science progress

Beyond the Box

Innovation Policy in an Innovation-driven Economy

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Introduction

Everybody agrees that innovation is important to our nation's economic growth and future prosperity, but what can the government do to promote it? The consensus of four years ago focused on remedying our perceived competitive shortcomings in science education and research, especially in the physical sciences. Today, the question takes on new urgency with the recognition that much of the economic growth experienced over the past decade was illusory. For the long term, we need to take a closer look at the institutions that enable innovation, not only to see how they can be better coordinated but also how they can respond to the evolving forms and practice of innovation.

This kind of adaptive intelligence has not been a strong point of the federal government, but it is essential to long-term economic growth and security. It will require infusing competence, innovation, and entrepreneurship into the government. Yet it also means recognizing that the capacity and role of government is limited, and that the functions of government are subject to high standards of transparency, accountability, and participation.

A national commitment to innovation requires not only remediation but exploiting our strengths and enhancing the fabric of innovation, especially in the social, commercial, and institutional applications of technology. Innovation policy as practiced to date tends to take a top-down macroeconomic approach that views public research funding and tax credits as the primary policy tools. Those are important tools, but they are limited (and costly) and get caught up political processes that have become all too familiar.

Important as they are, they should not distract from a closer appreciation and understanding of the processes of innovation—processes that can be improved by a focused and coordinated approach to standards, infrastructure, enabling technology, clusters, and patents, an approach that takes into account evolving practices and models in the many contexts in which innovation takes place.

Promoting Innovation

It's now clear: Innovation is the principal driver of productivity and economic growth. But what can and should the federal government do to promote innovation? The question is usually framed in terms of national competitiveness: How can we compete with the millions of scientists and engineers in China and India? The mainstream consensus, embodied in the America COMPETES Act of 2007, advocates more research in the physical sciences and more science, technology, engineering, and math education.

But despite bipartisan support for the COMPETES Act, its authorizations remained largely unfunded prior to the 2009 economic stimulus legislation. For example, the new Technology Innovation Program, which is run by the National Institute of Standards and Technology and which replaced the politically contentious Advanced Technology Program, received only $25 million for new projects. Other measures in the Act—a President's Council on Innovation and Competitiveness, studies of service science and barriers to innovation, and an ARPA-styled agency at the Department of Energy—also remain unimplemented. Meanwhile, the Act quietly abolished the Technology Administration at the Department of Commerce, along with its tiny Office of Technology Policy, leaving nothing in place to support innovation policy.

The impetus for the America COMPETES Act was the National Academy of Sciences 2005 report, *Rising Above the Gathering Storm*. Like other National Academy reports, *RAGS* (as it is affectionately known) represents a consensus of a distinguished committee, a mainstream document inspiring mainstream legislation. *RAGS* is a common-denominator approach to innovation policy, and the work behind it is now five years old.

Intuitively, of course, more research funding going into the pipeline will produce more innovation at the far end. And more funding for education will eventually produce more scientists and engineers, which should also produce more innovation. But what real difference will adding thousands of presumably less motivated engineers make? Why not just hire engineers from China and India willing to work for one-fifth as much? Will more of today's engineering education really help 20 years from now, or do we need something different?

More of what used to be our national advantage might be nice. But is it enough?

Like competitive advantage, innovation is a moving target. Just as businesses need to operate in a volatile global economy with knowledge and foresight, innovation policy must respond to challenges and opportunities. Occasional studies by the National Academy, the Council on Competitiveness, and others do not build capacity and sustained focus. Yet our long-term economic security depends on our ability to innovate. We need institutionalized capacity within the federal government, not only to support the vision of political leaders who care about innovation, but to endure beyond the next election.

We are already deeply invested in innovation. The federal government spends $150 billion a year on research that the private sector does not invest in. We have a patent system that dates back over 200 years but has grown complicated, costly, unpredictable, and controversial. We have a research-and-experimentation tax credit that keeps getting renewed and expanded but never made permanent, year after year.

