Accounting for Change in National Systems of Innovation:

A Friendly Critique Based on the U.S. Case

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Abstract

This paper advances a friendly critique of the national systems of innovation approach and offers some suggestions for its future development. I argue that the approach has difficulty accounting for bounded change in national systems. I review three recent changes in the U.S. innovation system – the Internet boom and bust of the late 1990s and early 2000s, the response to the terrorist attacks of September 11, 2001, and the acceleration of productivity growth since the mid-1990s – in order to assess the strengths and weaknesses of the framework in this respect. Future research might be enriched, at least in the case of large national innovation systems, by absorbing concepts developed in other strands of institutionalist literature, such as "intercurrence" and "embeddedness".

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The history of research on science, technology, and innovation policy can be told as a series of empirical challenges and analytic responses. An early impetus for work on the relationship between technological innovation and economic growth, and the appropriate role of public policy therein, was provided in the 1960s by the success of U.S.-based multinationals like IBM. This "American challenge", (as Servan-Schreiber (1967) characterized it) focused scholars' attention on the connections between R&D spending, industrial structure, and national economic growth. It also motivated institution-building, among other things contributing to the establishment of the Science Policy Research Unit (SPRU) at the University of Sussex, whose fortieth anniversary we celebrate in this issue, under the leadership of Christopher Freeman (Freeman, 1977; Salomon, 1977, 51-54).

Some twenty years later, the rise of Japanese competition in high technology helped to prompt a major rethinking of the received wisdom in the field. The analytic response to this empirical challenge was to widen the frame of inquiry in order to encompass a more diverse range of social institutions than had previously been seen to influence the innovation process. Freeman's 1987 book on Japan was among the first to advance the notion of treating these institutions as parts of a system. The systems of innovation (SI) theme was taken up by Freeman and his co-editors and

[1] The author thanks the reviewers and guest editors of this special issue of *Research Policy*, participants in the session at the SPRU 40th conference, the conference organizers, and Zak Taylor for helpful comments.

by other authors in Dosi et al. (1988), a publication that crystallized the formation of an "epistemic community" conducting research in this area (Sharif, 2006).[2]

The SI approach has been widely adopted over the past couple of decades. It has been used by researchers to characterize patterns of industrial specialization and international trade that did not make sense in the neoclassical economic paradigm (Nelson, 1993; Patel and Pavitt, 1994). It has provided a productive agenda for the study of newly industrialized countries that have followed in Japan's footsteps (Matthews, 2001; Furman and Hayes, 2004). It has yielded a framework of use to policy-makers, such as in Finland, which built its policy reforms of the early 1990s around the concept, and Sweden, which created a Systems of Innovation Authority (Metcalfe, 1994; Lundvall, 2004; Sharif, 2006; Albert and Laberge, 2007).

Many of the central insights of SI research have now been reproduced or substantiated by scholars from other intellectual lineages. In comparative political economy, for example, a literature on "varieties of capitalism" has focused on innovation as the critical differentiating factor among these varieties and located its sources in interlocking networks of social institutions (Hall and Soskice, 2001). Neoclassical economists (such as Acemoglu, Johnson, and Robinson, 2002), too, have found that durable differences in economic performance across countries are caused by variations in institutional endowments that affect the capacity of economic actors to create and adopt new technologies.

[2] Sharif (2006) shows that the NSI concept had been brewing in other circles as well, notably in Bengt-Ake Lundvall's group in Aalborg. Based on his interviews with Scandinavian researchers, Sharif sees the Japanese threat (and the expansion of global industrial competition more generally) as a motivating factor in their research. See also Lundvall et al. (2002).

Yet, despite its success, or perhaps because of it, the SI approach is starting to show its age. Edquist (2005) has recently elaborated a theory-driven critique, calling for a more formal and rigorous style of work. In this paper (and in the critical spirit called for by the SPRU fortieth anniversary conference organizers), I suggest the emergence of new empirical challenges to which SI researchers might respond with new analytical ideas in the tradition noted above. The next section articulates a friendly critique of SI research, focused on the challenge of explaining "bounded change" in national systems. In the following three sections, I characterize and analyze important changes in the U.S. system of innovation in the past decade. In these sections, I also draw on several other strands of institutionalist literature in the social sciences to advance concepts that might help SI researchers to better understand these changes. I identify some connecting threads among these concepts in the conclusion with the aim of advancing the SI research agenda.

