*September 2008*
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# KNOWLEDGE AND ECONOMIC PROGRESS
## THE ROLE OF SOCIAL TECHNOLOGIES

*Prepared for a conference on*
*The Dynamics of Institutions in Perspective:*
*Alternative Conceptions and Future Challenges*
*University of Paris, October 3-4, 2008*

SEPTEMBER 2008

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### *1. Introduction*

The main purpose of this paper is to raise the profile of social technologies and social innovation in the theory of social change and economic development. The literature on institutional change typically focuses on power, endowments, incentives, and physical technologies, paying scant attention to knowledge of social organization as a scarce resource. Here we reverse these procedures by focusing the spotlight on social technologies, often holding constant other important explanatory variables.

In his *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Joel Mokyr (2002) presents a strong case for associating modern growth with cumulative increases in useful knowledge and the application of knowledge in production. In Mokyr's definition, the set of useful knowledge contains all known measurements and regularities that mankind has discovered in its game against nature. Mokyr's (2002, 4-15) union of all statements of useful knowledge, however, excludes knowledge about the social game. In this paper, I extend the definition of useful knowledge to include measurements and regularities involving social systems and the social game. I follow Mokyr's approach by distinguishing between two aggregate sets: the science set and the technology set—each now containing data about both the social and physical worlds.[1] I use the term social technologies to represent how-to knowledge of initiating and maintaining social systems (here also referred to as social mechanisms and social organization). Social systems are the product of institutions, which I define as rules, enforcement mechanisms, and individual beliefs that generate regular patterns of behavior in social groups. Technical change involving social technologies can increase the productivity of inputs used either for providing social mechanisms or commodities. The same is true of advances in physical technologies. New surveillance cameras can improve the effectiveness of social systems, and redefinitions of property rights can increase the effectiveness of new physical technologies.

In my formulation of institutional policy, I borrow from applied macroeconomics. Rule makers rely on policy models, which incorporate their ideas about social technologies, in particular the relationship between policy instruments and targets. Rational expectations macroeconomics assumes that economic actors respond strategically to changes in their environment, which limits the choice set of policy makers. In effect, all actors, not only the authorities, are guided by social models and embody their strategies in policy models. We learn from bounded rationality macroeconomics that policy models often are incomplete, inaccurate, and divergent. When actors evaluate an identical situation, their beliefs about opportunities for reforms can vary greatly. Economists of the Austrian school are more pessimistic about government planning than are advocates of a national industrial policy.

The following Section 2 introduces social knowledge and social technologies into Mokyr's framework for useful knowledge and compares mankind's game against nature to the social

[1] Mokyr (2002) uses the terms "propositional knowledge" and "prescriptive knowledge".

game. Section 3 looks at social technology and the relationship between social and physical technologies. Section 4 borrows from macroeconomics and introduces policy models that embody subjective social models and technologies. Section 5 uses examples drawn from modern biotechnology as an illustration of the knowledge problem in the theory of institutional change. The final section concludes with a few thoughts about obstacles to technical progress in the social domain.

*2. Social Science as Useful Knowledge*

Mokyr (2002, 1-27) introduces his theory of "useful knowledge" in Chapter 1 of *The Gifts of Athena: Historical Origins of the Knowledge Economy* and defines useful knowledge as observations, measurements and regularities concerning the natural world that are of potential use in production. Mokyr's framework has two interactive branches: the set of propositional knowledge, Ω, and the set of prescriptive knowledge, λ. Useful knowledge accumulates during mankind's game against nature and resides in people's brains and in storage devices. Ω contains miscellaneous data, including measurements of the properties of metals and geographical observations, as well as formal and informal theories of natural science. Ω is the union of all sets of propositional knowledge, which reside in human minds and in storage devices. Ω often includes contradictory pieces of knowledge (beliefs). Prescriptive knowledge, λ, is the union of all sets that contain how-to knowledge and technologies. Technologies in use are selected from the λ set.

It is implicitly obvious from Mokyr's discussion that the Ω set contains the λ set, but he considers λ and Ω separately to draw attention to interactions between *what* knowledge and *how-to* knowledge in technical change. Each technique, $\lambda_i$, has a knowledge base in Ω. In the limit, the knowledge base is simply the technique itself, $\lambda_i$; the technique is a singleton. All we know about a singleton is that outcome B can be achieved by doing A. Other techniques have a broader scientific base in $\Omega$, and other things equal, a broad base for $\lambda_i$ facilitates debugging, adapting and improving the technique, which accelerates technical progress. Mokyr (2002) provides convincing evidence that over time the knowledge base of a typical $\lambda_i$ has grown. Singletons were common in the early phase of the British Industrial Revolution where improvements in techniques were relatively slow. Also in those early years, lessons learned when applying techniques (feedback from $\lambda$ to $\Omega$) were an important source of new scientific knowledge. Finally, the varying *acceptance* and *availability* of elements in $\Omega$ and $\lambda$ is of crucial importance. Availability depends on the cost of access, which is related to the technologies of storage. Acceptance of theories about regularities in nature depends on social conventions determining criteria and processes of verification.

