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What enables rapid economic progress: What are the needed institutions?

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Abstract

In recent years "institutions" have again become a central focus of economists and other scholars studying the processes of economic growth, and the reasons why nations have differed so greatly in their achievements on this front. However, with few exceptions the exploration of the role of institutions has not been connected with a coherent analysis of the relationships between institutions and institutional change and technological advance. This paper proposes a way of analyzing these relationships. The concept of "social technologies" which support "physical technologies" plays a key role in the analysis.

Keywords: Institutions; Technology; Co-evolution

1. Introduction

Particularly since the publication in 1990 of North's influential book, the writings by economists on economic growth have focused more and more on the "right institutions" as the key to economic progress. (For a fine recent study see Eggertsson, 2005.) It is important to note, however, that the focus in almost of these writings has been on how prevailing institutions affect the efficiency of economic allocation and action. Technological advance hardly ever is even mentioned. This would appear to be a severe limitation on the ability of this new body of analysis to illuminate the sources of economic progress, since it is well established that technological advance has been the key driving force behind the economic progress that has been achieved (in at least parts of the world) over the last two centuries. Therefore, it would seem that one can understand the role of institutions and institutional change in economic growth only if one comes to see how these variables are connected to technological change.

Increasingly scholars of technological advance have been bringing "institutions" into their analytic story, particularly in writings on innovation systems. (I would propose that the key nucleating event here was the publication of the volume by Dosi et al. (1988) which contained chapters on "innovation systems" by Freeman (1988), Lundvall (1988) and Nelson (1988).) However, despite the obvious interest of a number of the authors of the writings on innovation systems to move towards a theory of economic growth that is based on an empirically realistic characterization of the processes and institutions involved in the advance of technology, with few exceptions (later I will discuss Freeman and Perez (1988) and Freeman and Louca (2001)) there remains a significant gap between aspirations and achievements.

Thus there would appear to be a real need and challenge to build an intellectual bridge linking these two bodies of writing, helping economists to recog-

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nize better how institutions and institutional change relate to technological advance, and also helping scholars of technological advance to see better how what they are studying fits with a broader analysis of economic growth.

However, there are two obstacles to building that bridge. The first is that, while there is a family relationship across the way different authors use the term, in neither body of writing is it clear exactly what the term "institution" is supposed to mean. This diversity of meaning makes it difficult for either body of research to be cumulative, much less to link up. The second problem is related but different. The way institutions are treated in the economic growth literature makes it difficult to get an intellectual handle on how they fit into a theory of growth driven by technological advance (for a discussion see Nelson, 1998).

I think the obstacles can be cleared and a bridge can be built. My objective in this essay is to lay out a bridge design.

Section 2 is dedicated to unpacking the "institutions" concept. I shall propose that most of the writings about institutions, both by economists, and by scholars studying innovation systems, is concerned with explaining prevalent methods of doing things in contexts where the actions and interactions of several parties determine what is achieved, and therefore effective coordination is key to good performance—what Bhaven Sampat and I (Nelson and Sampat, 2001) have called "social technologies". This will lead me to suggest a conception of what institutions are – basically the factors and forces that mold and hold in place social technologies – that is compatible with the way the term is used in both bodies of writing, and which I think clarifies significantly the discussion in both.

I and others have been arguing for years that it is important to see the dynamics of economic growth driven by technological advance as an evolutionary process (see e.g. Nelson and Winter, 1982). I believe I see a growing, if implicit, recognition of that in the literature on economic growth (see e.g. Lipsey et al., 2005). The principal task on the economic growth theory front therefore would seem to be to build institutions coherently into the theory, and to link analysis of institutions with analysis of technological advance. Section 3 develops the argument that economic growth involves the co-evolution of physical and social technologies, and the institutions needed for their effective operation and advancement. Some institutions provide the broad background conditions under which technological advance can proceed, and others come into existence and develop to support the important new technologies that are driving growth.

Section 4 is concerned with the processes of institutional change. A principal argument is that institutional change, and its influence on economic activity, is much more difficult to direct and control than technological change, and hence prevailing institutions often are drags on economic productivity and progressiveness. Further, reforms can go awry. I will use the evolution of the institutions supporting biotechnology in the United States as a concrete example of how difficult it is to assess whether prevailing institutions are working well, or whether they need reform, and if the latter, what kind of reform.

In Section 5 I pull threads together.