Explaining Change in Systems of Innovation

I deliberately use the term "approach" rather than "theory" to describe SI in this paper. The members of the epistemic community who associate themselves with the SI label share a set of principles and problems, but not necessarily a set of agreed-upon, rigorously defined concepts and measures that would allow for hypothesis-testing and prediction (McKelvey, 1991; Edquist, 2005). The principles derive from the high degrees of uncertainty and complexity in the innovation process, which limit the applicability of rational actor models in this domain. Uncertainty is reduced and complexity simplified, according to SI researchers, by the response of innovating actors to institutions, which guide behavior, influence communication patterns, and constrain organizational forms (Metcalfe, 1994; Lundvall, 1998). The national institutions that are most influential in these respects, and thus that comprise national systems of innovation, vary across countries. These variations stem from the uniqueness of each nation's political and economic history (Nelson, 1993; Andersen and Lundvall, 1988).

Despite the diversity in conceptual frameworks and research foci within this community, the shared principles of the SI approach lead to some unity with regard to its findings. Perhaps the most pervasive observation is that national differences in innovation processes, such as technological areas of concentration, organizational location of activities, and patterns of financial support, tend to endure over long periods of time (Freeman, 1997; Carlsson, 2006**).** As Nelson (1993, 509) put it in the conclusion of his seminal edited volume, "institutional continuity is striking."

SI researchers have identified an array of mechanisms, grouped under the rubric of path dependence (or, more colloquially, "lock-in"), that limit or even prevent change. Skills and knowledge, for instance, take years to obtain and can be difficult to transfer to new domains of technological activity (Dosi, 1988). Routines, to take another example, limit experimentation and learning at the organizational level (Nelson and Nelson, 2002). A third example of such a mechanism is institutional co-evolution at the national level; interactions among co-evolved institutions tend to dampen or constrain change in any one institution, while simultaneous change across several institutions is hard to achieve (Murmann, 2003). Path dependence at the individual, organizational, and institutional levels is further reinforced by the expectations of partners in economic exchanges and by political and social power structures (Mokyr, 2002, ch. 6).

Most authors in the SI literature therefore argue the case for stability rather than change. To the extent that change is envisioned, it tends to be occasional and abrupt. Due to lock-in effects, stresses build up within an innovation system over long periods of time, and if they are released at all, it happens suddenly, usually prompted by an exogenous economic or military shock. Such a shock softens resistance to change, scrambles networks, spurs more-than-routine organizational experimentation, and shakes up relationships among institutions. Quite soon after the crisis recedes, however, new routines are established, and a new historical path is carved that soon becomes as deep and difficult to alter as the old one (Freeman and Louca, 2001; Perez, 2002).

SI research is not well-suited, therefore, to understand what Thelen (2004, 36) refers to as "bounded change." Bounded change is defined by the creation or restructuring of some of the central institutions, relationships, and expectations within a system of innovation, but which does not amount to a transformation of the system as a whole. Some key players in the system adopt a new "logic of action" (Streeck and Thelen, 2005, 18), while most continue to operate as they had before. For instance, academic science comprises one of the central institutional complexes in the U.S. system of innovation. One key element in the transformation of the U.S. system in the early Cold War was a massive reorientation of American academia – its research agenda, its funding, its organizational structure, even its physical infrastructure. Since the Bayh-Dole Act of 1980, these institutions have experienced bounded change; some players within it are much closer to industrial sponsors and more oriented toward economic development than before 1980, but most act in ways that would be instantly recognizable and acceptable to their forbears in the 1960s and 1970s.

The concept of “bounded change” provides an intermediate category between the extremes of continuity and transformation that dominate the SI literature. In applying it, I aim to retain the core assumption of the SI approach: that institutions, rooted in history, constrain the options that leaders, entrepreneurs, and other potential change-makers think of, act on, and are able to accomplish under normal, non-crisis circumstances. These constraints are, however, less binding in certain respects than the received wisdom suggests. The theoretical task is to specify more clearly how much less binding and in what respects. It is a task, I would note, that that SI scholars share with researchers in the broader fields of comparative political economy and historical sociology, such as Mahoney (2000), Pierson (2004), and Thelen (2004), who, in turn, originally drew their inspiration from Paul David, Brian Arthur, and other students of technological innovation familiar to readers of this journal. As SI scholars tackle this task, they will undoubtedly develop a richer vocabulary for describing and understanding change than the simplistic tripartite schema (continuity, bounded change, transformation) that I use here (Streeck and Thelen, 2005).