To better account for the relationship between social and physical technologies in virtually all production processes, we are now ready to expand Mokyr's (2002) definition of useful knowledge and to add social knowledge to the $\Omega$ and $\lambda$ sets.[2] The social elements in $\Omega$, like the natural elements, are divided into two classes: observations and theories. Social observations include descriptive material and measurements, such as legal codes, knowledge about organizational forms, public regulations, and Robert's *Rules of Order for Fair and Orderly Meetings and Conventions*.[3] Other examples include Elinor Ostrom's collection of rules for *Governing the Commons* (1990); national income statistics; and recent databases containing social, economic and political data for the nations of the world (Maddison 1982; Summers and Heston 1991).

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[2] Social technology would not influence production processes that involve only a solitary and isolated producer, and therefore no teamwork, joint consumption or exchange.

[3] First published in 1876 by US Army Major Henry Martyn Robert then under the title *Pocket Manual of Rules of Order for Deliberative Assemblies*.

The other major category of elements in Ω contains theories of social regularities, ranging from informal ideas to formal mathematical and statistical models. In social science, just as in natural science, the immediate policy relevance of the miscellaneous theories is very variable. The new economics of institutions and related fields, I think is fair to say, have not directly emphasized institutional policy, its instruments and limits, but instead attempted to explain the logic of social organization and social mechanisms, and the strategic interplay between various categories of actors in changing environments.[4] Moreover, the literature associates political and economic decisions with the endowments and interests of rational actors. The resulting social equilibrium implicitly assumes that all institutional change that the actors are willing and able to initiate has already taken place or is in the pipelines. In Acemoglu and Robinson's (2005) acclaimed study of the *Economic Origins of Dictatorship and Democracy* the authors present a uniform framework for analyzing social and political transitions along the dictatorship-democracy axis. Acemoglu and Robinson's basic insight is that a sufficient weakening of *de jure* power, favoring the rulers and embodied in social institutions such as the law, relative to the *de facto* power of the ruled (their violence potential) gives rise to social change. The underclass, when the time is ripe, uses its new *de facto* power (threat or use of violence) to demand concessions from the rulers. As the power pendulum may one day swing back toward the elite, rational underdogs demand some form of *de jure* power (such as voting rights) rather than (only) additional resource entitlements (wealth transfers) because, the authors claim, the granting of entitlements can be withdrawn more easily than institutionalized rights or *de jure* power. In other words, the granting of *de jure* power is, by assumption, a credible commitment. Note that the basic source of institutional change, shifts in the *de facto* power of social groups, is also exogenous: exogenous disturbance of power relationships is a fundamental determinant of whether or not democratic reforms occur. In a dictatorship and without appropriate exogenous disturbances, $\lambda_{democracy}$ is a null set. Acemoglu &

[4] For a similar viewpoint, see Banerjee, A. (2002). *The Uses of Economic Theory: Against a Purely Positive Interpretation of Theoretical Results.*

Robinson (2005) tell an insightful story about strategic responses to exogenous historical events, which through the unexplained mechanism of credible commitment move the political system toward democracy or dictatorship. Their story, however, belongs to the domain of propositional or science knowledge, $\Omega_s$, which is also the domain of many recent theories of why the West grew rich, especially those viewing economic growth as driven by appropriate social institutions, for instance North's (1990) *Institutions, Institutional Change, and Economic Development.*

By contrast, the early world of Keynesian macroeconomics provided policy makers with a toolbox full of instruments (Tinbergen 1952). Mid 20th century macroeconomic theory explicitly presents central administrators with a set of policy instruments for manipulating aggregate economic relationships. By leaving out political consideration, strategic responses by economic actors, and generally by overestimating available knowledge, the original $\lambda_{Keynes}$ set appeared to supply techniques for fine-tuning the economy. In other quarters, high hopes were associated with $\lambda_{central\ planning}$, partly because it was believed that a new physical technology, the computer, would strongly complement the social technology of planning and enable so-called scientific management of the economic system (Johansen 1977). Modern macroeconomics presents a more complex picture of the social technology for macroeconomic management, as I briefly discuss below.

Looking at the mezzo rather than the macro level, Ostrom in her work on *Coping with Tragedies of the Commons* (1999) also emphasizes "the complexity of using rules as tools to change the structure of commons dilemmas" (493). Ostrom (1999) concludes that a central authority typically lacks the capacity to design optimal or effective top-down rules for governing and managing common pool resources, such as water, forests, fisheries, and pastures. Finding the optimal governance system for common pool resources, in her view, involves an enormous information problem. Successful planners must select several rules from each of seven categories—boundary, position, authority, scope, aggregation, information, and payoff rules—and, crucially, select rules that work well together (Ostrom 1999, 509). As if these requirements were not severe enough, the choice of an optimal set of rules is not unique but, depending on local conditions, varies from one case to the other. For complex systems Ostrom recommends setting up mechanisms that encourage learning and adapting by local decision makers. She favors in particular polycentric governance mechanisms that function as complex adaptive system, combining governance and evolutionary selection.

