

## **“The Role of Graduate Schools in the American Innovation System”**

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Today I would like to compare the post-World War II performance of US universities with their European counterparts. In particular, I will be comparing the organization of US graduate education with that of European countries in fields relevant to economic performance, namely the sciences and engineering. I don't know much about Japan, but the more I learn, the more I am struck by similarities between the Japanese graduate and professional higher education system and that of Europe, so perhaps my comments on the European system will be relevant to this audience.

I would also like to say before I start that I am going to be painting with a broad brush on both sides of the Atlantic: certainly it is difficult to refer to Europe as having “one system” and there is considerable variety in the US as well.

There are approximately 3,500 “institutions of higher learning” in the United States, but that is, to be kind, a very general definition, and I will be limiting my comments to those commonly regarded as “research universities.” These institutions tend to be very responsive to changes in economic conditions, are highly decentralized, and intensely competitive. Professors compete for research support, and peer review is a very competitive process, evaluated on the basis of projected payoff of the research. This is much less the case in Europe: funds are distributed on a more or less equitable basis, with universities receiving block grants. These block grants are for teaching and research, and there is little release from teaching for those interested in research the way there is in the US. This may be in part because European universities are very full, and much more of the grant funds are earmarked for teaching. There is strong political pressure for more instruction due to the enormous student population.

Also, there is less impetus to do research, especially when the individual's desire to become a full professor is not especially strong. In Europe there is to some degree a two-tier system, in which there are lecturers and those who are full professors or on the professorship track. In some cases, lecturers may not be qualified or even eligible to

become professors, or to qualify for the available research funding.

Research productivity in science and engineering is more explicitly recognized and rewarded than in the soft sciences. Compared to Europe, the US system cannot properly be called a “system,” since it is so decentralized, and the way things are done in Europe would be quite foreign to US academics. It is common for education ministries to determine salaries and impose centralization in matters such as qualifications and degree requirements, something like the civil service system. This is changing, but very slowly.

Since there are very few private universities in Europe, there is little opportunity for competition with regard to salary. US universities, however, maintain autonomy to a great degree, up to and including getting funding. Consequently, they are also free to establish priorities and strengths of their own. There is no parallel to this in Europe. This is also true of US state universities, which are a very important part of the university system: the state university system is not considered to be civil service, and these institutions compete with private universities for faculty and research funds. The support they receive from the states is almost exclusively for teaching, not research.

Competition among US universities means there is a great deal of new material regularly introduced into the curriculum. The US “system,” if it can be called that, has achieved a synthesis of research and higher education that could be called unique, in that most research is done at universities by graduate students. In Europe, most research is done at research institutions that generally have very minor links to education. US universities can be seen as more “current” because graduate students participate in frontier research at universities because that is where it is being done, so they get more of what might be called “new science” than their European counterparts.

This could explain the high number of foreign students at US universities: 57% of engineering doctorates from US universities go to foreign students, and almost 50% of those in math and computer science go to foreign students. In Europe, teaching and research are separate to a very great degree; in eastern Europe especially, the Soviet model of having academies of various sciences is still very much in use, with researchers isolated and teaching thought to be a waste of their valuable time. I have read that this attitude has been especially damaging in Russia, where there is now literally no one who can knowledgeably lecture on the frontiers of scientific research.

In France, three government agencies control research funds, most of which is done in-house, although recently some universities with which the agencies have joint research centers have been receiving some funds. In the past 20 years, several good graduate schools for science have come into being, and there are distinguished institutes such as the Institute Pasteur. Many promising students, however, attend les Grandes Ecoles in preparation for the civil service, which takes them out of the university system (although they do get an excellent education). In Europe, prominent scientists will join a university faculty when they are older, but most do not teach when they are young. This is often seen with scientists from the Max Planck Institutes in Germany.

The US has exploited to good advantage the fact that the same people who are teaching are doing research on the graduate level. There seems to be an underlying belief that the instruction is better when the teacher is committed to doing serious research, and when bright graduate students participate. US academia is less hierarchical and authoritarian, and students are expected to question authority and be critical of their teachers. The research is better when bright, motivated graduate students are involved, and the necessity of lecturing to this type of student has raised the standard for academic rigor among professors. New science is then absorbed into US university curricula, which adds value all over the system: salaries increase, tuitions go up, and the graduate has a more practical, up-to-date education from the standpoint of the labor market. MIT is the classic example of this phenomenon.

The most important reason for US post-war leadership in graduate education is the aforementioned introduction of new material into the curriculum. There has been development of completely new disciplines, very rapidly, especially where it may have a practical application. A historical example is chemical engineering, and more recently computer hardware. The government funded computer research until the 1950s, when cutting-edge research began to be done by private companies. And later, universities played a critical role in ensuring US leadership in the computer software industry, with the introduction of the discipline of computer science. US dominance in this market was largely due to what I call the "Sputnik effect." The Russian launch of Sputnik has also been called "the best thing that happened to US science." In 1965, 30 US universities offered doctorates in computer science. By 1983, most BS degrees granted in the US were in computer science. The current openness of the Internet, I feel, is largely due to

the fact that it was developed in the university setting, without disputes over intellectual property rights and so forth. And the growth of this particular discipline has been, by standards of academia, extremely fast.

In the US, the majority of research funds are committed to the life sciences and molecular biology. Please see table 2: the 1996 figures show around 10% of funds to physical sciences, around 19% to engineering, including computers, and over 50% to life sciences. Over 25% of all research funds are going to medical research alone.

The core of the biotechnology industry has been university research, largely due to the recombinant-DNA breakthrough at Stanford in the 1970's. Virtually all of the first biotech startups involved scientists as decision-makers, determining business strategy and the direction of the industry. This is still a matter of some delicacy, in deciding what the balance must be between academic research and business activities, and is a contentious policy issue for some universities.