The U.S. Innovation System: Framing the Case

Empirical challenges to the SI approach in the form of “bounded change” appeared not long after it was first articulated. For instance, Japan (the case which originally motivated Freeman to set it forth in 1987) experienced the collapse of the “bubble economy” in 1989, followed by a long period of stagnation. During this “lost decade”, “the expectations and preferences of government and industry regarding the future have not necessarily coincided,” as they had under the leadership of the Ministry for International Trade and Industry (MITI) in previous decades

(Wakabayahsi, 1999, 12). This change in the logic of action of some actors in the Japanese national system of innovation did not change the logic of action of other actors, such as universities, which seem to be locked into rigid developmental paths. Analysts of this system thus face the challenge of accounting for "loose coupling" (Perrow, 1984) among components that had earlier been perceived to be deeply interdependent.

SI research will gain much by learning from the Japanese and other cases, and, of course, much work is in progress to this end. In this paper, I explore challenges to the SI approach that emerge from an effort to apply it to recent U.S. history. The U.S. is an important case for SI research to encompass, both empirically and analytically. Its empirical importance derives from America's leading role in the global economy, both in highly innovative industrial sectors and in scientific research. Unless scholars understand the innovation process in the U.S., they will have difficulty understanding innovation in the world as a whole. The analytic significance of the case stems from the vastness and institutional complexity of the U.S. system of innovation. Like the blind men in the Indian legend, SI researchers have found it difficult to agree on what the American "elephant" actually is. The appearance of more large innovation systems, in Europe, China, India, and perhaps at the global level as well, heightens the need for better understanding of this one.

The most succinct characterization of the U.S. national innovation system, and one that accords with the most widely-held image of that system among both scholars and the broader public, is offered by Ergas (1987). Ergas argues that that the U.S. is oriented toward technological "shifting", rather than "deepening". By this he means that American institutions more often generate radical innovations that perform new functions and displace older technologies than institutions in other industrialized countries. The U.S. is able to capitalize on these innovations by reallocating resources rapidly, capturing the gains from the steeply-sloped takeoff phase of the technology diffusion and market creation processes. In so doing, American firms, universities, and even government agencies – for better or worse – more easily abandon routines, commitments, and investments than their counterparts abroad.

The institutions that are most closely associated with "shifting" – and are thus most distinctively American – are those that facilitate entrepreneurship in high-technology industries. Academic scientists and engineers in the U.S., for example, are highly competitive, well-funded, and linked in a surprising number of ways to businesses that can make use of the knowledge that they produce. R&D-intensive start-ups are particularly well-positioned to take advantage of industrially-relevant advances in basic research (Rosenberg, 2003). The viability of such firms is furthered by the availability of angel finance and venture capital, deep equity markets, and relatively strong intellectual property and antitrust laws. Finally, the federal government, particularly the Department of Defense, has often patronized high-tech start-ups, "buying-down" new technologies in the expensive early stages of their life cycles (Mowery, 1992).

Many of these institutions were put into place during the early stages of the Cold War, although some have their roots in the World War II mobilization. They reflect a remarkable burst of institutional innovation. As the conventional SI wisdom summarized above would suggest, they were established primarily in response to exogenous military shocks, and they then grew and were consolidated into an interlocking institutional system over a period of decades (Hart, 1998;

Mowery, 1992). High-technology start-ups, of course, did not entirely displace the vertically integrated capital-intensive corporations that dominated the U.S. innovation system earlier in the century (Chandler, 1977; Mowery, 1983). Instead, the new institutions were often layered on top of and interacted with the older ones, which in fact dominated much thinking about technological innovation well into the postwar period, such as Servan-Schreiber's 1967 warning about the American "challenge".

Although it has not experienced a shock comparable to that of World War II and the beginning of the Cold War, the U.S. system of innovation has not been static since the launch of Sputnik fifty years ago. Biomedical research and associated technological activities in the pharmaceutical and medical device industries, for example, grew at an extraordinary pace in these decades, altering along the way such institutions as the federal research funding system and intellectual property law (Henderson, Orsenigo, and Pisano, 1999; Goodman and Walsh, 2001). More recently, in the 1980s and early 1990s, the federal and state governments and American manufacturing firms responded to international competition by restructuring university-industry relationships and devising new forms of public/private partnerships (Mowery, 1998).

The past decade has also been characterized by a mix of continuity and bounded change in the U.S. innovation system that might usefully be accounted for by SI researchers. I tackle what I would argue are the three most important aspects of this recent history in the next three sections. The challenges to the SI approach posed in these sections are different. In the next section, I consider the Internet boom and bust of the late 1990s and early 2000s. This episode is one of bounded change in the absence of an exogenous shock. The following section explores the U.S.

response to the shock of the terrorist attacks of September 11, 2001. The challenge posed by this thread of the history is that there was so little change, despite the severity of the shock. The last of these three sections inquires into the sources of the acceleration of productivity growth in the U.S. service sector, which coincided with but was only loosely connected to the Internet boom. The puzzle for SI researchers here is to understand a step-change in this vital indicator without a corresponding shift in the system of institutional relationships. I argue that the SI approach provides valuable insights into all three of these instances, but also leaves us with significant puzzles to work on, something which we may begin to do by considering how similar puzzles about institutions have been tackled in cognate fields of inquiry.

