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The University in the U.S. Innovation System

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Innovation and Its Organization

I would like to begin with an insight from one of MIT's most distinguished economists, Robert Solow. Professor Solow was the first of the growth economists, challenging the static model of classical economics and its explanation of economic growth as derived from capital supply and labor supply. He found – and perhaps this was not surprising from someone working at MIT – that over time more than half of U.S. economic growth since World War II had come from technological innovation.

Professor Solow won the Nobel Prize in 1987 for his work, but as a nation we are only now beginning to grasp its implications. An important moment came this January, in the State of the Union address. There, in a striking departure from the classical economics that has so long shaped the thinking of both our parties, President Bush drew an explicit connection between economic growth and investments in research and talent.

If we accept Professor Solow's argument that growth stems from technological innovation, then how we organize science and technology becomes very important, and I believe that the organizational models we adopt will have enormous implications for American competitiveness in the decades ahead.

During World War II, MIT's Vannevar Bush became science advisor to President Roosevelt. Under his leadership, science and technology were integrated, sheltered under a single, flexible organizational umbrella. The "R" of research and the "D" of development were truly connected, and the results were remarkable. Much of modern electronics has flowed from work at the Radiation Laboratory set up at MIT to develop radar, and Los Alamos in its turn followed the same model.

At the end of the war, Bush wrote the most famous polemic in the history of U.S. science: *Science, The Endless Frontier*. There, he argued that the federal government should not abandon the great system of scientific advance set up during the war. Instead, it should hold onto a residual role – the funding of basic research.

Bush's was essentially a pipeline model, segregating the stages of research and development, and focusing the federal role at the earliest stage. "R" and "D" were separated, in the belief that research activity early in the pipeline would result in development, prototyping, and products. Under the system that emerged, the role of the university was to perform fundamental research. The pipeline model, however, does not reflect the modern relationship between science and technology. That model assumes a one-way flow from science to technology, from basic to applied. But the one-way flow is

actually a two-way street. The relationship between semiconductor electronics and semiconductor physics is one example. There, the applied work transformed the fundamental research – not just the other way around.

The model that Vannevar Bush created has been enormously productive. The federal government supported basic scientific research that industry could not, and those federal investments fueled the emergence of the modern American research university, which integrates research and teaching and has become the envy of the world. But Bush worked in a very different context from our own. The economy of the late 1940s was a corporate economy characterized by mass production, by great national markets, by national factory systems, and by scale, not product individualization. The corporations that dominated that economy were interested in incremental rather than radical innovation; technology was not intended to be, as we now put it, “disruptive,” and we built great industry lab systems to support incremental innovation.

The New Innovation Model

About every 50 years, however, the U.S. is hit by a great disruptive innovation wave, where new technologies bring fundamental changes to organizations, the economy, and society. I hardly need tell you that we are in one of those periods now. Our mass-production economy is being superseded by a knowledge economy based on information technology. The models are very different. That mass-production economy was both hierarchical and bureaucratic. The emerging economy based on information is – so far, at least – flat and collaborative, and relies on networks.

We can see this emerging economy in changes within manufacturing. During the 1980s, the U.S. mass production model faced a tremendous challenge from a Japanese model focused on “lean manufacturing” and quality. In response, American manufacturing emulated Japan’s, seeking tighter integration between suppliers, assemblers, and customers. Now, our manufacturing sector is becoming disaggregated, distributed, dispersed – a radical departure from the integrated model of a decade ago.

We see a new rise in contract manufacturing. Perhaps the best example is the ubiquitous Apple iPod, which was brought to market in less than year because it was designed around component parts that were already being made by a number of other companies. Speed to market is critical for today’s new technologies, and disaggregated manufacturing is a crucial competitive strategy.

This new economy, based on information technology, is driven by startups and entrepreneurs who seek not incremental innovation but radical breakthroughs. It relies on new sources of capital – venture capitalists, angel investors, and IPO’s. And it is also forcing a new kind of research organization, one that is less integrated into established enterprises, and increasingly virtual. In yet another manifestation of the tendency towards disaggregation, the great industrial labs are being redefined – when they are not actually swept away. And with this change, the university has stepped into a much more central

role in the innovation system. Fortunately for our nation and our economy, a number of U.S. universities were ready for this change in research organization.