The introduction of social knowledge to $\Omega$ raises two interesting questions about technical change. First, has $\lambda_{social}$ grown in the last 250 years at a rate comparable to the remarkable expansion of $\lambda_{physical}$, which Mokyr (2002) maps in the *Gifts of Athena*? Or, it is perhaps more relevant to ask, has slow improvement in social technologies prevented us from fully enjoying the fruits of new physical technologies? We can seek answers in the context of growth laggards or with respect to new industries, such as biotechnology, in leading countries. In the last half-century new quantitative methods have revolutionized the conduct of academic social science, but the results in terms of policy applications are mixed. The second question that comes to mind concerns the gap between science and technology: the time lag between innovation in social science and useful applications. Many scholars believe that the gap between natural science and technology has narrowed over time (Mokyr 2002; Merges 2004), but is such narrowing also the case for social science? I am not aware of any systematic research in this area. In the case of macroeconomics, $\Omega_{macro}$ has expanded rapidly but recently spillovers to $\lambda_{macro}$ are apparently relatively insignificant. Gregory Mankiw (2008), the distinguished academic economist and adviser to the US Government, claims in a recent paper, "The Macroeconomist as a Scientist and Engineer," that, in the last twenty years, US policy makers in highest places no longer rely on recent developments in macroeconomic theory. Note, however, that technological progress involves both adding effective tools to $\lambda_{macro}$ and removing ineffective tools from the set. Section 6 briefly takes up the question of progress in social technologies.

Natural phenomena, such as gravity and orbits of the planets, are external to society whereas mankind has directly or indirectly created all social systems. Yet both classes of phenomena are equally puzzling to man. Our knowledge of how to transplant existing social systems or how to create new ones is limited but, what is more surprising, we are slow in discovering the operational properties of existing social systems, which are our own creations. The scholars briefly mentioned above, Mokyr, Keynes, Acemoglu & Robinson, and Ostrom, have all received wide recognition for discovering operational properties of existing social systems. And there are countless other examples: Ronald Coase (1937) discovering the nature of the firm; Weingast (1995) finding that specific forms of federalism are "market preserving"; Long (2002) observing that firms use patents to signal their technological prowess to financers and others; and various publications in the *Journal of Law and Economics* revealing that the structure of law embodies economic logic.

### *3. The Relationship Between Social and Physical Technologies in the Production Process*

Producers select a subset of techniques from the technology set, $\lambda$, for producing goods and services and for setting up and maintaining social mechanisms. Consider a conventional production function, $Q= f_{\Psi}(A_p, A_s; K, L)$, where Q is output, K and L represent capital and labor inputs, and $A_p$ and $A_s$ represent physical and social techniques, which producers select from $\lambda$. Producers, moreover, operate in an exogenous social environment, $\Psi$, which has two important implications. First, $\Psi$ sometimes puts elements in $\lambda_s$ off limits for producers because the corresponding social mechanisms conflict with political, social, and religious interests. At various times and locations, the authorities have ruled out private firms, indentured labor contracts, labor unions, and loans bearing interest.[5] Second, there are indirect effects of $\Psi$ on the expected effectiveness of $A_s$ –and associated $A_p$—through complementary environmental mechanisms. Greif (2006) provides evidence from the history of long-distance medieval trade on the influence of background factors, such as ethnic networks and public legal services on the effectiveness of agency contracts. Because indirect $\Psi$ effects impact the expected effectiveness of techniques, they also affect the *choice* of techniques and even the choice of outputs. Weak public enforcement of property rights in physical capital or land can direct production methods away from physical capital toward labor services, or induce farmers to use land as grazing fields rather than as orchards.[6]

North and Wallis (1994) divide the production process into two functions: the physical *transformation* of land, labor and capital inputs, here symbolized by the vector $X_p$, into goods and services, which gives rise to transformation costs; and the use of land, labor, and capital inputs, represented by vector $X_s$, to *transfer* property rights from one actor to another, which gives rise to transaction costs. More specifically, transaction costs arise when $X_s$ inputs are used to monitor the production process, and organize the purchase of inputs and selling of output. The production function also contains intermediate goods, D, and social and physical technologies, $A_p$ and $A_s$.[7] We can now write:

$$Q=f_{\Psi}(A_p, A_s; X_p, X_s, D)$$

[5] Known physical technologies and corresponding outputs can also be off limits because of domestic and even international constraints, for instance, nuclear technologies and some pharmaceuticals.

[6] Another way of accounting for the social environment is to map it directly into A and drop the subscript $\Psi$ from the equation. Whatever form we use, the point is that A is nested in a social environment that influences productivity.