There are a rich variety of agency-based programs and tools. NIST supports measurement infrastructure for industry. The Small Business Innovation Research Program cuts across all research agencies to ensure small business participation. NIST operates the Manufacturing Extension Partnership program and the Technology Innovation Program. The National Science Foundation funds programs to stimulate interdisciplinary research, support researchers early in their careers, promote collaboration between industry and academic researchers, and develop a scientific understanding of science and innovation policy.

Other tools for promoting innovation include visas for engineers and scientists, prizes, procurement, leadership by example, and legal and regulatory decision-making and workforce development programs. In short, there are many tools and vehicles for promoting innovation, but they are scattered and typically stovepiped, with little or no coordination and expertise at the top.

Understanding innovation

Can we at least agree on what we are talking about? The Commerce Department's Advisory Committee on Measuring Innovation in the 21st Century Economy recently defined innovation as an activity rather than a specific result:

> *The design, invention, development and/or implementation of new or altered products, services, processes, systems, organizational structures, or business models for the purpose of creating new value for customers and financial returns for the firm.*

Innovation does not necessarily involve research, although research is often a big part of the process. Innovation does not necessarily involve invention, although an innovation may include thousands of potentially patentable inventions. Innovation, in sum, means turning research, experimentation, inventions, raw materials, assembly processes, design, and testing into marketed products and services.

What's more, innovation is of marginal use unless it is successfully adopted and used. Read literally, the advisory committee's definition seems to exclude innovation by government agencies, nonprofit organizations, and users. But we want productive innovation wherever it can take place, and innovative producers need innovative users. The OECD definition is more expansive and lists four types of innovation: product, process, marketing, and organizational.

The term "open innovation" (as popularized by University of California, Berkeley Professor Henry Chesbrough) describes how innovation in manufacturing has moved from in-house research labs to become globalized and distributed. Following trends in manufacturing, research is increasingly outsourced, acquired from partners and collaborators, or bought on the open market, often by acquiring startup companies. Innovation is less directly controlled, less internal to individual companies, and more the combining of research, design, technology, and components from multiple sources.

Some U.S. companies, such as Cisco Systems and Dell, excel at pulling the pieces together. Apple Computer is uniquely capable of integrating invention, design, software, marketing, and customer skills in a coherent innovation-based product strategy. IBM, another microcomputer pioneer, has moved aggressively in the opposite direction, away from mass production to the design of integrated solutions and services that span business and technology.

In an article provocatively entitled "The Post-Scientific Society," George Mason Professor Chris Hill makes the case that the most significant innovations now come from the novel organization of economic activity rather than the traditional R&D pipeline:

Companies based on radical innovations, exemplified by network firms such as Google, YouTube, eBay, and Yahoo, create billions in new wealth with only modest contributions from industrial research as it has traditionally been understood. Huge and successful firms like Wal-Mart, FedEx, Dell, Amazon.com, and Cisco have grown to be among the largest in the world, not as much by mastering the intricacies of physics, chemistry, or molecular biology as by structuring human work and organizational practices in radical new ways.

These new ways include crosscutting collaboration within companies as well as the varieties of "open innovation." They include different strategies for engaging users, as well as upstream innovators and partners. This usually entails going beyond market transactions to long-term relationships based on trust and confidence. In other words, it's not just finding and integrating component parts, but nurturing relationships that support the different processes of innovation. The ultimate advantage comes in managing these processes in support of a powerful (and preferably unique) business vision.

"Open innovation" in the original sense contemplates distributed sources of innovation, but with bilateral relationships between, say, a supplier and a buyer. Yet "open" can also refer to the actual process of innovation. An open innovation *process* generally involves multiple parties working together in common activity. It may be open only at the beginning or throughout the process.

