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KNOWLEDGE AND THE THEORY OF INSTITUTIONAL CHANGE

Introduction

In his classic 1956 paper, *A Contribution to the Theory of Economic Growth*, Robert Solow rescued us from the unstable, razor-edge equilibrium of Harrod and Domar but unwittingly created a path-dependence in our collective mind about the nature of economic growth and development. William Easterly (2006) documents the phenomenon in a recent book, *The White Man's Burden*, and so have others. The original Solow growth model envisions an aggregate production function with constant returns to scale and neutral technical change.[1] Solow uses the letter A to represent total factor productivity. A change in total factor productivity, technical change, is represented graphically by an upward shift in the production isoquants. The following year, in an empirical study, Solow (1957, 312) attempts to separate "variations in output per head due to technical change from those due to changes in the availability of capital per head." Solow (1957) states, however, that he "uses the phrase "technical change" as a short-hand expression for any kind of shift in the production function. Thus slow-downs, speed-ups, improvements in the education of the labor force, all sorts of things will appear as 'technical change."' Using data for the United States from 1909 to 1949, Solow reports that "gross output per man doubled over the interval, with 87 ½ per cent of the increase attributable to technical change …" or *A* (Solow 1957, 320).

New institutional economics, and economics in general, focuses on the sources of productivity changes at the micro and macro levels, thus trying to explain changes in *A* over time. When we wonder how the West grew rich; why England lost its technology leadership; why some countries catch up with the growth leaders while others do not; or study the role of specialized assets in business organization, we are looking for the determinants of A. In new institutional economics, scholars usually focus on rules and enforcement mechanisms, implicitly or explicitly assuming that, with efficient structure of political and economic institutions, and consequently efficient incentives, economic growth will take care of itself. Mainstream growth theorists, at least until recently, took social institutions as given, technical change as autonomous, and examined changes in the stock of human and physical capital.

In the rush to study the role of institutions and capital accumulation, the role of new knowledge in the growth process often falls between the chairs. Yet, virtually all scholars agree that a growing stock of useful knowledge is a necessary condition for sustained growth in total factor productivity.[2]

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1 If we use a Cobb-Douglas production function, the aggregate production function can be written as $Y_t=A_tK_t^{\alpha}L_t^{1-\alpha}$, and $A_t=Y_t/K^{\alpha}L^{1-\alpha}$. The letter A represents technical change, L is the stock of labor units, K the stock of capital units, and t is time.

2 I exaggerate a bit. Scholars in several sub-fields explicitly study the creation of knowledge and technological change.

Knowledge is a scarce resource. Its supply elasticity is positive, not zero, and depends on complex economic, political, and cultural conditions, which are not well understood. I refer you to Joel Mokyr's (2002) book, *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Knowledge that already exists is said to have the characteristics of a public good (non-rivalry in consumption, non-excludability). Buying and selling pure knowledge is problematic because the buyer does not know what she is buying, and does not need the product when she knows. And the problems continue: knowledge is often tacit, which means that we cannot code it and copy it as information. To code tacit knowledge is either too costly or technically impossible. Tacit knowledge, therefore, spreads through learning-by-doing and during apprenticeship (David & Foray, 2003). And, finally, knowledge is inherently a perishable product.

Social technology

It is common to divide useful knowledge into two overlapping branches: science and technology, where the term technology refers to the application of knowledge for practical purposes. We sometimes say that science is *why* or *how* knowledge, and use the term technology to represent *how-to* knowledge. Let me further divide technology into *physical technology* and *social technology*. Physical technology refers to the application of physical science for practical purposes, and the term social technology refers to the application of social science for practical purposes. In this view, all production—whether it is knowledge, social mechanisms, or goods and services—involves joint application of physical and social technologies. Consider for instance the production or creation of social systems or social mechanisms. For any community, its social organization is constrained 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 very small set of political, economic and social structures is feasible. For the world as a whole, a revolution in physical technology enormously increases not only the capacity to produce goods and services but also the feasible range of social mechanisms. In the last 200 years we have seen how a series of revolutions in physical technology has increased, at least initially, the variation between countries both in their material wealth and social organization.