It will not surprise you if I take MIT as an example. For our university, the defining experience of the 20th century was the convergence of engineering and the physical sciences. Starting in the years before World War II, and drawing on the discoveries in physics earlier in the 20th century, MIT President Karl Taylor Compton developed strong science programs alongside our existing engineering programs. Our experience with the Rad Lab proceeded to demonstrate conclusively that strong science would support advances in both science and engineering.

After the war, MIT developed a new engineering curriculum anchored in basic science, and since then our interdisciplinary laboratories have created strong connections between engineering and science and supported the collaboration that is the essence of innovation. As a result, we have been able to make fruitful connections with an emerging entrepreneurial culture. MIT has not, of course, been the only university to do this, although we have been particularly successful at it.

The electronics and information revolution, which has so profoundly changed how we live, work, and communicate, emerged from the convergence between the physical sciences and engineering. Now we are witnessing a parallel convergence between the life sciences and engineering, growing out of the postwar discoveries of molecular genetics. The new life-science industries draw on the innovation systems and entrepreneurial culture developed in the information revolution.

The information and life-science industries have eroded the old divide between R&D, and the same process will increasingly take place in other innovation sectors. The “upstairs-downstairs” relationship between the academy and industry is over: careers involving both sectors are now commonplace. So while universities continue to train the next generation of researchers, we also increasingly serve as our society’s discovery center.

Universities themselves fit the emerging organizational and entrepreneurial models of the knowledge-based economy: they are relatively flat, their research cadres are relatively non-hierarchical and collaborative, and they are built around knowledge networks. Our task now is to intensify the creative relationships we have already built with the knowledge-based economy – to create new, connected models that supplement the long-established pipeline model.

Conclusion: Challenges Ahead

In recent decades, our nation has evolved a new model for economic comparative advantage in a global economy. David Ricardo’s early-19th-century theory of comparative advantage was resource-based; the model for the 21st century is innovation-based.

There is an inherent risk. As MIT Professor Paul Samuelson has noted, others can model your innovation system and capture the innovation advantage, and our global competitors

understand this well. Our comparative advantage will depend increasingly on our national investments in R&D and in science talent, and I have to say that I am worried about the outlook.

Federal R&D spending, the basis of the university contribution to the innovation system, has been falling when measured as a percentage of gross domestic product, from 2 percent of GDP in the mid-1960s to eight-tenths of one percent today. And while federal investments in the life sciences doubled between 1998 and 2003, federal investments in the physical sciences and engineering stagnated over the same period. We are now seeing welcome new public attention to these issues, from the American Competitiveness Initiative that President Bush announced in his State of the Union message to legislative activity in both houses of Congress. But such proposals must make headway in a very constrained budget environment.

At the same time, we are not doing a good enough job attracting young people to the fields most crucial for innovation, or giving them the skills they need: science and math education is the prerequisite for innovation. In China, 49 percent of bachelors' degrees are awarded in science and engineering. The equivalent figure in the United States is 15 percent. We are also falling behind both the European Union and Asia in doctoral degrees in the sciences and engineering. In short, while as a nation we still have a science lead, we are not in a good position to sustain it.

Obviously, this is not an exhaustive list of the challenges. We need to strengthen K-12 education in math and science. We need to ensure that university education remains accessible to students from all socioeconomic backgrounds. We need to welcome international students and scholars to study and work here. And we need to balance the goals of national security and intellectual openness. But if we can address research funding and expand the talent pipeline, we will go a long way toward retaining the comparative advantage the U.S. economy has built up since World War II.

Of course, the importance of innovation goes beyond even competitiveness. Think about energy, for example. This week we will release the report of MIT's Energy Research Council. The Council includes faculty from all of our five schools, whom we asked to help develop an Institute-wide plan to address the global energy challenge. If we are to solve the challenges of supply and demand, of energy security, and of environmental sustainability, we simply must innovate.

I am delighted to be here today with so many thoughtful people who care passionately about these issues, and I look forward to our joined efforts to keep our economy vibrant and competitive in an increasingly complex global environment.