The development of standards is a classic example. Standards accelerate market development and open up new opportunities for differentiation and proprietary advantage, but setting standards is a cooperative activity. It is not ordinarily a source of advantage—although it can be for companies whose technologies are chosen for the standard. Instead, it represents the kind of "coopetition" that has contributed greatly to the rapid innovation and productivity growth in information technology.

This kind of *multilateral* collaboration is especially suited to the collecting, organizing, and sharing of digital information—open source software development, open data initiatives in biotechnology, and the evolution of Wikipedia and other wikis. These new forms of innovation are typically enabled by software that supports process management by modularizing tasks, recording comments and interaction, and giving limited controls to a subset of the participants.

Missing: the process of innovation

Coming on the heels of the doubling of funding for the National Institutes of Health, *RAGS* was a reminder that physical science also matters, and that we need to pay attention to it. But the report is equally noteworthy for what it does not discuss. As Harvard University Professor Lewis Branscomb observes:

[T]he report claims to say how to make the U.S. economy more innovative, but it addresses only the vital necessity of improving public education, encouraging U.S. students to study science, and strengthening our research leadership. In this hugely influential report, the linkage between the generation of new ideas and the process of innovation is dealt with by an attention-grabbing list of ways in which our economy might fail to be internationally competitive. It leaves the role of enhancing the power to innovate to the private sector, except for one role for government: to revisit the world of intellectual property law.

In other words, *RAGS* gains political traction by focusing on basic necessities and statistical comparisons with ascendant economies such as competitiveness rather than innovation. The report avoids controversy about the role of the government to embrace a common-denominator political perspective.

There are no recommendations, for example, on providing funding to bridge the "valley of death" between research and commercialization. And there is no discussion of NIST's Advanced Technology Program, which was assessed favorably by economists but viewed as government intrusion in the market by conservatives in Congress.

RAGS also does not address extension services, innovation clusters, or state investments. It avoids discussing public support for generic, pre-competitive enabling technologies, a policy adopted by the George H. W. Bush administration. It argues for universal broadband, but otherwise it views information technology as one technology among many.

Then there's the brief discussion of intellectual property in *RAGS* that reiterates three (out of seven) recommendations on patent reform from an earlier NAS study and adds a fourth:

Change intellectual-property laws that act as barriers to innovation in specific industries, such as those related to data exclusivity (in pharmaceuticals) and those which increase the volume and unpredictability of litigation (especially in information-technology industries).

Rather than come to grips with the one-size-fits-all problem of the patent system, the report spends a single paragraph acknowledging that "[p]atent issues are also particularly important to the information technology industry," and concludes that "those issues are opportunities for Congress and other relevant federal entities to take productive actions."

Yet in the same breath, the report expends two full pages saying why pharmaceutical manufacturers need to have double the current five years of test data exclusivity. So even this "consensus" report includes a special-interest recommendation in the one area where it acknowledges a government role—a recommendation that probably would not have made had there been a generic drug producer or consumer representative on the committee.

RAGS offers its recommendations with great confidence, while sprinkling its pages with boxes offering "another point of view." It avoids controversy and does not acknowledge big unanswered questions or offer a research agenda. The America COMPETES Act at least mandates a study of barriers to innovation and a study of service science. (Services now constitute nearly 80 percent of the U.S. economy, yet the role of R&D in services is not well defined or understood.) The still-uninitiated studies could help balance *RAGS*'s heavy emphasis on the physical sciences and focus attention on innovation as a process.

Technology enabling innovation

The process of innovation encompasses a large number of intermediate inputs: research tools, standards, product design, manufacturing processes, financing, even marketing. There is often little cause for government involvement and a danger that intervention will have unintended effects. Yet in some cases, special treatment of enabling technologies may be justified to ensure that benefits are widely shared. Case in point: National Institutes of Health guidelines encourage non-exclusive licensing of research tools developed with public funding.