Internet Boom and Bust

The most striking feature of the Internet boom of the late 1990s from an SI perspective is the ease with which new technology-based ventures were financed and the speed at which they grew (Kirsch, 2006). Old rules and established relationships were loosened or abandoned as an avalanche of money flowed into the "new economy". Venture capital is a useful indicator of the degree of change. U.S. venture capital investments peaked at over $100 billion in 2000, some fifty times greater than their 1991 trough; by contrast, the previous cycle peak was only about three times the level of the previous trough (NSB, 2006, table 6-9). In order to process that much money, deals inevitably became much larger and were vetted less vigorously (Gompers and Lerner, 2002**)** A similar relaxation of "due diligence" is reflected in the performance of the stock market during this period and, on a smaller scale, in countless "leaps" into Internet businesses made by individuals with their own human capital (Ashbrook, 2000).

Many of these investments came to grief in the ensuing bust, during which many old rules were reinstated. However, the bust did not produce a full return to the status quo ante for the U.S. innovation system. Most obviously, a number of new industries and the hardiest firms that had helped to create them survived, including Amazon, eBay, Yahoo, and Google (Nocera, 1999). The innovation processes of such Internet-based firms deviated from existing practices, tending to involve both users and inter-organizational technical communities of practice more heavily than more vertically-integrated older firms (von Hippel, 2005; Benner, 2003). In addition, the venture capital pool remained several times larger than in the previous trough, while angel investing became more formal and institutionalized (PWC/NVCA, 2007; Sohl, 2007). Finally, despite several high-profile criminal cases that documented malfeasance in business and financial circles during the boom era, technology-based entrepreneurs retained their popularity after the bust among policy-makers, especially at the state level, and among the broader public (Cassidy, 2002; Hart, 2007).

At first glance, the Internet boom and bust seem to fit well with the established conception of the U.S. innovation system. Much of the underlying technology had been financed originally by the military and gestated by publicly-funded academic institutions (Abbate, 1999). Entrepreneurial start-ups, led by young, highly-educated technical professionals, were among the most innovative actors in this period, aided by their venture capital and angel backers. The legal and regulatory system generally favored the new entrants, for instance, by forbidding the application of state and local sales taxes to Internet services (Goolsbee, 2000). Antitrust authorities sought to nurture the new technology as well, for instance, by limiting the predatory tactics of Microsoft, although this litigation did not in the end save Netscape (Heilemann, 2000; Lopatka and Page, 1999). Moreover, when the bust arrived, the government did not step in to assist ailing firms.

Indeed, interpreting the boom and bust from the SI perspective is too easy; it produces a caricature that warrants deeper scrutiny. Even in a national system of innovation that is oriented toward "shifting" from one technological trajectory to another, institutional constraints were lifted in this period to a surprising degree. Investors in financial, human, and organizational capital, for instance, shouldered substantially more risk than they had in the past. Organizational boundaries among firms and between firms and consumers that had previously impeded information exchange turned out to be more permeable than one might have anticipated.

Two ideas may be helpful in understanding how such constraints were lifted. The first idea is that the increasing density of activities and institutions associated with shifting has gradually changed the logic of action of entrepreneurs, investors, and managers. The U.S. system is even more oriented toward shifting than it used to be, and the Internet boom and bust can be interpreted as an early manifestation of this trend. Kenney and von Burg's (2000) study of the history of Silicon Valley is suggestive. They describe what they term "Economy 2", a set of institutions that systematically encourage the launching of new business models and new industries, not simply new companies. "Economy 2" emerged when entrepreneurial activity in Silicon Valley became so extensive and so dense that activities that had earlier been rarities, such as the hiring of an experienced CEO to take over a high-tech start-up, became routine. New institutions were created to carry out these routines, which in turn set in motion positive feedbacks, in this case spreading "Economy 2" well beyond Silicon Valley.

