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Knowledge and the theory of institutional change

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Abstract: Modern theory identifies several sources of economic growth, such as capital accumulation, new techniques, secure property rights and contracts, and absence of rent seeking. This paper introduces new social technologies as yet another source of growth and emphasizes our incomplete knowledge of social systems. I introduce a framework for analyzing institutional policy and use the case of modern biotechnology to explain how uncertainty about social technologies, persuasion, and competing beliefs influence the evolution of property rights.

Introduction

In his classic 1956 paper, *A Contribution to the Theory of Economic Growth*, Robert Solow set out to rescue us from the unstable, razor-edge equilibrium of Harrod and Domar but unwittingly created 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: Why the West's Efforts to Aid the Rest Have Done So Much Ill and So Little Good*, 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. Increases in total factor productivity, technical change, are represented graphically by downward shifts 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 slowdowns, speedups, improvements in the education of the labor force, and all sorts of things will appear as "technical

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

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 has a primary interest in productivity changes at the micro and macro levels – or 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 ownership arrangements for specialized assets in business organizations, we are trying to find the determinants of *A*. In new institutional economics, scholars usually focus on rules and enforcement mechanisms, implicitly or explicitly assuming that with efficient structures of political and economic institutions and, consequently, efficient incentives, economic growth will take care of itself. In mainstream economics, growth theorists, at least until recently, have taken social institutions as given, technical change as autonomous, and analyzed changes in the stock of human and physical capital.

In the rush to study 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]

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 process it as information through coding and copying. To code tacit knowledge is either too costly or technically impossible and it typically spreads through informal learning-by-doing and apprenticeship (David and 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* 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

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

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.

Social organization in primitive, isolated, and preliterate farming societies provides a striking illustration of the joint contribution of social and physical technologies. In primitive societies, the capacity to organize is critically constrained by the limited availability of physical technologies for supporting, for instance, communication, measurement, monitoring, and enforcement. Yet, primitive societies of a long standing are likely to have relatively efficient social systems because nature filters out the most ineffective social structures. Famine is the cost of poor organization. In a thoughtful essay, Richard Posner (1980) works his way through organizational forms that are likely to be available and used in traditional societies that have no written records, scant knowledge of the laws of nature, and access to only the most elementary techniques of farming and agriculture. In an ideal-type primitive society, he asks what social institutions do we expect to find in the spheres of politics, property rights, insurance against hunger, protection of order, economic exchange, and religion? Posner then relies on the presumption of high information and transaction costs to explain why preliterate societies that utilize primitive physical technology usually are stateless, lack specialized organizations such as firms and government bureaus, are elaborately organized into clans, rely on communal property rights, strict liability in torts, gift exchanges, joint or interrelated institutions for production, government, and religion, and sometimes block the accumulation of surpluses by fortunate individuals. In short, Posner demonstrates that with primitive physical technologies only a small set of elementary non-specialized social structures is feasible. The corollary is that advances in physical technologies expand the set of feasible forms of social organization. In the last 200 years, 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 nineteenth 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 twentieth century, the science base of physical technology 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? In the last two centuries, 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: we lack the necessary how-to knowledge (Berkowitz *et al.*, 2003). Our *why* knowledge is also shallow: we are still trying to discover the nature of already existing social systems. I am reminded, for instance, of Barry Weingast's (1995) work on market-preserving federalism and economic development, attempts by Coase (1937) and his followers to discover the nature of the firm, and numerous studies in the *Journal of Law and Economics* claiming that the structure of law embodies economic logic.

With technical progress 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 toward the end of the nineteenth century the development of long-distance railroads and telegraphy 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 and marketing, as well as inducing improvements in the physical methods of large-scale production. Note, however, that vital complementary financial mechanisms (social technologies) – such as investment banking, securities markets, organized bond markets – preceded the modern corporation and helped induce both new production and governance methods.

Induced change has an important role, but the narrow knowledge 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. Richard Nelson (2008), focusing on industrial (rather than macroeconomic and political) processes, 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's second point is that a social mechanism is usually 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 a 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* questions, with limited emphasis on *how-to* knowledge (Banerjee, 2002). Modern macroeconomics emerged during the Great Depression with a strong emphasis on policy, although the link between theory and application has apparently weakened. In a recent paper, 'The Macroeconomist as Scientist and Engineer', Gregory Mankiw (2006) documents how, in the last two decades or so, leading US policy makers no longer rely on recent developments in macroeconomic theory. But that is another story. In *Imperfect Institutions*, I look to the evolution of macroeconomic theory and policy for ideas about institutional policy.

If we begin with Keynesian macroeconomics of the mid-twentieth century, it is clear that economists framed their policy questions in terms of mathematical decision theory. A decision maker models the social system; the model identifies available instruments of policy, maps their relationship to target variables, and specifies the set of available outcomes; the policy maker uses the instruments to obtain the best outcome available.