Information technology is a powerful and pervasive general-purpose enabling technology, intimately tied to the fabric of innovation and the forces of specialization and globalization. It is the essential enabler for new services and for innovation in marketing and organizations, including the government. The IT sector is also extraordinarily innovative in its own right, with a history of double-digit productivity gains that far outstrips other sectors of the economy.

Indeed, with advances in performance, declining costs, new processes, products, and services, IT has become the primary factor in increasing productivity and enabling innovation across the economy. It has driven the post-creation costs of information to near zero—zero reproduction costs, zero distribution costs, zero degradation, and zero depletion—with dramatic effects on encyclopedias, newspapers, and the music business, as well as on personal, social, and political use of information.

IT's dual role as an innovative technology and as a powerful enabling technology makes IT-related policies a de facto driver of innovation policy, especially in the absence of a well-defined approach to innovation policy. Critical IT policy domains include:

Broadband

The United States has fallen behind other leading economies in broadband penetration. *Rising Above the Gathering Storm* recommended support for universal broadband access as an essential platform for innovative applications and services. This year, Congress provided $7.2 billion in the $787 billion economic stimulus package.

Patents

Patents pose unique challenges in IT because of the complex, networked nature of IT-based products and services. The possibility of thousands of potentially patentable functions in a single product makes individual patents less valuable but increases the risk of inadvertent infringement. Judicial and administrative decisions making patents easy to get has led to massive portfolios—and to opportunities for arbitrage and extortion. The IT and financial services sectors have been the strongest advocates of patent reform.

Standards

Standards enable interoperation of components, products, and services. They are strategically important for innovation in IT because they assure that investments will not be stranded and help create markets for new technology. The need for rapid development of IT standards to support innovation has led to alliances and consortia, mostly based in the United States, as agile alternatives to formal standards development organizations. However, the increased scope and volume of patenting has led to increasing tension with collaborative standards development.

Research

Reflecting the crosscutting importance of IT, federal research agencies invest heavily in IT research. Their activities are coordinated through the Networking and Information Technology R&D Subcommittee of the National Science and Technology Council (supported by a National Coordination Office, which reports to the Office of Science and Technology Policy in the White House). The President's Information Technology Advisory Committee provided outside oversight until it terminated in 2004.

Advanced cyberinfrastructure

The National Science Foundation supports the development of advanced user-centered, software-based cyberinfrastructure. Operating out of the NSF Director's Office, the cyberinfrastructure program addresses the relationship between system design and social, economic, and legal institutions—all under the rubric of "virtual organizations." Although funding is generally targeted to research and education, advanced cyberinfrastructure can support a wide range of applications, including process management and cross-sector collaboration.

Federal operations and infrastructure

The world's largest user of information technology, the U.S. government is increasingly dependent on IT in its interaction with citizens, businesses, and state and local governments. Intentionally or otherwise, government use of IT helps set standards, diffuses new technologies and applications, and, when it contributes to the efficiency and effectiveness of public functions and services, can lead by example.

In fact, the public-facing use of IT has been a major initial focus of the Obama administration, building on the campaign's achievements in using the Internet. With no need to go to Congress for new legislation, the administration is using IT to implement a commitment to competent, transparent, participatory, and collaborative government. And in doing so, it demonstrates that government itself has the capacity to learn, adapt, and innovate.

Knowledge infrastructure

President Obama's memorandum issued the day after Inauguration speaks of "participatory" in terms of the need to access distributed knowledge:

> *Public engagement enhances the Government's effectiveness and improves the quality of its decisions. Knowledge is widely dispersed in society, and public officials benefit from having access to that dispersed knowledge.*

But while information has gone digital, free, fast, and global, knowledge remains sticky, local, complex, tacit, and context-dependent. Knowledge can't simply be posted or pushed down a pipeline; it is hard to transmit, absorb, and apply. Whereas information is increasingly cheap and plentiful, knowledge is in short supply—and a growing source of advantage.