2. Unpacking the concept of institutions

There is, first of all, the question: what do we want the term "institutions" to mean? Clearly the definition we choose must be broadly consistent with the way the term tends to be used now; a definition that is far away will not be accepted. But actually the situation now cries out for an attempt to establish an agreed upon meaning because, at first glance at least, use of the term is all over the map.

Among economists, perhaps the most widely accepted notion is that institutions should be understood as "the basic rules of the game", the broad legal regime and the way it is enforced, widely held norms that constrain behavior, etc. (the most recognized reference surely is North, 1990). But there are various bodies of writing that associate institutions with "governing structures" molding aspects of economic activity, like a nation's financial "institutions", or the way firms tend to be organized and managed (see e.g. Williamson, 1975, 1985). While this conception is not radically inconsistent with the notion that institutions are the rules of the game, it is not quite the same. Still other economists associate the term institutions with customs, standard and expected patterns of behavior in particular contexts, like the acceptance of money in exchange for goods and services. (Veblen (1899, 1915) is the canonical reference here. Among contemporary economists, Hodgson (1988, 2006) is the strongest advocate for a Veblenian perspective.) The conception here is with the ways things are done, rather than broad rules or governing structures that constrain behavior; although these things are connected, they are somewhat different.

Also, while many authors use the term "institution" to refer to somewhat abstract variables, like the consistency and perceived justice of the rule of law in a society, the modern research university, or the general use of money in exchange, other scholars associate the term with particular concrete entities, as the Supreme Court of the

United States, the agricultural research system of the University of California, or the Bank of England.

I note that the term institutions in the writings on innovation systems – national, regional, sectoral – tends to be used to refer to relatively concrete entities. Thus there is analysis of what business firms do, patterns of cooperation and competition among firms, the role of technical societies, and universities, industry–university links, prevailing patent law, public programs, etc. Indeed, most of the authors writing in this arena have shied away from presenting a general statement of what they mean by the term. However, for our purposes here, we must hazard one.

Bhaven Sampat and I have proposed (Nelson and Sampat, 2001) that, despite the apparent diversity in the literature regarding how institutions are defined, there is a family relationship at least regarding the intentions of the writings. Explicitly or implicitly, a large share of the writing is intended to shed light on the character and factors supporting generally used ways of doing things in contexts where the actions and interactions of a number of different agents determines what is achieved. We suggested that the concept of a "social technology" was a useful one for thinking more coherently about these.

Our social technologies concept involved a broadening of the way economists conceptualize an economic "activity". In its standard use in economics, an activity is thought of as a way of producing something, or more generally doing something useful; Sampat and I take a broad view of what the term encompasses. Undertaking an activity or a set of them – producing a radio, growing rice, performing a surgery, baking a cake, procuring a needed item, starting a new business – involves a set of actions or procedures that need to be done, for example as specified in a recipe for the preparation of a cake. These steps or procedures may require particular inputs (like flour and sugar for the cake, cash or a credit card to procure the ingredients for the cake), and perhaps some equipment (something to stir, a stove, a vehicle to go to the store). Economists are prone to use the term "technology" to denote the procedures that need to be done to get the desired result.

However, a recipe characterization of what needs to be done represses the fact that many economic activities involve multiple actors, and require some kind of a coordinating mechanism to assure that the various aspects of the recipe are performed in the relationships to each other needed to make the recipe work. The standard notion of a recipe is mute about how this is done. Sampat and I proposed that it might be useful to call the recipe aspect of an activity its "physical" technology, and the way work is divided and coordinated its "social" technology.

From this perspective, virtually all economic activities involve the use of both physical technologies and social technologies. The productivity or effectiveness of an activity is determined by both aspects.

In turn, the social technologies that are widely employed in an economy are enabled and constrained by things like laws, norms, expectations, governing structures and mechanisms, customary modes of organizing and transacting. All of these tend to support and standardize certain social technologies, and make others difficult or infeasible in a society. Sampat and I have suggested that the term "institutions" is used by most of the writers on the subject to denote structures and forces that mold and hold in place prevalent social technologies.

This conception of social technologies and institutions supporting them seems broad enough to encompass most of the kinds of things treated as institutions in the literature on innovation systems. Industrial R and D certainly can be regarded as a set of activities involving both physical technologies (e.g. lab procedures) and social technologies (a division of labor among scientists and various structures of coordination and direction), with the organization and governance structure of the industrial research laboratory the key institution enabling and supporting the latter. The relationships between university medical schools and biotech firms that have developed in the United States in recent years involve a complex set of ways of interacting, that is–social technologies – supported by such institutions as a set of beliefs and norms at universities that encourage entrepreneurship, strong patent protection for university "inventions" that exists in this area, the patent and licensing offices that now are a standard feature at universities, and a counterpart set of expectations, norms, and structures at most biotech firms, etc.