Joel Mokyr (2002), Nathan Rosenberg (1982) and other students of technical change during the First Industrial Revolution have described how new knowledge flowed back-and-forth between physical science and technology, with each side learning from the other. They also emphasize that the physical technology of the 19th Century had only a narrow base in science. The technologists often didn't know why their techniques worked, which limited their capacity to improve them. In the 20th Century the science base of physical technology has expanded, reducing the time interval between invention and innovation and making it easier to debug new techniques.

Can we make a similar claim for social science? Have we seen revolutionary improvements in social science and comparable leaps in social technology? The answer is both yes and no, but mostly no. The social science base of social technology is narrow, which means, for instance: that attempts to export legality from one country to another often result in negative transplant effects (Berkowitz et al. 2003); or that we are still trying to discover important properties of already existing social systems—still attempting to map the underlying social technology. I am reminded, for instance, of Barry Weingast's (1995) excellent work on market preserving federalism and economic development.

Once technical progress is on the roll, the two technologies often induce each other: new physical technology creates potential business opportunities and induces essential complementary social technology, and also the other way round. Alfred Chandler (1977) describes this circular process in his account of the modern corporation. In the United States the development of long-distance railroads and telegraphy had toward the end of the 19th century increased the potential size of the market and created opportunities for large-scale production. These developments induced new social technologies required for developing the modern corporation, including mechanisms for governance, financing and marketing, as well as improvements in the physical methods of large-scale production.

Induced change has an important role, but the narrow social science base of social technology continues to be a serious barrier. The bottleneck is particularly obvious when we try to adjust modern economic systems to major new scientific discoveries or try to rapidly modernize backward economies. Focusing on industrial (rather than political) processes, in a new paper Richard Nelson (2008) discusses why social technologies are usually more difficult to implement than physical technologies. He mentions first that "physical technologies ... are easier to replicate and imitate more or less exactly, than are social technologies." Nelson 2008, 8) Empirical studies, for instance, "have constantly shown large differences in productivity between establishments of the same corporation producing the same things and using the same production machinery ... " (Nelson 2008, 8). Nelson attributes these productivity differences largely to the managers' inability to standardize and control social technologies.

Nelson' second point turns on the fact that a social mechanism usually is embedded in a larger social system and that the two influence each other's effectiveness in a complex manner that severely complicates measurement. In the case of physical technologies, however, we can learn at lot "by building prototypes and doing controlled experimentation "offline", as it were, in research and development" (Nelson 2008, 8). For various reasons, we have limited ability to set up controlled experimentation with social technologies and then transfer them to actual practice. In Nelson's own words: "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 an 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" (8). And learning online about social technologies usually involves greater uncertainty and measurement problems than is the case with physical technologies.[3]

Learning from macroeconomic policy

In my 2005 book, *Imperfect Institutions*, I look to macroeconomics for lessons about how to formulate our ideas about social technologies and institutional policy. The original thrust of New Institutional Economics primarily involved *why* and *how* questions, with limited emphasis on "*how-to*" knowledge (Banerjee 2002). Modern macroeconomics emerged during the Great

[3] These difficulties with implementation partly depend on the fit between a new social mechanism and the pre-existing large social system. In my own backyard, the Scandinavian countries often successfully import social arrangements from each other, for instance social legislation.

Depression with a strong emphasis on policy, although recently the link between theory and application has grown weak. In a recent paper, "The Macroeconomist as Scientist and Engineer," Gregory Mankiw (2006) documents how, in the last two decades or so, US policy makers in the highest places no longer rely on recent developments in macroeconomic theory. But that is another story. In *Imperfect Institutions*, I look to three phases in the evolution of macroeconomic theory and policy for ideas about institutional policy.