The next lesson from macroeconomics is due to Robert Lucas (1976) and his rational expectations critique. Lucas argues that traditional Keynesian theory does not recognize that economic actors respond rationally to changes in their regulatory environment, seeking to minimize their costs and maximize their gains from a new set of rules. In consequence, statistically observed macroeconomic relationships that appear to be stable may break down if policy makers attempt to reach their targets by relying on these relationships. Note, however, that rational expectations theory assumes that all actors share common beliefs, without explaining the origins of these beliefs and how they are shared; the problem of knowledge is assumed away. Which brings me to the final

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

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lesson: bounded rationality macroeconomics and Tomas 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). Sargent, therefore, 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 misspecified. 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 scientists generally agree that mankind does not have complete knowledge of the world. Indeed, complete knowledge leaves no room for scientists and their discoveries. Yet, scholars have not agreed on a common method for incorporating mankind's cognitive limitations in their models but rely on several specialized approaches that vary in their usefulness with the research questions at hand. De Figueiredo *et al.* (2006: 385), for instance, list 'three ways to relax the boundaries of rationality'.[4] The first method builds on lessons drawn from psychology, cognitive science, and experiments that reveal limits to rationality. These limits are shared by the entire human species. Prospect Theory of Kahneman and Tversky (1979) is one of a number of theoretical approaches associated with this first category. The second approach is associated with 'scholars who argue that under certain circumstances, particular mechanisms of interaction imply that cognitive limitations are not binding' (de Figueiredo

4 The three approaches are not mutually exclusive; they can complement each other.

et al., 2006: 385). In new institutional economics, many scholars theorize that social institutions emerge to mediate knowledge problems (North, 1990), and there is Hayek's (1960) well-known claim that in a market system the price signals provide low cost solutions to the information problems of dispersed producers and consumers. The final approach is the social models approach used, for instance, by Sargent (2008) in his work on bounded rationality macroeconomics, and, in various shapes and forms, by other scholars (including myself in Eggertsson, 2005). People (scientists included) respond to complexity by creating simple mental constructs of their worlds. The models are incomplete, sometimes misleading, and the actors are often not even aware of relevant information sets. The level of ignorance and the duration of the learning process vary. Sometimes the ignorance is high with surprises at every turn but people make sense of the feedbacks they receive and rapidly adjust their models and make them more relevant. Such situations of rapid adjustment are of lesser theoretical interest than the long-run survival of seriously flawed models. The key challenge for the social models approach lies in better understanding of the latter situation.

Exogenous events or shocks sometimes overturn social models that appear to have stood the test of time (Eggertsson, 2005: Chapter 10). Consider, for instance, Sargent's (2008) claim, mentioned above, that the use of commodity money, and the associated limited variation in the money supply and the price level, indirectly had the effect of concealing for centuries the quantity theory of money. Similarly, de Figueiredo *et al.* (2006) explore events leading to the crisis of 1763–76 in Anglo-American relations and eventually to the American Revolution. The authors postulate that the British and the colonists were unaware that they held mutually inconsistent views about their world – about the structure of the empire and about British authority – and co-existed in peace for more than a century. In game-theoretic terms, the relationship was self-confirming equilibrium. The end of the Seven Years' War (1756–63) shattered the equilibrium. The British now had the incentive to exercise power over the Americans, power which they had all along believed was rightfully theirs. The end of the War created a new moment of truth, and so did also the end of commodity money in Sargent's example. In both cases, the actors suddenly became aware of a new information set, which was off their old equilibrium path. Consequently, the actors revised their social models as well as their behavior.

Social models and modern biotechnology

In the previous section, I draw three lessons from the theory of macroeconomic policy: we need to be clear about the instruments of policy and their limitations; we must not forget that economic actors often respond trying to undermine policy measures; and both policy makers and economic actors rely on subjective models, which are not necessarily self-correcting. These ideas have been known

Table 1. A stylized schema of institutional policy in a world with incomplete social models

Types of Actors	Instruments of Policy	Foundations of Strategies
rule makers	rules	positive theories
right holders	enforcement	normative theories
duty bearers	persuasion aimed at changing social models	power resources

for some time in new institutional economics. In the mid 1970s, the notion that policy makers depend on incomplete subjective models and deal with unyielding actors was already implicit in Steven Cheung's (1975) work on rent control in Hong Kong. In Cheung's rent control story, the feedback is straight forward, the regulator gradually learns from its mistakes, particularly about evasive actions taken by landlords and renters. In Sargent's words, the system (apparently) converges on intelligent design.

Table 1 presents a stylized overview of the main dimensions of institutional policy. These dimensions are: three categories of actors, three types of policy instruments, and, finally, three foundations of strategy.