While the Web facilitates access to information, hyperlinks define relationships and give context to content, an important step toward representing and communicating knowledge. At the same time, the Web has democratized information technology. Authoring websites is not rocket science; it is designing soft-wired structures that require editorial judgment more than technical skills.

Before the Internet, infrastructure was conceived in simpler terms as networks of standardized modality—rails, roads, electricity, voice telephony, mail—in which there was no connection between the network and whatever it carried. The Internet combined two different models of infrastructure: the network, as in the phone system; and the platform, such as the personal computer, upon which a vast superstructure of applications could be developed.

Unlike the telephone system, the Internet carries multiple protocols performing different services. It supports email but it also supports the Web, file transfer, video conferencing, and Twitter. The Web allows unsophisticated users to construct networks out of information, specifically links that point from small objects (words, images) to web pages and other addressable objects.

Search engines go a step further by using algorithms to evaluate links and enabling users to create an ad hoc knowledge infrastructure out of keywords. Wikis enable collaborative processes for organizing large and complex knowledge bases. The most evolved and institutionalized wiki, Wikipedia, combines ongoing construction of linked content with a set of policies, rules, and a small number of individuals with the power to mediate and manage differences of fact and opinion.

The wiki is the closest model for the collaborative process of assembling knowledge—implicitly embraced by the Obama memo's commitment to "collaborative government:"

> *Executive departments and agencies should use innovative tools, methods, and systems to cooperate among themselves, across all levels of Government, and with nonprofit organizations, businesses, and individuals in the private sector.*

Unlike transparency and participation, collaboration is a relatively new principle that raises new and challenging questions. The president's memorandum views collaboration as an IT challenge, which it assigns to the Chief Technology Officer in coordination with the Director of the Office of Management and Budget and the Administrator of General Services.

Boundary spanning and beyond

The prepositions in the memorandum's description of collaboration ("among, across, with") signal the critical importance of boundary spanning, both within government and between government and the private sector. The Internet famously enables boundary spanning at levels from undersea cables on up the stack to wikis.

But boundary spanning is not just a matter of technology. "Boundaries" take many different forms—from departmental boundaries to disciplinary boundaries to institutional and company boundaries to political and jurisdictional boundaries to boundaries between the academy, government, and industry. Barriers of time and space are, in effect, boundaries. Free trade, migration, study abroad, multidisciplinary programs, top-level decision-making, research consortia, patent pools, partnerships, and academic networks all involve boundary spanning.

However and wherever the spanning takes place, the boundaries do not dissolve or disappear. They are there for reasons. Free trade is promoted while political identity is preserved. The U.S. federal system has evolved under this principle, and Europe aspires to market integration while retaining national and regional identities.

But capabilities for boundary spanning are growing. International mail, telegraph, telephone, and fax provided thin, rudimentary forms of boundary spanning. The Web enabled information sharing on a large scale and gave us global electronic commerce. The richness of information sharing, combined with inexpensive travel, enables the management of R&D across boundaries—*open innovation.* Boundary-spanning infrastructure enables not only remote transactions, but continuing relationships—not only reliable suppliers and customers but real-time collaborators engaging in the complex and uncertain processes of innovation.

By connecting outlying buyers and sellers who would have a difficult time finding each other in physical space, eBay, Innocentive, and other new business intermediaries are able to expand markets to include the famous "long tail" of rare, nonstandard, and complex transactions. Similarly, the Web enables specialists to identify each other as sources of knowledge or as potential collaborators. These unformed relationships are hard to value, except after long experience or tangible outcomes, but the Web enables informal contacts to evolve organically through exchange of information and ideas with no formal investment or commitment.

The informality and ease of connection combined with basic Internet functionality gets beyond the conventional bilateral relationships that characterize marketplace transactions and analog forms of communications (letters, telephone). Bear in mind that the most revolutionary feature of email was not its speed or ease of use but multipoint-to-multipoint communications—the unprecedented ability to construct networks out of distribution lists.