Starting with applied Keynesian economics in mid-20th Century, we see that the thinking about policy was based on mathematical decision theory. In this world there is a decision maker who models the social system that she wants to control. The model defines the instruments of policy, their relationship to the target variables, and the set of available outcomes. The policy maker uses policy instruments to obtain the best outcome.

The second lesson from macroeconomics is Robert Lucas' (1976) rational expectations critique. Lucas argued that traditional Keynesian theory failed to recognize that economic actors respond rationally to changes in their regulatory environment, seeking to minimize their costs or maximize their gains from a new set of rules. In consequence, statistically observed macroeconomic relationships, which appear to be stable, may break down if policy makers attempt to manipulate them.

Let me elaborate. Rational expectations theory assumes that all actors share common beliefs, without explaining where these beliefs come from and how they are shared; the problem of knowledge is assumed away. Which brings me to the third lesson: bounded rationality macroeconomics and Tom Sargent's critique of rational expectations.

In his 2008 presidential address to the American Economic Association, entitled "Evolution and Intelligent Design, Sargent (2008) explores the consequences of inaccurate subjective models, emphasizing modeling errors by the chief rule maker, the state. He also minimizes the departure from formal rational choice modeling because "leaving the rational choice equilibrium concept sends us into a 'wilderness' because there is such a bewildering variety of ways to imagine discrepancies between objective and subjective distributions" (2008, 26). Finally, Sargent employs an adaptive model that allows "our adaptive agents to use economic theory, statistics, and dynamic programming" (2008, 26). Even when minor deviations from the rational expectations approach are introduced, Sargent finds that a system of adaptive actors converges to a self-confirming equilibrium in "which all agents have correct forecasting distributions for events observed often along an equilibrium path, but possibly incorrect views about events that are rarely observed" (6). "Wrong views about off-equilibrium path events shape government policy and the equilibrium path" (15). Under these circumstances, a sufficiently large variation in data sometimes reveals that the government's model is mis-specified. Sargent uses 700 years of monetary history and practice, including the post-World War II experience of the USA, to frame his discussion about modeling errors and adaptive evolutionary processes. He cites David Ricardo's famous recommendation in 1815 of fiat money. Ricardo admits that in an earlier period the introduction of precious metals for the purposes of money was an important step for man, but recent advances in knowledge and science suggest to him a more productive technology: fiat money. Finally, Sargent (2008) claims that commodity money concealed the quantity theory of money for centuries because the arrangement was associated with limited variance in the relevant variables, the money supply and the price level.

Social models and modern biotechnology

In sum, the three lessons are: We need to be clear about the instruments of policy and their limitations; we must not forget that economic actors respond strategically to policy measures; and both policy makers and economic actors often rely on inaccurate subjective models, which are not necessarily self-correcting, except perhaps in the long run. These ideas, of course, are not unknown in new institutional economics. The notion that policy makers use incomplete models and deal with strategic actors is already implicit in Steven Cheung's (1975) work in the mid-1970's on rent control in Hong Kong. In Cheung's rent control story, the regulator gradually learns from her mistakes and, in Sargent's words, the system converges on intelligent design. In a pioneering paper, Barry Weingast and his co-authors (de Figueiredo, Rakove & Weingast 2006) actually use the framework of inaccurate subjective models and self-confirming equilibrium to solve long-standing puzzles concerning the American Revolution.

We are now able to identify the main elements of institutional policy, which are: three categories of actors, three instruments of policy, and, finally, social technologies. The three types of actors are rule makers, right holders, and duty bearers (Riker & Sened 1991). The three instruments of policy are rules, enforcement mechanisms, and persuasion aimed at changing subjective models. Policy makers are guided by their knowledge of social technologies, which are subjective blueprints that indicate which policy goals are within reach, and how they can be reached. The strategies of all types of actors stand on three legs: the actors' positive theories, their normative theories, and their power resources.