My proposed analytic approach to institutions is to focus on the prevalent social technologies of interest, and be eclectic and inclusive about the "institutions" that support them. Under this orientation, institutions certainly turn out to be a diverse lot of things. But that strikes me as fine, actually illuminating, if the objective of the research is to explain why prevalent social technologies are what they are, and how they change.

As the above examples suggest, there generally will be a number of different "institutions" that support and constrain particular social technologies, and they operate in different ways. Some institutions have a broad and somewhat diffuse affect on the social technologies that are used or not used. Thus in the above example, the influence of "belief in the value of university entrepreneurship" is largely atmospheric, affecting a wide range of activities and the social technologies used in them. Other institutions are more specific to the particular social technologies under study, as strong patent rights in the field of biotechnology. In the following section I will consider in some detail three cases, each of which involves particular governing structures and particular laws. Some institutions provide the background context within which the particular social technologies under study evolve. Others change as an essential part of the evolutionary process.

Some writers, for example North (1990), want to make a clean distinction between institutions and organizations. However, under the conception I propose, broadly accepted organizing principles, to use a term employed by Kogut (1993, 2000) would definitely be considered a part of the institutional environment, even if particular extant organizations embodying those principles might not (but then what about the Bank of England?).

Some institutions, for examples laws bearing on particular activities are, in a sense, external to social technologies, and mold them. Situations like these clearly are what is in the minds of scholars who want to distinguish sharply between institutions, for example in the sense of rules or governing structures, constraining and supporting a particular pattern of behavior, and the behavior itself. However, social technologies also can be self-institutionalized, if I may use that term. This is an important reason why the lines often are blurred between a prevalent practice and the "institutional" supports for that practice.

Social technologies can be self institutionalized in several ways. First, customary behaviors, modes of interacting, organizing, tend to be self reinforcing because they are expected, and familiar, and doing something different may require going against the grain. Second, social technologies tend to exist in systems, with one tuned to another, and self supporting. This may make going against the grain in one social technology especially difficult, because it involves losing touch with complementary social technologies. Third, social technologies, like physical technologies, tend to progress over time, as experience is accumulated, and shared deliberately or inadvertently. Trying a new social technology, like pioneering a new physical technology, is risky, and involves abandoning the fruits of what may be considerable prior experience. I note that these forces of self institutionalization are important reasons why a society's ability to control the social technologies in use through conscious designing of institutions may be limited.

Institutions clearly have a certain stability. Yet economic growth, as we have experienced it, clearly has seen old social technologies fade away, sometimes abruptly sometimes slowly, and replaced by new ones. It is time to explore more deeply the role of institutions and institutional change in the process of economic growth.

3. Institutions and economic growth

Today economists studying economic growth are in accord that technological innovation is the key driving force. The "technology" on which attention has been focused almost always has been "physical" technology, in the sense that I laid out in the previous section. It will not surprise the reader that I now will bring "institutions" and institutional change into a theory of economic growth by arguing that physical technologies and social technologies go together. The argument that I will develop in the this section is that innovation driven economic growth needs to be understood as involving the co-evolution of physical and social technologies, and that the dynamics of institutional change should be seen in this light.

Of course the notion that physical and social technologies are tied together is an old one in social science. Karl Marx proposed a very tight linkage, with the causal structure running cleanly from physical technologies to the social technologies of production. There is an extensive literature in sociology on how changes in physical technologies affect the organization and social order of economic activity.

Below I briefly describe three historical episodes that nicely illustrate the dynamic connections: the rise of mass production in the United States in the last part of the 19th century, the development of the first science based industry – synthetic dyestuffs – in Germany during roughly the same period, and the development of specialized research firms and of strong university–industry interactions that has marked the rise of pharmaceutical biotech in the US over the last quarter century. My treatment of the first two cases will be very compressed, since I have described them in another place (Nelson and Sampat, 2001). My discussion of biotech will be more extended.

Chandler's work (1962, 1977) is central to my telling of the first story. Under his analysis, the processes that led to mass production in a range of industries were initiated by the development of the technologies that enabled the establishment of the telegraph and the railroad, which in turn made it possible for business firms to market their products over a much larger geographical area. At the same time advances were being made in the ability to design and manufacture highly productive machinery. Together, these developments opened the possibility for significant economies of scale and scope.