The multilateral functionality that we now take for granted in email has radically changed the prospects for collaboration. For instance, consortia are not new, but they have suffered from a variety of institutional limitations: competing agendas, defensive conduct, opportunistic behavior, free rider problems, ineffective management, and so on. These problems do not go away, but IT provides tools and infrastructure for addressing them creatively, consistently, and in a structured, well-documented manner. IT supports new models of innovation—Internet standards, open source software, wikis—unburdened by the delays, negotiations, overhead, and direct costs of capitalizing the enterprise and providing fair and accurate compensation to contributors.

But the IT-enabled boundary spanning only goes so far. Ultimately, it can run up against laws, rules, policies, institutions, and practices established long ago under different circumstances for reasons that may or may not make much sense today. These limitations can be modified, and should be if we believe that our nation's innovative capacity is at stake. Congress, for example, has encouraged standards development and cooperative R&D by limiting the application of antitrust law. But it is often difficult to draw lines between the old and new environments, as the struggle over patent reform has shown.

Less tangible factors may affect capacity for collaboration. Diversity teaches cooperation and promotes creativity. The United States has struggled with diversity in the context of federalism, immigration, the Civil War, and racism while ultimately benefiting culturally from its existence and enjoying both economic and political returns from overcoming old barriers. Most countries lack our diversity of make-up as well as the long experience in learning to accommodate differences. While experience with diversity may not seem to matter much for narrowly defined technology, it may help considerably where technology meets design, expressive content, management, and institutional innovation.

Other drivers in boundary-spanning innovation

If we recognize the interaction between knowledge infrastructure, boundary spanning, and innovation, we can see a number of drivers that put the United States at the epicenter of global innovation.

Language

For practical reasons, English has become the lingua franca of international commerce, research, higher education, political discourse, and management. It is not the number of native speakers that matters but the breadth and depth of use.

The dominance of the English version of Wikipedia can be seen in the number of articles, but even more in the scope of treatment and editorial intensity in each one. The European Union has 23 official languages, but English is the de facto common language, in part because it has been both a commercial and cultural bridge between the U.S. and Europe. Other languages once served to span linguistic boundaries in science (German) or diplomacy (French), but the broad role of English today is the result of network effects operating across all nations and all disciplines and professions.

Universities

As the name implies, universities aspire to address all areas of knowledge within their walls—and do so with increased attention to spanning disciplines and methodologies. American universities were the first to embrace the integration of research and graduate education and, more recently, to assume a role in innovation as a public service, through helping to commercialize research, collaborating with industry, disseminating research results, launching startups, and seeding regional clusters.

Standards

Unlike other governments, the U.S. government does not participate directly in traditional international standards development, but the United States was and remains the home of consortium-based global standards setting. The Internet itself was the product of a revolutionary open standards process that brought together experts from academia, national labs, and industry—predominately from the United States but not to the exclusion of researchers from other countries.

Cyberinfrastructure

NSF's vision for highly integrated, standards-based, user-centered knowledge infrastructure is designed to support particular research communities while making use of common standards and services. The cyberinfrastructure agenda is not limited to classic research and education functions but includes workflow processes and the activities of virtual organizations. Meanwhile, different forms of advanced cyberinfrastructure (under a variety of names) are emerging in business applications, as well as in privately developed social networks, virtual worlds, and software as a service.

Virtual organizations

New forms of organization have been enabled by the Internet, including the Internet Engineering Task Force. The IETF had no formal membership but relied heavily on the Internet for organizing and managing its work. Different forms of virtual organization have since proliferated, such as open source software projects, collaborative content development such as wikis, and community-specific cyberinfrastructure. Virtual organizations may have legal and financial structures, but they are shaped by a common project or activity realized over the Internet.

Regional innovation clusters

Regional clusters have a long history as centers of specialized economic activity. The classic example is the apparel industry in northern Italy, which dates back over hundreds of years.