[7] North and Wallis (1994) do not use the terms physical and social technologies. They refer instead to techniques and institutions.

Note that in this formulation the firm has already selected specific social and physical technologies and uses its inputs to operate within these physical and social systems. Here $A_s$ represents forms of organization or contracting for buying inputs, monitoring the production process, and selling outputs. The firm uses the $X_s$ inputs to operate these mechanisms.

When analyzing organizational change, transaction cost economics of the firm has traditionally assigned a passive or adaptive role to social technologies and given the initiative to new $\lambda_p$ (Williamson 1985). New transformation techniques typically raise transaction costs within existing social mechanisms, for instance by requiring investment in expensive specific, capital assets, complex specialization in production, and long-distance trade. New transformation methods, therefore, induce demand for complementary social technology (transaction methods), then new social technologies are somehow added to $\lambda_s$, and finally market competition filters out the most effective form, $A_s$.

North & Wallis (1994) assign an active role both to social and physical technologies. Moreover, they emphasize the importance of directly measuring transaction costs (as attempted in Wallis and North 1987). The usual practice in transaction cost economics à la Williamson (Williamson 1985) is to rank business projects and assets by expected relative transaction costs (for instance, transactions involving specific assets have high expected transaction costs).[8] The reason for ranking assets in this manner is to avoid the (almost) impossible task of measuring *ex ante* transaction costs and, at the same time, make it possible to derive and test hypotheses about organizational choice, such as decisions about make-or-buy and vertical integration.

[8] The Williamson approach focuses on *ex ante* transaction costs as an obstacle. Measuring *ex post* transaction costs is not of interest, and *ex ante* transaction costs are hard to estimate directly because the market does not price them. Wallis and North (1987), using national accounts, measure *ex post* transaction costs associated with occupations and industries engaged in the transaction function. They conclude that between 1870 and 1970 the transaction sector grew from 25 to 45 percent of GNP.

This approach, however, puts the complex relationships between the transformation and transaction functions in a straightjacket, and by definition assigns a residual role to $\lambda_s$. Economic history indicates that new social technologies, $\lambda_s$, may induce changes in $\lambda_p$ and further changes in $\lambda_s$. Also, new physical techniques that emerge in one industry are often transmitted to other industries via intermediate goods, D, raising productivity of inputs in either or both the transformation and transaction functions in the receiving industries. In sum, the relationship between $\lambda_s$ and $\lambda_p$ is interactive and often forms a virtuous circle. Consider a new communications technique, such as the telephone or the computer, which belongs to the $\lambda_p$ category. When the new communications technique travels as an intermediate good, D, to other industries, it increases the productivity of inputs in their transaction functions, perhaps induces new forms of organization, which in turn paves the way for new transformation techniques. North and Wallis (1994, 618), discussing Chandler's *The Visible Hand: The Managerial Revolution in American Business* (1977), point out that new financial mechanisms (investment banking, securities markets, organized bond market), $\lambda_s$ innovations that migrated as intermediate goods, enabled improvements in both $A_s$ and $A_p$ in industries outside the financial industry. North and Wallis (and also Chandler) emphasize that in the United States various complementary financial mechanisms emerged prior to the large corporation. The modern business enterprise took its impetus from developments in transportation and communications (transformation techniques), employed already existing financial techniques, and perfected large-scale manufacturing transformation methods that induced a managerial revolution (North and Wallis 1994, 620).

Q, the output, in the production functions above refers to commodities, capital assets, new social mechanisms, and the operation and maintenance of a social system. The maintenance and use of social systems or social mechanisms usually require explicit enforcement, involving information-gathering, measurement, and monitoring. New physical technologies are particularly important for increasing the productivity of inputs employed in operating the systems. All communities are constrained in their choice of social structures by available physical technologies. Richard Posner's (1980) essay, "A Theory of Primitive Society with Special Reference to Law," illustrates my point. Posner shows that with primitive physical technologies only a small set of elementary non-specialized social structures is feasible. That is why the last two hundred years have seen the rise of enormous, previously unknown, variation in both gdp per capita and social organization among the countries of the world.

The main purpose of this paper twofold: to raise the profile of social technologies in theorizing about economic development and above all to emphasize the importance of incomplete knowledge, search, innovation, and experiments in the social domain. Recently the new economics of institutions has studied the structure of social systems in terms of incentives and endowments, but usually assumed, often implicitly, that the content of $\lambda_s$ is a) reliable and b) available at a cost. Political economy, admittedly, recognizes rational ignorance, which arises when secondary actors, who have little at stake individually, lack the incentive to invest in discovering the relevant elements in the $\Omega_s$ and $\lambda_s$ sets and are therefore open to deception. The idea that the $\Omega_s$ and $\lambda_s$ sets contain inaccurate and conflicting knowledge substantially complicates attempts to theorize about institutional change. First, when even the rule makers and their specialists believe in unworkable social technologies and walk in the dark, unintended consequences of institutional policy become an important issue. Second, when reliable social technologies are not readily available for those who have the incentives and resources to access available knowledge, the process of change is characterized by struggles over "the true" social model. Third, incomplete knowledge of relevant social technologies affects the dynamics of institutional change. Instead of having a reliable picture of the long-term path of social change, the players learn by doing and sometimes abandon relatively sound social technologies in response to random shocks.