In 1970, 1/8 of all patents were biomedical inventions. In 1990, 1/4 of all patents were, and now, 60% of university licenses are biomedical inventions. At Columbia University, the medical school has 85% of licenses, many of which are for software. At Stanford, the highest earners are medical patents, and the medical school brings in eight times as much revenue as its nearest competitor, the engineering school. If you look at the table on the 2<sup>nd</sup> page of the handout, you will see that the top five US patent classes are medical. In Japan, the top five are photo or imaging-related (liquid crystal).

**Commentator:**

**Fumio Kodama, University of Tokyo, Faculty Fellow, RIETI**

Thank you, Dr. Rosenberg. I think I have learned today why Japan has “lost” the last ten years. The role of universities could have been important [during this period] but we didn't know how to discuss this issue. I wonder how the Japanese system would be characterized?

I was involved in US-Japan discussions on scientific research from 1982-1999. In the early part of this period, the US was very concerned about its competitiveness, and under a great deal of pressure to improve. We did not discuss biotechnology or computers—the areas that the US is now strong in didn't exist then. Although the

forum I was involved in remained in existence until 1999, the US lost interest around 1991. US competitiveness improved: how did you achieve this so quickly? Various US speakers on the subject said that it was largely due to the US university system, but they couldn't give me any solid evidence of this. You have shown me convincing evidence today. How do we move on from here?

You referred to the responsiveness of US universities, particularly to the economic environment. Japan is just the opposite: we are very rigid in defining academic disciplines. Public regulation of education could be a cause. For example, University of Tokyo student quotas were fixed for 20 years. This means that a certain number of students will study in each of the 21 departments. Until 1986, there were no changes at all in the numbers. Last year, the university added a graduate school of information science. But it was mostly a re-grouping of existing faculty, so maybe it is not so new. Some have argued that computer science should be taught in the context of existing disciplines. But now computer science does seem completely independent, so this issue is still being debated.

By way of comparison, let's look at these data.

Patent applications by universities:	Japan- .04%	US- 1.83% (of total)
Universities licensing to private companies:	Japan- 2	US- over 2,000

In Japan, university professors often turn over the title of inventions to private companies for little or no fees, without filing for a patent. They then become the co-applicant when the company files for a patent. In a survey by the Japan Biomedical Association, 38% of patent applications in genetic engineering have a university professor as a co-applicant. 72% of all patents are applied for by public companies, and virtually none are applied for by universities.

If we look at industry paper collaborations, most were between firms, or "intramural." Next in number were collaborations between firms and universities, and there has been a big increase in the number of papers produced through both these types of collaborations. One of my students did a comparison of US and Japanese industry papers produced using National Science Foundation data, and found that the number of papers produced in the US and in Japan are just about the same.

We believe that we can be responsive but still keep our organizations intact. The

personnel remain the same, but change their focus. Many people believe this is possible, but we may be approaching the limit of this style of responsiveness. There is technology transfer and patent activity in Japan, but one area we seem to be lacking in is new firm creation.

**Response to commentary:**

In the US post-war experience, university research breakthroughs have been commercialized by startup firms. This has been the main vehicle for change in the high-tech arena. Since the war, smaller firms have been much quicker to move on new technologies than giants like GE, and venture capital has made this possible. In the US, we seem to think it's ok to make tons of money as long as the access to opportunity is seen as equitable and open. New firms can function easily; it's an attractive environment, due to things like US antitrust law. The Justice Department has a history of getting after big companies to make technology available to the market. Even the Pentagon will use small firms and asks for a second-sourcing agreement, the name of another firm who can provide the same technology to maintain competition for the contract. There is great political support for entrepreneurship (even though it is not always most effective when support is a direct government effort, such as the Small Business Investment Corp.) and small businesses are regarded as a very important part of the US economy.

**Question & Answer**

***Q: In Japan, we are undertaking higher education reform. You have talked a great deal about the relationship in the US between research and graduate education. Can you please share your views on the relationship between undergraduate and graduate education?***

**Nathan Rosenberg**

The US system has produced a number of small and excellent (undergraduate) liberal arts colleges that place a great emphasis on teaching, places where research is less important. People who are serious about research do not last long at such places, and aspire to teach at the graduate level. There is still a certain tension between research and teaching.

***Q: Can you please give some explanation of the granting system? It doesn't seem to be a system that would promote the creation of new disciplines, since peer review of projects would naturally be slanted to existing areas of research.***

**Nathan Rosenberg**

Peer review is often vulnerable to fashion. Most brilliant and cutting edge work was difficult to get published at first. New fields often stem from new funds coming available (such as the \$150 million recently donated to Stanford) or events such as needing to put a man on the moon; as I said, the Sputnik effect. Philanthropy also plays a huge role- organizations such as the Rockefeller and Sloan Foundations.

***Q: What is the role of military research in the US?***

**Nathan Rosenberg**

As much as it goes against my liberal leanings to say so, the Pentagon and the military have done a great job of funding basic research. The Office of Naval Research has had a very enlightened policy for funding research. ARPA was key in developing computer science as both a discipline and an industry, and is of course responsible for what we know today as the Internet. A little-known but very important funder has been a place called The Joint Services Electronics Program (JSEP). They have funded some top universities to research solid-state physics, and this has produced quite a few Nobel laureates.

***Q: It has been said that US scientific research has been supported by two fears- fear of a Cold War and fear of cancer.***

**Nathan Rosenberg**

Even good things are easier to get funded in Congress if you call them a war: hence Nixon's War on Cancer. It has produced some good research.

*-The RIETI editorial department is responsible for this article.*