This episode might also focus the attention of SI researchers more closely on the role of culture in shaping logics of action that lead to technological innovation. Technology-based entrepreneurship acquired a celebrity status during the boom that transcended the money involved. The industry's cultural prominence became an intangible asset for its constituent firms, attracting investors, employees, and partners that would otherwise have been beyond its reach (Rindova et al., 2006). The media played a central role in this process, describing a technologically determined revolution to which existing institutions had no choice but to adapt (Kirsch, 2006). "Irrational exuberance", to borrow Federal Reserve chairman Alan Greenspan's famous assessment of the stock market, had its mirror image in irrational imitation (or mimetic isomorphism – see Dimaggio and Powell, 1983), perhaps best expressed by Time-Warner when it was acquired by AOL. Cultural processes that produce fame and provoke fear may resolve uncertainty differently than the institutional rules and conventions that have traditionally been most prominent in the SI framework.

Counterterrorism

The second set of changes in the U.S. national innovation system that I consider in this paper were prompted by the terrorist attacks on New York City and Washington, D.C., on September 11, 2001, about a year and a half after the stock market's dot-com peak. While counterterrorism immediately became the dominant rhetorical motif of U.S. foreign and domestic policy, the response to this shock – which was likened by many observers to Pearl Harbor and Sputnik – has fallen far short of the systemic transformation that the SI framework might lead one to expect based on those analogies. The response to 9/11 thus poses the challenge of explaining how a major exogenous shock could provoke only bounded change.

The rhetorical shift noted above definitely extended into the domain of science and technology policy. To fight the so-called "long war" (Rosensweig and Carafano, 2005) against Islamic terrorists, defense intellectuals have called for a new national security strategy built around ICTs. Intelligence, domestic security, and border control agencies, in this vision, would gather and "mine" vast data-bases in order to anticipate and prevent further terrorism in the U.S. Military operations to attack terrorists and their state sponsors would use these data resources as well, in conjunction with precision weaponry and sophisticated communications networks (Trajtenberg, 2006; Krepinevich, 2007). As in the Cold War, new technologies lie at the core of U.S. strategy in this new era, but they are different technologies than the strategic weapons that characterized the previous era and they seem to call for a different set of institutional arrangements to support them.

That call has not been entirely ignored. The shock of the attacks prompted the establishment of a major new institution, the Department of Homeland Security (DHS), in 2003. At the urging of a National Academy of Sciences panel (2002), among others, a Science and Technology Directorate was created within DHS, along with a Homeland Security Institute and, later, a Homeland Security Advanced Research Projects Agency (HSARPA) modeled on the Defense Advanced Research Projects Agency (DARPA). Publicly reported expenditures on federal homeland security R&D grew approximately tenfold over the five years subsequent to 9/11, leveling off in 2007 at about $5 billion (AAAS, 2005; AAAS, 2007a). This spending provided a new focus for technology-intensive defense contractors, and firms that had not previously been involved with national security agencies were drawn into pursuing this mission. The BioShield program of the National Institutes of Health (NIH), for example, which seeks to develop vaccines against potential bioterror agents, has spent its entire budget to date on small biotechnology firms (Kaiser, 2006).

These changes are not trivial, but they pale in comparison to those that followed Pearl Harbor, the start of the Korean War, or Sputnik. DHS remains an ungainly amalgam of elements plucked from other departments that have yet to be woven together (Lehrer, 2004). Its capacity to stimulate and sustain innovation has been limited to date. DHS directly controls only about a quarter of the homeland security R&D budget, a smaller proportion than NIH. NIH's preponderant position in homeland security R&D is less the reflection of a bioterrorism threat assessment, the focal point of its research agenda, than of a budget situation in which growth could be more easily accommodated by that agency than by others that receive such funding.

More importantly, the Department of Defense (DOD), which controls the lion's share of R&D resources (more than $80 billion, about 58% of total federal R&D spending), continues to invest far more heavily in "legacy" weapons systems that reflect the Cold War threat environment rather than the new challenges of "asymmetric" warfare. Its logic of action seems to have survived 9/11 intact. The R&D budget of the Air Force, for instance, the military service most closely tied to the Cold War strategy, has grown more rapidly in recent years than the R&D budget of any other component of DOD (AAAS, 2007b). Trajtenberg (2006) finds that about 30% of U.S. defense R&D is devoted to "big weapon systems of dubious significance", while some 13% goes to intelligence and counterterrorism. Only two major weapons programs have been cancelled since 9/11 (Korb and Bergmann, 2007). Richard K. Betts (2007, 67) makes the point most sharply: "If Rip van Winkle had fallen asleep in the Pentagon's budgeting office twenty years ago and awoke today, his first reaction would be that nothing had changed."