The concept of incomplete social technologies is not a substitute for the usual stories about search for efficiency and exercise of power; it complements these other approaches. To incorporate the notions of knowledge, power, and efficiency and complete the framework, the next section borrows from macroeconomics and introduces decision makers who rely on policy models; a notion that originated in applied Keynesian economics, and has coevolved with macroeconomic theory.

## *4. Policy Models and Social Technologies*

In mid 20$^{th}$ century it was common for economists to view economic and social relationships in mechanical terms and express optimism about the capacity of governments to plan economic activity from the macro- down to the micro-economic level. Immediately before and after World War II, Jan Tinbergen, Ragnar Frisch and others, who were inspired by the new field of Keynesian macroeconomics, popularized the idea of a policy maker who relies on a complex model of the economy to redirect the system and reach desired outcomes.[9] The old theory of macroeconomic policy was an application of mathematical decision theory. The decision makers (usually the state) rely on a macroeconomic model that maps how instruments under their control (such as taxes or interest rates) relate to desirable targets or outcomes (such as full income and stable prices). The decision makers evaluate available outcomes, using their objective functions (often said to correspond to the social welfare function of the community), and select the best available outcomes (Tinbergen 1952).

[9] See Eggertsson (2005), Chapter 8 for greater detail and references for this section.

In this initial phase the theory of macroeconomic policy deliberately avoided dealing with political constraints and self-interested decision makers, assigning such complications to political science. Political economy soon rose to the challenge and has extensively studied macroeconomics and politics (Alesina 1995). If we focus on the economic domain, the last forty years have seen radical changes in the way economists view the social technology of macroeconomics. Their views have also diverged, as we can see from the title of Ned Phelps 1990 book: *Seven Schools of Macroeconomic Thought.* The most important new ideas, from our point of view, are rational choice macroeconomics and bounded rationality macroeconomics. Rational choice macroeconomics, in its purest form, assumes that the policy models of all actors—the central authority and economic actors—have converged on a correct element in the $\lambda_{\text{macroecon}}$ set (Lukas 1976). Policy measures impose costs and benefits on economic actors, and informed rational actors, who correctly anticipate the measures, use all means at their disposal to protect their economic status, which reduces the set of choices available to the government. Bounded rationality macroeconomics, a second major departure from traditional Keynesian theory, also assigns a policy model both to the central authority and economic actors, but the theory no longer assumes that all parties have converged on reasonable or correct social technology (Sargent 1993). Bounded rationality macroeconomics is concerned with how the actors solve their "scientific problem," how they learn, and whether the rule maker and the ruled converge on a common workable social technology.[10]

Students of bounded rationality macroeconomics sometimes use the experience of national governments in the 1960s and 1970s with the so-called Phillips curve to illustrate the knowledge

[10] For a recent discussion of the knowledge problem and bounded rationality macroeconomics, see Sargent's (2008) Presidential Address to the American Economic Association, which explores the consequences of inaccurate subjective models.

problem in macroeconomic policy.[11] The Phillips curve, which postulates a stable relationship between the rate of inflation and the level of unemployment, creates an opportunity for the central authority to trade inflation for unemployment, and vice versa, along the curve. The presumed stable relationship, it turned out, is an empirical illusion: the relationship disappeared when governments attempted to exploit it for policy purposes. The futile experience with the Phillips curve raises several interesting questions (Sargent 1993): Did neither side know that the social technology in the $\lambda_{PhillpsCurve}$ set did not work? Or did the government know but found it politically expedient to behave as if the Philips menu existed? And economic actors, did they perhaps know that there was no Phillips curve and somehow exploited that knowledge? If governments did believe in the inflation-unemployment trade-off, exactly how did they learn that they were mistaken—how did they eventually receive unambiguous feedback indicating that the $\lambda_{PhillipsCurve}$ set did not contain useful tools? The Saga of the Phillips curve (although it involves the management of a system rather than system change) has obvious relevance for institutional policy; consider for instance frequently unsuccessful attempts to transfer legal systems from one country to another.[12]

We are now ready to summarize. Ubiquitous policy models are the core of our framework for thinking about institutional policy and institutional change. The policy models of actors define their opportunities as seen through the filter of subjective social models. The policy models also allow for exogenous factors (changes in relative prices, new techniques), as well as the actors' endowments of material resources, legitimacy, and power. The instruments of institutional policy

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[11] The Phillips curve is named for A. W. Phillips, an economist who discovered what he saw as an inverse stable relationship between the rate of inflation and the level of unemployment for extended period in British economic history.

