Continuing the example given earlier, Professor *Y* from U.S. university *y* will take his student to *x* for the summer, because of specialized equipment in Professor *X*'s laboratory. *x* is so pleased to have *Y* in residence that they bestow a temporary professorship on him. Will *y* allow *Y* to be a professor simultaneously at *y* and *x*? (Some U.S. universities do, some do not.)

Let us now raise the stakes one notch. The collaboration of *X* and *Y* has gone on so well that *Y* wishes to spend half of his time in residence at *x* for a period of three years. *Y* wishes to do this because of the unique laboratory at *x* and, perhaps more important, he will have access to brilliant nationals of *x* whom he would otherwise never have met. Some of these might even eventually become faculty members at *y*. What will *Y*'s dean, provost, and president say? If they say no, there may well be another U.S. university *z* which will say yes to *Z*, a highly qualified competitor of *Y*.

Summary and Conclusions

Globalization is with us. It is a wave we must ride rather than resist. Although the effects of globalization have revolutionized corporate behavior, they are only beginning to affect the thinking and much less the policies of U.S. research universities. We are on the cusp of a rapid and deep change in this situation. The premier U.S. research universities of today are global in that they draw students and faculty from all over the world. The premier research universities of a few decades from now will have a central location but their activities will take place in several countries through some combination of “branch” campuses, alliances with other universities, and multipartite research organizations, the latter belonging to no one university, but interpenetrating with several of them.

Successful adaptation to globalization will require broadened definitions of what it means to be a “member” of a university community. This brings into question such issues as loyalty, financing, and IP rights. Eventually, even the sacred ground of tenure might be impacted.

Revision of core principles comes hard, both to individuals and to organizations. Nevertheless, if U.S. universities are serious about retaining leadership positions through the 21st century, some of the core principles cited above will require modification. It will be necessary to move from rhetoric to action.

There are good reasons for universities to be conservative when changes affect the experience a student will have. There is no such thing as a “nondestructive test” so far as a single student's educational experience is concerned. That said, students will be ill served and the global rankings of our universities will decline if we are unwilling or unable to grasp the opportunities afforded by the challenges of a globalized society.

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