I will now use the example of modern biotechnology to illustrate the complex nature of institutional change and focus on three themes or ideas:

The first theme draws on Harold Demsetz' (1967) well-known theory of property rights: When the value of assets increases, property rights tend to move in the direction of individual ownership and more clearly specified rights.

The second theme introduces a new lion on the road to efficient exclusive rights: The journey is often interrupted by inaccurate theories, in addition to the usual savage beasts of conflicting interests, power, and high transactions costs. In Tom Sargent's (2008, 10) words: We" …study data that can be weakly informative about parameters and model features. Ultimately, this is why differences in opinion about how an economy works can persist."

The final theme introduces persuasion as a new policy instrument that targets subjective models. The process involves both deliberate falsification and honest exchanges of beliefs.[4]

Let's first look at the effects of an increase in the expected value of assets. In the last third of the 20th Century, advances in molecular biology and new research tools in biotechnology increased the expected value of health records, samples from the human body, and research findings, including those of university and other non-profit laboratories. As the value of these assets increased, potential right holders put pressure on both government and private rule makers, asking them to redefine and clarify the relevant property rights. Many potential duty bearers resisted these moves. For instance in Iceland toward the end of the 1990s, the corporation Decode Genetics convinced the country's government to introduce a bill that in effect

[4] As an example of honest struggles between subjective models, think of the debate between neo-Keynesians, the new classical synthesizers, and the real business cycle people, etc.

authorized the firm to collect the nation's health records, going back to 1918, into a central electronic database. The *de facto* owners of these records, members of the local medical establishment and their organizations, protested.

In the United States, the business plans of the new for-profit biotech research firms required secure property rights in their outputs and techniques. In 1980, the U.S. Supreme Court in *Diamond v. Chakrabarty*, in a 5:4 decision, over-ruled the Commissioner of Patents and Trademarks, asserting that genetically modified microorganisms can be patented. Also in 1980, Congress yielded to demands and passed the Bayh-Dole Act, which allows US universities, non-profits, and small businesses to patent inventions arising from federally funded research. Also, increasing value of samples taken from the human body were causing ownership tensions between patents and inventors. In 1990 the Supreme Court of California, in *Moore v. the Regents of the University of California*, decided that John Moore had no right to profits from the commercialization of anything developed from his discarded body parts. In sum, we can still learn from Demsetz but not the whole story.

Let's now turn to the second theme: How accurate are our models of the new social technology in the biogenetics sector? Do we understand the new structure of incentives and corresponding outcomes that recent adjustments in rules and enforcement mechanisms have created? Opinions, or should we say models, differ. Skeptics and pessimists claim that by assigning property rights to small bits of basic scientific findings, the new social technology has put the breaks on progress both in basic and applied research. The new arrangements are said to have created anti-commons problems–excessive fragmentation of property rights (Heller & Eisenberg 1998). The critics argue moreover that the profit motive is eroding the highly successful norm-based incentive system of science: eroding Robert Merton's (1973) four social norms of science: universalism, communism, disinterestedness, and organized skepticism. By weakening or destroying communism and non-pecuniary incentives, the critics argue, the new system will destabilize the very foundation of modern science, although it may take some time before all adverse side effects appear.

The optimists counter that new conditions—rapidly expanding science base and a shrinking time span between invention and application—require new structures and new incentives. The optimists see no evidence suggesting that progress in biotechnology is slowing down. Other observers have followed Bob Ellickson's (1991) example, in his famous study of *Order Without Law* among the ranchers and farmers of Shasta County, California: They try to establish whether the biotech sector has evolved a private order that differs from its formal rules and ideal-type norms. According to Robert Merges (2004), the biotech sector apparently has a distinct, adaptable private order. Prior to the extension of patents to basic research and modified microorganisms, the scientific community often diverged from the norm of communism: When sharing results and research methods, scientists would form medium-size exclusive communal networks. And in the post Chakrabarty-Bayh-Dole world, scientists do not always, and to the utmost, enforce their patent rights; they often share patented results with other scientists, especially with those who are involved in basic research. The evidence also shows that some firms put patentable findings in the public domain with the aim of reversing anticommons effects. Firms also set up patent pools and negotiate various arrangements to lower transaction costs. Yet, we don't know how significant these private order arrangements are relative to the size of the anticommons problem.