[12] Legal transplants have sometimes succeeded in creating comparable levels of legality in the host country as in the mother country but failures are common. Several recent studies have explored the causes of success and failure. See Eggertsson 2005, Chapter 11.

include new rules, new enforcement mechanisms, and persuasion. The instrument of persuasion is aimed at reshaping people's social beliefs. Actors, subject to new rules, protect their interests, when needed, through attempts at evasion and through their own campaigns of persuasion. When official rules allow or when they are not properly enforced, private rules and private mechanisms substitute for or complement the public order.

*5. Social Technologies and the Uncertainties of Institutional Change*

In *Section 3* I argued that inaccurate and conflicting knowledge in the $\Omega_s$ and $\lambda_s$ sets seriously complicates attempts to model institutional policy. The knowledge problem generates unintended consequences; honest conflicts over the nature of social technologies (on top of campaigns of deception); gradual learning and stepwise adjustments in policy and behavior; and over-reactions to random shocks. The current section deals with the problem of knowledge in greater detail, using the emergence of biotechnology as an example.

New property rights do not materialize and take hold without (at least tacit) cooperation and support of three classes of actors with divergent interests: rule makers, right holders, and duty bearers (Riker & Sened, 1991). Moreover, the members of each category often have conflicting interests and beliefs. A system of property rights usually consists of public and private rules. In spheres where official rules are lacking or where they are not enforced, private rules and private enforcement often fill the vacuum. In domains where the state provides and enforces property rights but where right-holders are dissatisfied with the system, three responses are possible (in addition to appealing to the state or doing nothing): a) strengthen the system with complementary private rules; b) use private rules to fill gaps in the system without challenging its core structure; or c) substitute private rules and enforcement for official property rights and restructure the system. All three responses are common. In addition to rule making, persuasion often plays an important role in the process of institutional change: Each group (and sub-group) tries to persuade others of the merits of its favorite social model.

In stable societies, major adjustments in property rights are usually associated with unexpected events or developments that are important enough to upset the social equilibria, either by changing power relationships (à la Acemoglu and Robinson 2005) or by inducing widespread revisions of relevant elements in $\lambda_s$, and sometimes $\lambda_p$ (Eggertsson 2005, Chapter 10). Various pivotal events can initiate major revisions of the elements in $\lambda_s$, including the collapse of financial and economic systems (the Great Depression; the Financial Crisis of 2008); rapid shifts in political power (enfranchisement of working men and women in Europe); new technologies (biotechnology); sharp changes in asset values (new markets open); environmental crises (climate changes); delayed side-effects of social systems (abuse of welfare services); and challenges by foreign powers (colonialism).[13]

When scholars trace the causes of large-scale structural changes in social systems, they have a tendency, as already mentioned, to overplay the independent role of physical technologies and assign an adaptive role to social technologies. We are familiar with many of these claims: In Modern Europe, new $\lambda_p$ in warfare required large armies, forcing the elite to offer voting rights to the working class in return for military service. New fishing technologies (including peaceful use of sonar devices) have depleted fish stocks, inspiring a search for new fisheries regulations such as individual transferable quotas. And toward the end of the 20th century various developments in the natural sciences have given rise to knowledge-based industries, which in turn have called for major revision of intellectual property rights. A closer look at the historical record reveals, however, that structural changes typically do not have a clean starting point but

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13 Eggertsson, 2005, Chapter 3: Competing Social Models, discusses the rise and fall of social models.

involve interactions back and forth between the $\lambda_s$ and $\lambda_p$ sets, as well as between propositional and prescriptive knowledge. For instance, cumulative scientific work depends on complementary social mechanisms and appropriate incentives (such as relief from persecution by the state and religious authorities). Scientific progress also requires effective social systems for storing and accessing knowledge, including informal networks of scientists, learned societies, libraries, and educational systems. And, finally, to sustain economic growth the social system must encourage the practical application of new knowledge (Mokyr 2002).

Yet, notwithstanding the argument above, when analyzing social change, expediency requires that we enter the endless chain of causation at one point or another, and great innovations in natural science and technology usually are more visible than social innovations. Therefore, I begin my story about the evolution of the biotechnology industry by pointing at major scientific progress in molecular biology in the last third of the 20$^{th}$ century. Biotechnology is an interesting case for our purposes: it provides revealing examples of complementarity between $\lambda_s$ and $\lambda_p$; substitution of private for public rules; intensive efforts to influence social models; and high variance and uncertainty in $\lambda_{biotech}$. We now turn to these issues.