However, to exploit these opportunities, firms had to be much larger than had been the norm, and large size posed significant problems of both organization and management. The organizational problem was partly solved by the emergence of the modern hierarchically organized company, and later by the multidivisional form of organization (the M form). I note, with Chandler, that the railroad and telegraph companies themselves had to deal with this organizational problem.

New modes of business organization were only a start. To manage these huge companies required many more high level managers than an owner could garner by canvassing family and friends, which had been the usual practice. The notion of professional management came into being, and shortly after business schools emerged as the institutional mechanism for training professional managers. The financial needs of the giant companies were beyond what could be met through existing financial institutions, and both modern investment banks, and modern stock markets, emerged to meet the needs.

All of these developments raised complicated issues of corporate, labor, and financial, law. Gradually these were worked out. At the same time, the market power of the new large firms and their tendency to collude with each other gave rise to new regulatory law and antitrust.

Murmann (2003) provides the most detailed and analytic account of the rise of the industry producing synthetic dyestuffs. Here the initiating event was a breakthrough in the science of organic chemistry. As a result, persons with advanced training in the theory and techniques of chemistry had a special capability for developing synthetic dyestuffs. In order to take advantage of this new capability, business firms had to develop the concept and structure of the industrial research laboratory, as a place where university-trained scientists could work with their peers in discovering and developing new products. German patent law was tightened up better enabling German firms to protect the new dyestuffs they created. Also, in the new regime involving hired scientists, new law also had to be developed to establish who had patent rights on products coming out of the labs.

And the German university system had to gear itself up to train significant numbers of chemists inclined to work for industry. The various German governments provided significant funding to enable this latter development to happen.

Turning to my third case, the rise during the 1960s and 1970s of molecular biology as a strong science, and the creation of the basic processes used in modern biotechnology, clearly was a watershed for the American pharmaceutical industry. These developments opened up a new route to pharmaceuticals discovery and development, one in which, at least at the start, established pharmaceutical companies had no particular competences, and at the same time, one where certain academic researchers had expertise. Several lines of university-based research began to appear very promising commercially. A number of new biotech firms were formed, staffed by university researchers and their students, with plans to develop new pharmaceuticals, and either license the successful results to established pharmaceuticals companies, or themselves go further downstream into the pharmaceuticals business.

Several prevailing broad institutional factors enabled and encouraged these developments. One was the traditional openness of American universities to entrepreneurial activity on the part of their researchers. Another was an established venture capital industry, which quickly came to see the finance of biotech startups as a potentially profitable business. These two features of the prevailing institutional framework in the United States should be regarded as part and parcel of a general institutional friendliness toward entrepreneurship. However, the emergence of firms specializing in research, and of university researchers closely linked to these firms, was a quite new institutional development. (For a history see Mowery et al., 2005.)

To make this arrangement viable commercially required that the research firms have control over the new products and techniques they developed. Here, a key legal decision in 1980 assured skeptics that the products of biotechnology could be patented. At about the same time, Congress passed the Bayh-Dole Act, which encouraged universities to take out patents on the results of government-funded research projects, and to try aggressively to commercialize those results. While the language of the act is not specifically focused on biotech, an important part of the argument that led Congress to believe that technology transfer from universities to industry would be encouraged if universities had strong patent rights and could grant exclusive licenses to a firm to develop their embryonic products was specifically concerned with pharmaceuticals.

In all of these cases one can see clearly the intertwining of the development of new physical technologies, and the emergence and development of new social technologies. Various general aspects of the broad institutional environment clearly were necessary for the innovations that drove developments in these cases to proceed effectively.

First of all, the economic and social cultures had to encourage entrepreneurship, and the risk taking that is inevitable when new activities are launched. The relevant “institutions” here probably mostly involved norms, and expectations, although the legal system had to such that potential entrepreneurs could expect to get rich if they succeeded. Second, in all of these cases developments involved sharp breaks from the "circular flow" of economic activity, and finance needed to be available to support new firms doing new things. Again, the supporting institutions involved a mix of norms and expectations, laws providing some security for investors, and appropriate organizational structures. Third, labor market institutions had to be compatible with new firms being able to attract workers with suitable skills.

In each of these cases new social technologies came into place, and new institutions to enable and support them. Many of the institutional developments that occurred came about largely as a result of private actions, but a number required collective action, generally involving government and the political process. The latter two cases involved new government programs. All three saw the writing of new law.