"Bounded change," I would argue, captures the response to the exogenous shock of 9/11 better than "systemic transformation." It might reasonably be argued, drawing on the SI approach, that this shock was not as great nor as sustained as those with which it is typically compared, and that the original expectation was exaggerated. In addition, the institutional structures that tend to keep innovation systems on their existing paths are larger and denser in the 2000s than they were in the 1940s and 1950s. A proportionately greater shock may be necessary today to produce a comparable degree of change as in the past. Yet, even if one accepts these interpretations, this episode still provides an opportunity to extend and deepen the SI approach. In particular, we can understand in greater detail the mechanisms by which the U.S. system of innovation absorbs and channels severe environmental turbulence away from some of its central components.

This theoretical issue has been explored in some detail in a variety of other policy areas (such as labor and social policy) by scholars of comparative political economy and American political development. Orren and Skowronek (1994, 2004), for instance, argue that the complexity of the U.S. policy-making system both provides the means for existing power-holders to resist environmental pressure for change and, at the same time, supplies avenues for reformers to accomplish at least some of their objectives. Even if they lack the power to dismantle old institutions, advocates of change may be able to graft a new layer of institutions onto the old system by working around or offering side payments to entrenched interests (Schickler, 2001). "The normal condition of the [U.S.] polity", Orren and Skowronek (2004, 108) conclude, "will be that of multiple, incongruous authorities operating simultaneously." They call this condition "intercurrence". Thelen (2004) applies the same sort of analysis to the history of the German industrial training system.

In addition to allowing the present institutional system to absorb turbulence while resisting radical change, intercurrence provides a mechanism for bounded change in the future. The overlapping missions and powers of intercurrent institutions tend to produce conflict, which can lead eventually to institutional innovation if circumstances warrant. Indeed, such dynamics are sometimes anticipated by reformers, who see new institutions as "wedges" that will provide future leverage against their establishment rivals. In the case of DHS, at least to date, the context has not favored this outcome. The absence of a terrorist attack within the U.S. subsequent to 9/11 and the pursuit of war abroad, not to mention DHS's own severe "growing pains" (AAAS 2007a), seem to have relegated it to the second tier in counterterrorism-related science and technology. Nonetheless, if a second shock were to occur in the next few years, we should anticipate a more dramatic shift in the U.S. system of innovation, because of the bounded change made in response to the first one.

Acceleration of Productivity Growth

The final instance of bounded change in recent U.S. history that SI researchers might try to account for is the resurgence of productivity growth across the entire economy. From an average of 1.39% per year in the doldrums between 1973 and 1995, the rate nearly doubled to 2.64% per year since, exceeding even the pace of growth during the "golden age" of the 1950s and '60s (Jorgenson et al., 2006, table 1) The surge predates the emergence of the so-called "new economy," which was in any case too small to have such large aggregate effects (McKinsey Global Institute, 2001; Foster, Haltiwanger and Krizan, 2002), nor can it be linked with any other exogenous shock. Jorgenson et al. (2006, 9) note that the acceleration has been sustained through "the NASDAQ collapse in 2000, the 2001 recession, the 9/11 terrorist attacks, an investment bust, corporate accounting scandals, the war in Iraq, and rising oil prices….[it] is nothing short of phenomenal!" Although scholars (Triplett, 1999) had long predicted that investments in ICTs would yield a productivity payoff, they had grown accustomed to seeing their hopes disappointed.

The productivity growth surge is all the more impressive when one considers that the U.S. economy is much less reliant on manufacturing than it was during the "golden age" and more reliant on services, which had been thought to be much less susceptible to productivity improvement (Baumol, 1967). To be sure, a significant fraction of U.S. productivity growth is the result of continuing improvements in manufacturing, especially ICT manufacturing. However, what seems to have changed most dramatically since 1995 – and what differentiates the U.S. most markedly from Europe, including the U.K.– is the productivity performance of a small group of ICT-using service industries, such as retail and wholesale trade, brokerage, and business services (Gordon, 2004; Bosworth and Triplett, 2004; Hughes and Scott Morton, 2005; McKinsey Global Institute, 2001).

Important aspects of the acceleration in productivity growth can be understood by using the lens provided by established SI research. The contributions of the manufacturing sector, for instance, are derived from the operation of Moore's Law, as each new generation of semiconductors substantially outperformed the previous one and diffused into a wider array of products (Bosworth and Triplett, 2004). Silicon Valley entrepreneurs and their venture capital patrons lie at the core of this process. "Shifting" in the sense that Ergas (1987) uses the term also occurred in the service sector. For instance, the brokerage firm Charles Schwab transformed its business model in the late 1990s by combining Internet stock-trading with retail branches, "clicks and mortar", in the phrase of its CEO. This shift helped the firm to stave off purely on-line entrants and drive large productivity gains in the brokerage industry (Kador, 2002; Pottruck and Pearce, 2001; McKinsey Global Institute, 2001).