I begin by considering complementarity between $\lambda_s$ and $\lambda_p$. In approximately the last three decades of the 20$^{th}$ century, breakthroughs in the biological sciences and new scientific instruments created high hopes for a new profitable biotechnology. But there were lions in the way. A new biotech and biogenetics industry would require huge investment in research and development projects with uncertain payoffs. In the United State, biotech was able to obtain financing from the venture capital industry, a pre-existing but relatively recent business model (social technology). The new biotech industry also required secure and clearly defined property rights to its assets, inputs and outputs with all the related transaction services provided at reasonably low costs. Control rights over life samples (inputs) and genetically modified microorganisms (outputs) are prime examples of these requirements. Demsetz's (1967) classic theory of the origins of property rights is of some relevance here. The theory states that adjustments in property rights arise to limit expected external effects, which are positively correlated with the value of an asset. Therefore, as the value of an asset increases, the owners' property rights become more secure and more clearly defined. Note, however, that Demsetz assumes that the demand for property rights creates its own supply; the theory does not consider the behavior of rule makers and duty bearers or problems of collective action among right holders. Yet, as anticipated by Demsetz (1967), rising expected resource values created tensions about ownership of biotech resources, such as medical samples, health records, and genetically modified microorganisms.

In Western democracies various branches of the state, the most important being legislatures, the executive branch and the courts, supply public property rights. In the United States, court decisions have played a key role in changing the property rights environment of the biotech industry. Duty bearers have strenuously opposed the new order but eventually tacitly acquiesced. I will briefly discuss the two best-known cases.

In John Moore v. the Regents of the University of California (1988; 1990) the rights to profits from a valuable biotech invention was the matter of discord. Scientists, who had treated Mr. Moore for cancer, had, for research purposes but without his knowledge, established a cell line from his white (lymphocites) blood cells. The scientists and the University of California had acquired a patent on the cell line, commercialized the invention, and made substantial financial gains. The Supreme Court of California found that Mr. Moore had no rights to profits made on products developed from his discarded body cells. For our purposes, two dimensions of the ruling are particularly interesting. First, the opinion is based on controversial social models, which even all justices did not share. Second, the opinion is explicitly concerned with supporting progress in biotechnical research by keeping down the transaction costs of using medical samples (Epstein 2003).

Profit-seeking investors in biotechnology need to establish secure property rights in their outputs but in the United States, according to official interpretations, prior to 1980 the law did not permit patents in living organisms. On these grounds, the U.S. Patent Office had rejected an application for a patent by Ananda Mohan Chakrabarty, a genetic engineer working for General Electric.  Mr. Chakrabarty, who had created bacterium capable of breaking down crude oil, took his case to court. In 1980, the U. S. Supreme Court, in an expansive mood, ruled in a five to four decision that the law permitted the patenting of genetically modified microorganisms because the "respondent's micro-organism constitutes a "manufacture" or "composition of matter."" The decision had a profound impact on the industry (Eisenberg 2006).

When faced with the opportunities of the new biotech industry, many investors, business leaders and academic scientists concluded that successful operations required substantial reorganization of the enterprise. In particular, they wanted (partial) commercialization of basic research and the introduction of for-profit research firms. At least two beliefs supported these new models: First, there was the theory that new developments in the biological sciences had virtually erased the gap between basic and applied research, which reinforced the second point that essential manpower and knowledge were available in university laboratories, but at the time the big pharmaceutical companies lacked resources in biogenetics and related fields (Nelson 2008; Merges 1996). The commercialization of basic science has many opponents, some claiming that the new social technology may undermine the foundation on which the Western knowledge revolution rests (David 2004). The traditional view (the previously dominant social technology) is that for-profit organizations should only be involved with applied science whereas basic research belongs to Michael Polanyi's (1962) *Republic of Science*, a regime based on openness, cooperation, peer evaluation, and search for prestige rather than profits. Similarly, Robert Merton's (1973) classic study *The Sociology of Science* identifies four key norms of science: communalism, universalism, disinterestedness, and organized skepticism. At a practical level, U.S. law limited the ability of universities to seek patents for their inventions. In 1980, the proponents of the new social technology scored a victory when Congress passed the Bayh-Dole Act, which allows U.S. universities, non-profits, and small businesses to patent federally funded inventions. Academic organization responded by setting up internal administrative structures supporting the commercialization of research. Scholars now move more freely than before between universities and enterprise laboratories, many university scientists have set up their own for-profit research firms, and university patents have skyrocketed.

In sum, the rapid rise of modern biotechnology is closely associated with new and controversial social technologies. The industry is evolving rapidly and many aspects of both its physical and social technologies are poorly understood. Consider first uncertainty about biotech's $\lambda_p$. Will the industry deliver safe and useful products or are some of its products, such as genetically modified food, hazardous? Are key strategies for research scientifically viable, such as current approaches to find cures for major diseases by establishing their genetic bases and then look for drugs that neutralize the malignant genes? And there is uncertainty about biotech's $\lambda_s$, which is our focus. I conclude by sketching conflicting beliefs about appropriate social technologies for the new industry, emphasizing the incompleteness of our knowledge about both the current business model and workable reforms.