Companies in clusters often compete with each other but benefit from being co-located where there is a substantial pool of skilled labor and a vigorous market for raw materials, equipment, and complementary products and services.

Innovation clusters add other elements to the mix: universities, venture capital, specialist start-up companies, and sometimes assistance from local or regional governments. Silicon Valley stands as the archetype by virtue of its long-established combination of leading research universities, availability of venture capital, and numerous innovative companies.

It may seem odd to include localized innovation clusters in a list of technological and institutional factors, but nothing connects like proximity. Just as universities benefit from combining knowledge, knowledge skills, and knowledge creation together in a single location, a regional cluster benefits from the proximity and interaction of skills and institutions (including universities). A common location offers the greatest opportunities for boundary spanning at the highest bandwidth. Spillovers, synergies, and community can be enjoyed without administrative or legal overhead. There are no walls or gates; participants may come and go as they wish.

Conventional thinking is that location matters less now, but this thinking again confuses information with knowledge. In a flat world where information flows easily and freely, virtual tools and virtual organizations are accessible to everyone. Advantage lies in the ability to generate and manage knowledge in all its recalcitrant complexity. The richness of colocation provides a competitive edge against the world by offering the nuance and rich interaction that physical presence makes possible. Where smart, ambitious, creative people get to know and trust each other, innovation is "in the air."

Regional innovation clusters have not been supported by targeted federal funding in the past. Yet even very modest federal funding could stimulate and focus local and regional thinking so that it goes beyond bidding with tax breaks for particular companies and industries—a notorious zero-sum manifestation of the "more of the same" problem. The administration's 2010 budget provides $50 million for regional innovation clusters.

Building capacity and engagement

Like innovation, innovation policy runs all the way from insight and invention to implementation and impact. Just asking the right questions requires intellectual bandwidth, always in short supply. The Office of Technology Assessment and Office of Technology Policy are gone. Congress has many issues demanding its attention.

Without concerted attention, it's easy to remain stuck on old models. A pipeline running from funding to research to patents to products remains the dominant metaphor—a model of controlled exclusivity that still looks compelling enough in some circumstances to be dangerous in others. But in the sector most crucial to productivity—information technology—nonexclusivity and cross-licensing is the norm. In software, innovation is prolific and massively parallel.

Rather than focus on how our economy might fail to be internationally competitive, we should concentrate on building on our strengths. Like U.S. industry, we must recognize that more innovation is taking place beyond our boundaries and work to take advantage of it. Rather than just shoveling more into the front end of the pipeline, we should enhance processes, relationships, and networks that are the fabric of innovation. Rather than focusing exclusively on hard science, we should look at the soft-wired upper layers where economic, social, and cultural design make the difference—where context is king.

The upside to the elimination of the Technology Administration is that it leaves a clean slate for the Obama Administration to embrace innovation on its own terms. The authorized President's Council on Innovation and Competitiveness should be properly chartered and constituted with committees working to ensure that all agencies are engaged and talking across departmental lines. Direction and inspiration must come from the White House, but operational support is needed.

For the present, NIST is uniquely suited to serve as the coordinating office by virtue of its spectrum of expertise and its experience in spanning academic, industry, and government interests and perspectives. While NIST's budget goes primarily to fund its labs in Gaithersburg, Maryland, and Boulder, Colorado, it also houses the Technology Innovation Program, Manufacturing Extension Partnerships, and the Baldrige Quality Prize. The Director's Office includes a Strategic Planning and Economic Analysis unit that performs economic impact assessments and policy analysis grounded in economics.

Some new directions

Innovation policy should be open to innovation. Evaluation of innovation programs and policies should be a top candidate for the Obama administration's vision of participatory and collaborative government. The process should be objective, empirically grounded, and multidisciplinary. Self-assessment by agencies should still be encouraged but must be understood as only part of the picture. We must remember that innovation is not predictable, mistakes will be made, and failures must be expected and tolerated—although perhaps not as routinely as in Silicon Valley!