Note that institutions enter these stories in two ways. First, as background preconditions that enable the developments to arise in the first place and take the shape they did. Here the relevant institutions tend to be associated with broad economy-wide context conditions, like a legal system that defines and enforces contracts, a financial system capable of funding new enterprises, flexible labor markets, and in the dyestuffs and biotech cases, a strong university research system. But second, as the case studies show, the dynamics of development often require old institutions to change or new ones to emerge. Here the institutions in our stories are more technology or industry specific, like bodies of law tailored to a technology or industry, or the development of university research and training in particular fields.

Many contemporary writers attempting to describe effective institutions have proposed that economies are productive and progressive when institutions support market mechanisms. In each of the cases sketched above, one can see the central role market organization of economic activity plays in fostering productivity and progressiveness. However, the advantages of market organization, and the disadvantages of trying to plan and control economic development from a central authority, are not those highlighted by the neoclassical theory of market organization and its virtues. It is the fundamental uncertainties involved in innovation, the inability of economic actors to see clearly the best things to be doing, that make the pluralism, the competition, that is associated with market organization of economic activity so important. Competition also often tends to keep prices from getting completely out of line with costs. But as Schumpeter (1942) argued long ago, by far the principal benefit that society gets from market organization of economic activity, and competition, is innovation and economic progress. Also, as I have stressed, non-market institutions play key roles in each of these case studies.

My discussion above has focused on particular technologies and industries, rather than the economy as a whole. However, as Schumpeter argued long ago, economic growth cannot be understood adequately as an undifferentiated aggregated phenomenon. Rather, one needs to understand an economy as consisting of many different sectors, each with its own dynamics. Schumpeter also argued that the history of economic growth tends to divide into different eras, and that within any particular era there is a relatively small set of technologies and industries that are driving economic growth. From this point of view, the Chandler and Murmann stories are particularly interesting because mass production undertaken by large hierarchical firms, and industrial R and D tied to firms engaged in production and marketing, are the hallmarks (sometimes combined and sometimes not) of the industries that drove economic growth in the advanced industrial nations during the first two thirds of the 20th century. Biotech has been forecast by many people to be a key technology of the 21st century.

Freeman and Perez (1988) and Freeman and Louca, Part II (2001) have proposed that the key technologies and institutions of different eras generally require different sets of supporting institutions. The countries that are successful are those that have the basis of these institutions already in place when they are needed, or which manage to build the appropriate new institutions quickly and well. The large internal market of the United States clearly provided a very favorable environment for the rise of mass production, but the prevailing institutional environment and the rapid development of new institutions tailored to the needs of mass production certainly also was a force behind U.S. leadership in this area. Murmann and other have argued persuasively that the existing strong university research system in Germany, and the ability to support its expansion in chemistry, was a principal reason why German industry led the world in dyestuffs, and later in organic chemical products more generally, at least up until World War II. Clearly the dominant U.S. position in biotech is largely the result of U.S. institutions: a strong university research system well funded by government that is open to entrepreneurship, an existing venture capital industry, strong intellectual property rights.

The argument that rapid economic progress in different eras requires different sets of particular supporting institutions is not to deny the broader point of view, associated with an evolutionary or Schumpeterian perspective on the general nature of economic progress, that to support innovation and take advantage of its potential fruits the institutions of an economy need to be supportive of entrepreneurship, broadly defined, and enable resources to be shifted from rising economic sectors and firms to declining ones. But it does suggest strongly that those generalizations cannot carry the analysis very far. Rather, analysis of the institutions required for economic productivity and progress must get into the details, which inevitably are going to differ from sector to sector and era to era.

However, evaluation of the need for or value of particular institutions often is very difficult, and prone to bad judgment. I next turn to this issue.

4. The processes of institutional change

How do a country's institutions come to be what they are? To what extent can salutary institutional reform be subject to deliberate analysis, planning, and implementation?

There is a longstanding divide about these issues in the writings of institutional economists. In the early part of the 20th century, Commons (1924, 1934) focusing on the evolution of the law, staked out a position that to a considerable extent the institutions that a society had were the ones it had deliberately put in place, wisely or not. Hayek's theory (1967, 1973) of why societies had the institutions that they had was different, stressing "private orders" that changed over time through a relatively blind evolutionary process. There is a similar divide among the "new institutional economists" regarding this matter. Indeed, Douglass North himself has taken both views, starting from a position that institutions were the result of a deliberate, rational choice processes (Davis and North, 1971), and later moving to a position very similar to Hayek's (North, 1990, 1999): that institutions could not be effectively planned, and that the societies that had good ones should regard themselves as fortunate. Thrainn Eggertsson has followed a similar intellectual traverse.