First consider the old and new Republics of Science: What exactly was the previous social technology underpinning the Western natural science enterprise, and how has it actually changed? Has the system until recently been one of openness and unconditional sharing of results (in addition to published findings), research techniques, tools and data; has it been a pure open-access regime? Merges (1996) claims that there is a discrepancy between the ideal-type model of Polanyi and Merton and actual practice. Actual practice was based on medium-size common pool regimes, which, in another context, Ostrom (1990) has immortalized. The traditional social model of science was not one of open access but was made of exclusive networks of scholars that cooperated selectively. In practice, the new system with its patenting of basic research and modified microorganisms—which makes Eisenberg (2006, 357) wonder "whether the patent system has any subject boundaries at all"—differs perhaps less from the previous regime than we suspect. The reason is twofold: the old ideal-type system is partly a myth, as mentioned, and the players have to some extent substituted private for public rules; they play by their own rules.  According to Merges (1996; 2004) the fragmentation of property rights and associated insurmountable transaction costs, the so-called anticommons problem (Heller & Eisenberg 1998), is not as severe as many observers fear. Scientists do not always and to the utmost enforce their patent rights: they often share patented results with other scientists, especially with those working on basic research. The evidence also indicates that some firms try to reverse potential anticommons effects by putting patentable findings in the public domain. Moreover, firms sometimes set up patent pools and negotiate various arrangements to lower transaction costs (Merges 2004).

The point is that we do not fully understand the new system. We do not know for sure whether the private order substitutes that Merges (1996, 2004) discusses outweigh possible harmful anticommons effects. We neither know for sure whether anticommons effects have held back progress in biotechnology nor how to repair the system, if required. Expert opinion has not converged on common answers to these questions. Some scholars, when contemplating repairs of the new patent system, advocate, in urgent cases, confiscation of patents by the state; compelling owners to license their patents to particular firms; and, when bargaining breaks down, let state agencies decide the contract terms. Epstein (2003) disagrees with this fine-tuning approach and claims that information problems would overwhelm government regulators when they attempt to estimate fair value for upstream patents prior to their commercial exploitation; when they try to select efficient receivers of patents; and when they try to design efficient contracts. Moreover, forcing A to contract with B, gives B the upper hand in bargaining, making voluntary agreements unlikely. Epstein (2003) recommends an either-or-system: either temporary monopoly (patents) of knowledge assets or open access, with government agencies not entering the fray. Still, we need to agree on efficient rules for determining the boundaries between the two categories.

Ideas about the effectiveness of for-profit research firms are also divergent. Richard Nelson (2008, 9-10) notes that in an earlier period industrial firms successfully established internal research and development departments whereas the concept of specialized research and development firms did not catch on. Recent losses and outright bankruptcies of biotech research firms suggest to him that their business plans and expectations are flawed. Nelson (2008, 10) goes further and claims, "…the effectiveness of the institutions that have grown up in the U. S. in support of biotech is quite uncertain." Many scholars and investors share Nelson's opinion, many others do not.

*6. Conclusion*

In this essay I have emphasized the independent role of social technologies in economic progress, the importance of social innovations, and the limits to our knowledge of social systems. Many observers believe that during the last two hundred years social technologies have progressed much faster than social technologies. I am not aware of reliable methods for comparing the two technologies, but various factors that complicate institutional policy are rather obvious. I conclude with a few thoughts about these complications. The most obvious difficulty is the link between personal policy models and social systems: the operational qualities of a system depend on individual social models or the vagaries of human beliefs. The properties of physical technologies do not depend on interactions with human beliefs and incentives in this manner. Another related difficulty is that local social systems or mechanisms are related to one another in a complex way that determines their effectiveness, as Ostrom (1999) emphasizes. For instance, attempts to transplant social mechanisms from one nation or culture to another depend on how well the imports harmonize with local systems in the receiving community.

Physical technologies do not depend on local conditions to this extent, although, for instance, they can be sensitive to local climates or altitudes, which is usually foreseeable. Nelson (2008, 8) summarizes these difficulties when he states "physical technologies … are easier to replicate and imitate more or less exactly, than are social technologies." 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 …" Nelson (2008, 8) attributes these productivity differences largely to the managers' inability to standardize social technologies. The sensitivity of social mechanisms to local conditions implies that we cannot learn a lot about them "by building prototypes and doing controlled experimentation "off-line", as it were, in research and development" (Nelson 2008, 8). Unlike physical technologies, we have limited ability to set up controlled experimentation with social technologies and transfer them to actual practice. Again, in Nelson's words (2008, 8): "Another important difference is that, because of the ability to routinize, shield and control, it is often possible to experiment with a part of a physical technology offline, and to transfer the improved version of that piece to the larger system with confidence that it will work in that context and in actual practice. … However, virtually all learning regarding social technologies and the institutions that mold and support them has to proceed on line." And learning on line about social technologies usually involves serious uncertainty, measurement problems and mistakes.

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