Innovation policy must span agency interests, insights, and policymaking. Duke University professors Arti Rai and Stuart Benjamin make a compelling case that innovation policy is made *de facto* by a wide range of regulatory agencies, but without due attention to effects on innovation. They recommend an Office of Innovation Policy within the White House Office of Management and Budget to address innovation-related decision making across regulatory agencies.

Patents remain the centerpiece of U.S. innovation policy, but the patent system starkly exemplifies the stovepiping and absence of leadership on innovation. The U.S. Patent and Trademark Office is chartered to conduct studies and provide policy advice, yet it lacks the capacity to analyze the effects of patents on business practice (including innovation) and remains captive to a one-size-fits-all legal culture.

Patent reform is long overdue, a consequence of a system grown complex and costly, with a proliferation of competing interests that makes consensus hard to come by. Despite five years of intensive debate following major Federal Trade Commission and National Academy studies, the U.S. Patent and Trademark Office has failed to provide leadership on reform, and Congress has been unable to pass legislation. The courts have made some progress on reform, although they are bound by statute and must decide between two parties without the benefit of a policy apparatus. We need innovative intellectual leadership for intellectual property—leadership that recognizes that patent policy should promote innovation, not just more patents.

Standards should also be a centerpiece of U.S. innovation because they have become essential to collaboration, interoperation, and the downstream path of innovation. Under well-established policy, government agencies do not dictate standards, but they should take an active role in advancing standards, including the semantic standards to carry innovation to higher levels on the Web.

Recent NIST initiatives on standards in manufacturing and health care should be strengthened and expanded in scope in partnership with industry and academy experts. Agencies should work with NIST to support standards for advancing knowledge infrastructure in their areas of expertise. This means promoting standards whose terminology and terms of use are consistent with the expectations of their respective constituencies and communities.

A genuine government-wide commitment to innovation means maintaining a focus on the short-term *and* the long-term—not just one or the other. The agenda for advanced cyberinfrastructure should not be limited to NSF but should engage all research agencies. Advanced cyberinfrastructure merits a presidential advisory committee on par with the old President's Information Technology Advisory Committee as well as a more collaborative form of outside engagement.

In addition, federal agencies that are not involved with advanced cyberinfrastructure should at least be charged with developing a long-range vision in parallel with the near-term reengineering needed for transparent, participatory, and collaborative government. We need to know where to get to from here.

Conclusion

The digital age started out simple. Unlike analog, digital meant either yes or no, on or off. But in practice, digital technology has evolved to span what were once thought to be big bright lines, including barriers between countries, sectors, industries, technologies, and people. It allows us to construct and design relationships in new ways, mediated by shades of gray, informed by choices, and accommodating diverse talents and perspectives. The U.S. government, the world's largest user of information technology, should embrace its potential—not only in practice but in a clearly articulated set of policies for promoting innovation and economic growth, now and in the future, across our entire economy.

While the government must play a key role, innovation depends on individuals. The United States in its entirety—government, academia, companies of every size and focus, and non-profit groups—needs innovators who can think, and operate, outside of the box. Some service science experts have argued for "T-shaped professionals" who have deep technical understanding of a disciplinary base but who also know how to apply this expertise in a wide variety of contexts. The real value of an education, including an engineering education, may be the ability to go broad and deep and versatile within a volatile ecosystem, making the best use of the tools as they become available.

Yes, we need adequate funding for physical sciences and STEM education. We should fund the Technology Innovation Program well enough to see what it can do. But we also need to capitalize on the changing fabric of knowledge and innovation by giving talented people the training and tools to make the best of it.

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Science Progress, a project of the Center for American Progress, is a magazine specifically designed to improve public understanding of science and technology and to showcase exciting, progressive ideas about the many ways in which government and citizens can leverage innovation for the common good. Since its inception in the fall of 2007, *Science Progress* has helped shape the conversation about our country's investment in science.

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