Partly the difference here relates to the assumed influence and effectiveness of human purpose, intelligence, and forward looking planning, versus more or less random change and ex-post selection. Partly the difference is in regards to whether institutional change is seen as occurring largely through collective, generally governmental, action, or whether the process is seen as being largely decentralized, involving many actors. The position I espouse here is that on both counts the contrast often is drawn too sharply. I want to agree strongly with the economists and other social scientists who argue that institutions evolve rather than being largely planned. However, I also want to argue that beliefs about what is feasible, and what is appropriate, often play a major role in the evolution of institutions. Human purpose, and human beliefs, play an important role both in the generation of the institutional alternatives on which selection works, and in determining what survives and what does not. And in many cases the process involves both decentralized and collective action.

The mix of course depends on the kind of institution one is analyzing. The development of formal law obviously involves deliberate governmental action. Generally there is debate about what the law should be, and some kind of a formal decision process. On the other hand, the evolution of custom generally is highly decentralized and whatever conscious deliberation there is tends to be myopic. But, it may be a mistake to see the processes here as completely separated. Thus Commons noted explicitly that, particularly in common-law countries, the development of formal bodies of law tended to be strongly influenced by the customs of the land that were broadly deemed appropriate. And Hayek too recognized that formal law often was developed to support custom, while warning of the dangers of putting in place formal law, or public policies more generally, that were not based on the wisdom of custom.

In the cases described earlier, the development of new organizational forms was an important part of the story. While Chandler's account of the emergence and development of the organizational structure of the modern corporation highlights innovation by individual companies, a body of corporate and financial law developed along with, responsive to, and supporting and constraining these private developments. Murmann' account of the development of the modern industrial laboratory involves a mix of private experimentation and decision making, and the formation of laws and public programs responsive to the emergence of industrial research. The rise of the industrial structure in biotech that we see now in the U.S. clearly has been developed by a mix of private and public actions.

While each of these cases shows an evolutionary process that is sensitive to changing needs and conditions, I now want to argue that the process of evolution of social technologies and their supporting institutions is erratic, compared with the way physical technologies evolve. The ability to design institutions that work as planned is much more limited than the ability to design new physical technologies. Selection forces, including the ability of the human agents involved to learn from experience what works well and what does not, usually are significantly weaker for institutions and social technologies than for physical technologies. And usually there is much less ability to compare alternative institutions analytically.

One important reason is that physical technologies are more amenable to sharp specification and control, and are easier to replicate and imitate more or less exactly, than are social technologies. The performance of physical technologies, including the nature of the output they produce, tends to be relatively tightly constrained by the physical inputs and processing equipment used in their operation. On the other hand social technologies are much more open to the vagaries of human motivations and understandings regarding what is to be done, which seldom can be controlled tightly. Granovetter (1985) has argued against the "over institutionalization" of theories of human behavior.

Certainly, the institutions that can be consciously designed tend to mold behaviors only relatively loosely, and themselves often are difficult to specify and control tightly. Thus, it is clear from Chandler's discussion of the multi-divisional form (the M form) of business organization, that arose in the early 20th century and became "standard" among companies producing a range of products and selling them in different areas, that there was very considerable variation among firms. The variation involved both formal structure and the actual division of decision making between the central office and the branches, which were only partly a matter of managerial choice. Indeed, there was a certain fuzziness to the general concept, and even individuals in the companies who were nominally in charge seem not to have known in any detail just how the system they had actually worked.

As I have noted, physical and social technologies sometimes are tightly intertwined. Mass production methods, of the sort that Chandler argued were an important part of the reason for the development of the modern corporation, is a good example, involving both specialized machinery and a complex division of labor and management and control system. Over the years empirical studies have consistently shown large differences in productivity between establishments of the same corporation producing the same things and using the same production machinery (perhaps the best of these studies remains the old one by Pratten (1976).) The differences here clearly were due to different social technologies which management was not able to control in any detail.

A second important difference is that in most cases, not always, it is far more difficult to get reliable evidence on the efficacy of a new institution or social technology than for a new physical technology. In part this is a consequence of the phenomena just discussed. For a company contemplating adoption, the problem of estimating the efficacy of the M form of organization surely was made more difficult by the fact that what the M form actually was and how it actually worked differed significantly from firm to firm, and within a particular firm tended to change over time. But even without this complication, it tends to be very difficult to sort out the effects of a particular institution or social technology from the influences of a wide variety of other variables that bear on the profitability of a firm, or to estimate reliably the benefits and costs reaped by society from a complex of strongly interacting policies and laws. In contrast, it is much easier to gain a reliable assessment of the efficacy of a new pharmaceutical, or the performance of a new aircraft design.