The experts moreover disagree whether the authorities are capable of repairing presumed inefficiencies in the biotech sector via direct case-by-case interventions. Richard Epstein (2003) thinks that regulators lack the capacity; he advocates an all-or-nothing approach to patent rights; other scholars hold contrary views.

Finally consider the very concept of for-profit biotech research firms, which hope to survive by licensing their products to other firms. Dick Nelson (2008, 9-10) notes that in an earlier period, industrial firms that were involved in regular production and distribution successfully set up internal R & D departments, but the concept of specialized R & D firms did not catch on. Recent losses and outright bankruptcies of biotech research firms suggest to Nelson that their business plans and expectations are flawed. Nelson (2008) goes further and claims, "…the effectiveness of the institutions that have grown up in the U.S. in support of biotech is quite uncertain." Other scholars and investors do not share Nelson's subjective model.

I now turn to the final theme: the role of persuasion and model competition in institutional change. A model contains a set of assumptions, concepts, values, and practices that constitute a way of viewing reality. The promotion of subjective models can involve honest exchanges of ideas or deliberate model falsification for strategic purposes. Let's begin with the latter and use as an example the struggle in Iceland between members of the medical establishment and the firm Decode Genetics. Both sides needed support from the general public: In Parliament, public opinion was needed to influence voting on a bill authorizing the firm to operate a centralized electronic data bank of the nation's health records. And direct public support was required to obtain blood samples and other forms of public cooperation in the firm's research projects. In the war of models, the medical establishment emphasized: threats to privacy; why it is technically impossible to securely encrypt medical data; and how the project would paralyze medical research in the country. The opponents also described the data bank project as an attempt to steal the nation's genetic heritage, a national treasure. Decode Genetics similarly painted an exaggerated picture of the future. In its propaganda, the firm claimed that it had a good chance of finding the cure for some 50 major diseases; that the population's unique genetic structure was critical for success; and that the small island nation of less than 300 thousand inhabitants could make an immense contribution to mankind. These arguments sound simplistic but they were an important input in the evolution of biogenetic property rights in the country.

As for (relatively) honest battle of ideas, I have already outlined serious disagreements about the prevailing social technology in modern biotechnology. The experts disagree with each other on: The consequences of expanding patent rights far upstream from viable commercial products; the regulatory capacity of the state; the capacity of biotech firms to find efficient solutions through private ordering; the overall viability of biotech institutions. And they not only disagree, they try to influence policy. In the gray zone separating social science, ethics, and falsification we have heated struggles over genetically altered food, stem cell research, and commercial DNA testing. And I have not discussed the other key sector of the modern economy: digital industries and the Internet. The war of models is no less intense in the digital sector. Consider the following questions: Do digital markets differ from conventional markets in terms of efficiency? Do conventional anti-trust measures apply to modern network industries? What impact does digital technology have on crimes? Should the law treat computer-internet crimes differently from comparable hands-on crimes? Is open access the most productive structure for software production? What is the most efficient structure of property rights for digital music?

Conclusion
The purpose of this talk is to draw attention to the mysteries of Robert Solow's exogenous *A* variable, to Joel Mokyr's *The Gifts of Athena* and the intellectual roots of the Industrial Revolution, and finally to Tom Sargent's adaptive rather than intelligent agents. In the study of economic progress, we have paid great attention to secure rights of property and contracts, and justly so. Problems of capital accumulation have also been closely examined. Much less thought has been given to the production and distribution of useful knowledge; and how national systems of innovation contribute to technological leadership. At another level of analysis, our work often assumes, implicitly or explicitly, that subjective models are accurate and policy makers capable of intelligent design. I am suggesting here that we might turn a good yield by investing more resources in studying the problem of knowledge in institutional change.

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