Yet, comparable productivity growth rates were *not* achieved in all U.S. service sectors, even those that invested heavily in ICTs. Productivity growth in retail banking, for instance, remained slow, despite massive ICT spending and the entrance of entrepreneurial ventures pursuing on-line business models (McKinsey Global Institute, 2002). Indeed, venture capital-fueled, Internet-based entrepreneurship (and the response of incumbents) does not explain the bulk of recent U.S. service sector productivity growth.

To adequately account for service sector productivity growth, our understanding of the U.S. national innovation system needs to embrace what Ergas calls "deepening" as well as "shifting." Ergas (1987, 223) defines "deepening" as "improving the productivity of resources in existing uses." The paradigmatic U.S. firm in this regard is Wal-Mart, which largely drove the acceleration of productivity growth in the retail sector, the largest sector for employment in the U.S. Wal-Mart's key innovations involved creating new organizational routines to coordinate internal activities better and to handle linkages with suppliers and customers more smoothly. These firm-specific investments, which involved much customized, in-house system and software development, allowed Wal-Mart's ICT spending to yield substantially larger productivity payoffs than comparable spending by other firms (McKinsey Global Institute, 2002; Hughes and Scott Morton, 2005; McGee, 1998). Brynjolfsson and Hitt (2000) estimate that "soft" complementary investments by firms that use ICTs effectively may be an order of magnitude larger than the costs of the technology itself.

In adding "deepening" to the research agenda on the U.S. national innovation system, however, we will need to reframe our understanding of the concept. Ergas (1987) associates it with horizontal coordination and standardization among firms within an industry, as exemplified by the German system of innovation. Industry-wide institutions in Germany facilitate the convergence of expectations and the reduction of risk and uncertainty, thereby enabling investment. That is not the process that has been observed in the key U.S. ICT-using sectors, which are highly competitive. Wal-Mart, Charles Schwab, and their peers generate productivity-enhancing knowledge through large internal investments, embody it in organizational routines, and capitalize on it through economies of scale and scope. Competition among firms that are vertically integrated in these respects then drives diffusion, through both imitation and replacement (Hughes and Scott Morton, 2005; Baily, 2002). The national character of this pattern is suggested by Bloom, Sadun, and van Reenen (2007), who find that U.S. firms operating in the U.K. use ICTs more productively than do the U.K. operations of multinationals based in other countries, including in their former U.K. establishments that U.S. firms have taken over.

These observations hint at a broader challenge that students of the U.S. national innovation system may wish to take up. Many theorists of the firm argue that new technologies have enabled vertical *dis*integration, a process that has extended in recent years into the R&D function (Mowery and Macher, 2007). Yet, the service sector firms that have been most effective at raising productivity have not merely retained control over their critical knowledge assets, but extended that control with firm-specific investments. They rely heavily on external vendors to carry out an ever-widening variety of routine tasks, but not those vital to the firm's competitive position (Manyika and Nevens, 2002). Indeed, firms that jump most heavily on the ICT outsourcing bandwagon tend to do so out of weakness, rather than strength (Lacity and Hirschheim, 1993; Hall and Liedtka, 2005). The construction of a new synthesis that balances the "visible hand" perspective on management associated with Chandler (1977) and the "vanishing hand" view of critics like Langlois (2003) may be a project to which this line of research could contribute.

In addition to revisiting the question of firm boundaries, a fuller understanding of innovation in ICT-using service industries may also require a more precise characterization of the cultural norms that guide U.S. consumer behavior. "Everyday low prices" (Wal-Mart's motto) certainly play an important part here, but so too do convenience, quality, choice, and other attributes of the consumer experience that are not entirely captured by prices. The valuations placed on these factors by American consumers seem to differ from those in Europe and Japan. As electronic commerce grows and weighs more heavily in the productivity performance of these industries (and as ICT use grows in other sectors as well), these factors and others rooted in culture, such as trust in the vendor, payment, and delivery systems, may become even more potent drivers of innovation.

Whether the recent American productivity growth performance can be sustained is hotly debated. Gordon (2007) argues that the productivity gains from ICTs are "largely over;" Jorgenson et al. (2007) find "little evidence" of an impending return to lower growth rates. The SI approach leads me to favor the latter position, anticipating that the new logics of action of the most successful U.S. service firms will be emulated in other sectors in which ICTs have yet to yield a productivity payoff.