Both of these differences are related to the fact that a lot can be learned about physical technologies, product designs or modes of production, by building prototypes and doing controlled experimentation "offline" as it were, in research and development. It is much harder to do this for institutions. Thomke (2003) provides a convincing and detailed analysis of the role of deliberate experimentation in the design and development of physical technologies. If a physical technology can be made to work in a controlled setting, it often is possible to routinize and imbed it in physical hardware, and in this and other ways shield it from environmental influences that could be different on-line from experimental conditions. The looser coupling of institutions that can be designed and the behaviors they generate means that transfer from controlled setting to actual practice does not work nearly as well, even if the institution as a whole could be operated in an experimental setting.

Another important differences is that, because of the ability to routinize, shield, and control, it often is possible to experiment with a part of a physical technology off-line, and to transfer an improved version of that piece to the larger system with confidence that it will work in that context and in actual practice. In contrast, the likelihood that a piece of an institution or social technology that works well in an off-line experimental setting will work well when imbedded in an on-line system is small.

This is not to deny the important role of learning by doing and using regarding the efficacy of physical technologies. However virtually all learning regarding social technologies and the institutions that mold and support them has to proceed on line. And for the reasons suggested above, even that learning is difficult and uncertain.

Relatedly, "scientific" understanding bearing on institutions, and indicating ways that they might be improved, generally is much weaker than the scientific understanding bearing on physical technologies. The applications oriented natural sciences and engineering disciplines often can provide very helpful illumination of prevailing practice and potential roads to improvement of physical technologies. They can point relatively sharply to what is essential to the performance of a product design, or production process, and what is likely peripheral. While Ruttan (2003, 2006) has proposed otherwise, I would argue that the behavioral and social sciences provide much less light on how present institutions work and how to improve them. In trying to understand why, it is important to recognize that the productive knowledge of applied scientists and engineers comes not only from the underlying basic sciences, but also from observation, experiment, and analysis of prevailing practices and artifacts, or models of these that are built expressly for experimentation and analysis. For the reasons discussed above, the kind of knowledge about institutional effectiveness, and the key institutional elements that determine effectiveness, that behavioral and social scientists can achieve is relatively limited.

The emergence and adoption of new social technologies can proceed rapidly and fruitfully if there is a reasonably well-defined problem that needs some solution, one can readily identify a new social technology that solves that problem at least broadly, and the needed institutional supports for that social technology are relatively obvious. Under these conditions, the needed new institutions can come relatively quickly into place, at least if those who are in a position to make the institutional changes have an interest in doing so. Thus in the United States the M form spread relatively rapidly among multi product multi market firms. The M form did at least mitigate the problem of overload of decisions to be made by top management of such firms. The industrial research laboratory provided a way for firms to hire groups of scientists and put them to the task of inventing, and relatively quickly became an "institution" in industries where the competitiveness of firms depended on their prowess at creating new products and manufacturing processes.

On the other hand, the history of both the M form and the industrial research laboratory is one of firms continuing to struggle to fine tune the structures so that they would work well in their particular context. It is illuminating to contrast the experience here with the evolution of mass production machinery. In the latter, many engineers were involved in designing machines, and getting relatively reliable information on performance from their own testing, and from feedback from users. Efforts to improve design could be guided by that user feedback, and by the ability of designers to experiment off line, with reasonable confidence that what they learned from that experimentation would hold up in actual practice. And designers could learn from studying the characteristics and performance of the machines made by other designers.

There is little evidence of anything like this progressive cumulative learning regarding business or research organization. The evolution of social technologies and the institutions that support them is a difficult uncertain process, compared with the evolution of physical technologies. Indeed, as noted earlier, corporations running different establishments producing the same things with the same physical equipment often find it very difficult to establish a common set of "social technologies" for the different establishments.

Indeed, in some circumstances institutional evolution can result in building into place social technologies that are quite ineffective, or worse. For the most part, evidence of the benefits and costs of using new physical technologies is sharp enough so that few really bad ones ever get into widespread use (although there unfortunately are a number of cases where deleterious side effects, or problems that arose in particular contexts, were discovered only after a technology was around for awhile). In contrast, the introduction and spread of social technologies can be driven by fad, or ideology. Given the difficulties in getting reliable feedback on actual performance, social technologies, and the institutions supporting them, once in place may be difficult to dislodge, even if there is little evidence that they are accomplishing what they were established to do.