New Threads for the SI Tapestry

A phenomenon as big and complex as the economy-wide acceleration of productivity growth undoubtedly has many diverse causes, not all of them to be found within the national system of innovation. Yet, the SI approach has the potential to capture more than it does, and perhaps more than the alternatives. The intimation in Mowery (1998) that researchers should focus primarily on the global forces that are shaping national innovation systems, and expect these systems to converge as a result, remains premature. In the U.S. case, at least, there is substantial internal dynamism in the national innovation system. And while a global innovation system is emerging – more institutions are interacting more fully across national boundaries than in the past – its impact on national systems is often mediated by national institutions, including cultural and political institutions, producing different effects in different places.

My exploration above of recent changes in the U.S. points to several concepts drawn from other strands of institutionalist literature that might be woven more deeply into the SI approach:

Cultural Embeddedness As we observe in the behavior of capital holders during the Internet boom, in the U.S. government's interpretation of the threat of terrorism, and in consumption of ICT-intensive services, cultural forces seem at times to dissolve the constraints imposed historically by other kinds of institutions. Following Granovetter (1985), it might be said that national culture embeds the national innovation system. "Embed," in this context, refers to a causal relationship, rather than a geographical or jurisdictional relationship (as in the relationship of national systems of innovation to regional or global ones). Cultural processes condition and enable interactions between institutions within a national system of innovation. Williamson (2000, 597) provides a more elaborate typology of embeddedness: culture (level 1) embeds law and politics (level 2), which in turn embed organizations and markets (level 3), which in turn embed individual decision-making (level 4). Each higher level, Williamson argues, is more durable and less consciously designed, than the levels below it. Yet, economic sociologists, such as Clemens and Cook (1999) and Dobbin (2004), point out that the causality may go both ways. Culture is shaped by the polity and the economy , even as it shapes them. There is a rich menu of possible research projects that could examine these possibilities in the context of national systems of innovation.

Intercurrence Multiple institutional systems may co-exist within each level of Williamson's typology, as they do in the case of U.S. counterterrorism science and technology. Intercurrence, to use Orren and Skowronek's term for this situation, is familiar to SI researchers at Williamson's level 3. We accept, for example, that there may be diverse, overlapping sectoral systems of innovation within the same country. Intercurrence in political institutions and in cultural norms and values extends this conception significantly. Intercurrence at these levels may lower the barriers to institutional change. The defenders of existing institutions are more likely to accept sharing some of their turf than being replaced, as they would be if institutions hold functional monopolies. In addition, intercurrence, like embeddedness, provides a basis for bounded change within the national innovation system. Co-existence may give way to conflict among intercurrent institutions when resources grow tight or external circumstances change, disrupting routines, driving experimentation, and altering the selection environment.

Endogenous institutional change Cultural embeddedness and intercurrence suggest that institutional and systemic trajectories are more variable and less path dependent than SI researchers usually assume. A further challenge to the narrow interpretation of path dependence follows from the observation that new institutions may arise (and the interactions among older institutions may thereby be altered) when formerly rare activities become common. During the Internet boom period in the U.S., for instance, the intense demand for certain services, such as angel investing and entrepreneurship education, stimulated institutional formation. Some of these new institutions acquired sufficient momentum that they proved to be sustainable even after the boom had ended. Neither the emergence nor the survival of such new institutions is inevitable. Existing institutions may block them, kill them, or absorb their functions. Increasing density of the pertinent activities may also bring with it new costs and constraints. But if such endogenous institutional change occurs, the further evolution of the innovation system may deviate from its earlier path. This concept recalls Adam Smith's discussion of the division of labor within the economy, as specialization leads to learning, the rise of new occupations, and technological change.

Size matters All three of the concepts discussed thusfar in this section imply that the size of the system may have a powerful effect on its dynamics. SI researchers have long recognized, of course, that countries such as the United States and Denmark are diverse units of analysis. This diversity, on the one hand, provides explanatory leverage, but it also substantially complicates the analysis (Nelson, 1993). The challenge of diversity within SI research will become greater as more large innovation systems arise in places like India, China, and the European Union (Borras, 2004). Indeed, if one can say that there is a global innovation system, it is more like that of the U.S. than Denmark. The SI approach may be strengthened by more explicitly incorporating size into its analysis and considering whether different conceptual frameworks apply to systems of different sizes. Intercurrence, for instance, may be more easily accommodated and density more likely to provoke institutional change in large systems than in small ones.

SI research is a success story, but it cannot rest on its laurels. The changing world poses continual challenges. Our own technology is subject to the same creative destruction and need for incessant innovation as the objects of our research. Much work remains to be done to further develop the notions introduced here and to integrate these fragments with insights from other cases to construct a more coherent and useful perspective.

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