This just might be the case regarding the institutions that have been put in place in the United States in support of the development of biotech. I am not arguing here that this is the case, but there are some worrying signs.

There is, first of all, the question of whether firms that specialize in biotech research, and aim to make profit by licensing their research products to other firms, are commercially viable. It is somewhat curious, and I think highly relevant, that the notion that a biotech firm could be profitable simply by doing research, without having close organizational linkages to production and marketing, gained enthusiastic credence so readily. This proposition was inconsistent with the history of industrial research that was recounted above, where firms making and selling products learned the advantages of doing R and D internally. While there were a few earlier exceptions, by and large firms that tried to make profit by specializing in R and D were not successful. Regarding the present case, it has been recognized widely for some time that most biotech firms who have specialized in research, and have not moved themselves into production and marketing, are not making any money. However, until relatively recently this problem has been treated as something that time would cure, and not an indication that the business plans and expectations involved in this structure possibly were not viable, except in quite special circumstances. Recently there has been more recognition of this possibility. Pisano's new book (2006) makes this argument forcefully.

There also are good reasons to be open minded or even skeptical about the economic value, and more generally of the wisdom, of the new policies encouraging universities to patent what they can out of what comes out of their research, an institutional development that, while not tied to biotech, has been exercised especially vigorously in this field. It is clear that since the 1970s many important new products and processes have been made possible by academic research. Over this period, university patenting has increased greatly, as has university revenues from technology licensing. These facts have led some sophisticated observers to argue that Bayh-Dole has amply met its goals. Thus in The Economist (2002) opined that "possibly the most inspired piece of legislation in America over the past half-century was the Bayh-Dole act of 1980".

However, the enthusiasts for Bayh-Dole generally have suffered from an historical myopia. University research was contributing importantly to industrial innovation long before Bayh-Dole and much of what industry was drawing on was in the public domain, not patented. Bayh-Dole was brought into a university research system that already was strongly oriented to spurring innovation, and quite successful at it. Thus it is not clear that the new university patenting has been as important in facilitating technology transfer as the advocates have claimed. Put another way, contrary to the message of the cite from the Economist, it is quite possible that much of the university contribution would have occurred without university patents.

On the other hand, the downsides of Bayh-Dole, and the policies of universities to patent as much as they can, and earn as much money as they can from their patents, are now more visible than they were a few years back. Recently there has been some backing off from the enthusiasm for university patenting that marked the 1980s and 1990s. A recent issue of The Economist (2005) focused on many of the issues raised above, implicitly arguing that the costs of university patenting and often exclusive licensing needed to be weighed against the benefits. The National Institutes of Health have issued guidelines calling for its grantees to license their patented inventions widely not narrowly.

Both the attractiveness to investors of the business plans of specialized research firms, and in many cases the ability of universities to patent the results of their research, have been dependent of the tendency of the U.S. Patent Office to give patents on material far upstream from a viable commercial product, and for the Courts to uphold these patents. Recently concerns have been expressed that these kinds of patents, which control paths of future research, can seriously interfere with the progress of science (for a discussion see Nelson, 2004).

In sum, the effectiveness of the institutions that have grown up in the U.S. in support of biotech is quite uncertain. There are major uncertainties regarding the effectiveness, or the economic viability, of firms that specialize in research and do not themselves get into production and distribution. It is uncertain whether on net Bayh-Dole, or rather the set of incentives and practices symbolized as well as reinforced by Bayh-Dole, has been a plus or a minus. The practice of granting patents on research results some distance from a practical product is generating growing resistance. The uncertainties here show clearly how difficult it often is to evaluate new social technologies, and the institutions supporting them. Mistakes can be made, and can last a long time.

5. Concluding remarks

The objective of this essay has been to suggest a design for an intellectual bridge between the body of writing by economists on the roles that institutions and institutional change play in economic growth, and the body of writing on technological advance. My basic proposal is that the concept of "social technologies", which complement "physical" technologies, and of "institutions" as the structures and forces which support and hold in place social technologies, together point the way to a bridge design.

Readers who start from the study of technological advance, as do most readers of this journal, will recognize at once that the innovation systems literature recognizes these relationships and connections, but mostly implicitly. I would like to conclude this essay by suggesting that the vast field of social technologies, their intertwining with physical technologies, and the fact (or my argument) that they develop much more erratically and slowly than do physical technologies, provides a very attractive agenda for scholars of technological advance. Pursuing it will enable us to expand our horizons and get a much more complete hold on the processes that drive economic progress.

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