The three types of actors are rule makers, right holders, and duty bearers (Riker and Sened, 1991). We are concerned here only with deliberate attempts at institutional policy by those in authority either in the public or private sphere, which excludes spontaneous adjustments in social norms (except in response to new formal rules). Rule makers are those in authority for social organizations, ranging from international organizations, to national and local governments, and private associations. Rule makers assign particular rights to a sub-category of social actors, the right holders, and require other actors, the duty bearers, to honor these rights. Rule makers supply rules to advance their interests (for instance, to increase their chances of reelection), and right holders demand new rules to better reach their goals. The effectiveness of rules depends on enforcement and on active or passive cooperation by duty bearers, which also try to protect their own interests.

The instruments of institutional policy are rules, enforcement, and persuasion. Rules include laws, court rulings, regulations, bylaws, codes of conduct, and other edicts by authorities. The term enforcement refers to the design of enforcement mechanisms and the allocation of resources to enforcement. To these two traditional components of policy, we add a third one: persuasion aimed at altering beliefs about social models and social technologies. Rule makers, right holders, and duty bearers are all known to invest in campaigns of persuasion aimed at changing peoples beliefs about which policy goals are legitimate and within reach and how they can be achieved.

The sources or foundations of the strategies employed by rule makers, right holders, and duty bearers are the third dimension of institutional policy. Again there are three elements: normative theories or ethics, positive social theories, and the actors' power resources. These elements influence how the various parties

express their basic interests, and how they act in the process of institutional change.

I will now use the example of modern biotechnology to illustrate the complex nature of institutional policy. Let us begin with Harold Demsetz's (1967) well-known theory of property rights. Demsetz makes the following claim: when the expected value of assets increases, property rights tend to move in the direction of exclusive ownership and toward clearly specified rights. He also predicts that the new solutions are efficient, but two factors undermine Demsetz's efficiency claim: high transaction costs combined with conflicting interests and use of power, and conflicting beliefs. In 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.'[5] In a world of incomplete knowledge and frequent failures of collective action, therefore, we cannot claim that an increase in expected asset values always bring forth efficient adjustments in property rights. Demsetz's (1967) contribution is to recognize that, other things equal, the demand for exclusive rights increases when the value of an asset increases.[6]

Consider now the effects of an increase in the expected value of assets in modern biotechnology. In the last third of the twentieth Century advances in molecular biology and new research tools and techniques 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. Potential duty bearers resisted many of 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 authorized the firm to collect the nation's health records, with some time series 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 inputs, outputs, and techniques. The industry took various measures to secure these rights at the expense of duty bearers. In 1980, the US Supreme Court in *Diamond* v. *Chakrabarty*, in a 5:4

5 Macroeconomics provides many examples of (relatively) honest struggles in the market for ideas. Think of the debates between neo-Keynesians, the new classical synthesizers, and the real business cycle people, etc. See Phelps (1990), *Seven Schools of Macroeconomic Thought*.

6 The justification for ignoring collective action problems and incomplete social models is usually based on assumptions about a selection process such as market competition, which weeds out inefficient forms of organization. Note, however, that these selection mechanisms can only select from structures in use. Demsetz's theory is often consistent with the evidence in cases involving relatively simple new structures, and political processes that do not interfere with joint maximization of resource values (for example, sometimes when natural resources are discovered on a newly settled land).

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. Rights to biotech inputs were moreover in dispute. Increasing value of samples taken from the human body caused 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.

We now turn to subjective social models: how accurate are our models of the social technology used in the new biotech sector? Do we understand the new structure of incentives and corresponding outcomes that recent adjustments in rules and enforcement mechanisms have created? Here, even experts favor widely different models. Skeptics and pessimists claim that by assigning property rights to small bits of basic scientific findings, the new social technology has retarded progress both in basic and applied research. The new arrangements are said to have created anti-commons problems–excessive fragmentation of property rights (Heller and 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 arrangements will erode the very foundation of modern science, although it may take many years before all adverse side effects are known.

The optimists counter that new conditions – rapidly expanding science base and shorter time lag between invention and application – require new structures and new incentives. The optimists see no evidence indicating that progress in biotechnology is slowing down. Other observers have followed Ellickson's (1991) example in his study of *Order without Law: How Neighbors Settle Disputes*, which examines informal dispute settlement among ranchers and farmers in Shasta County, California. These scholars attempt 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 developed 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 new world of Chakrabarty and Bayh-Dole, 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. There is also evidence that biotech firms put some of their patentable findings in the public domain with the aim of reversing anti-commons effects.

Firms have also organized patent pools and negotiated various cooperative arrangements to lower transaction costs. Yet, we do not know how significant these private order arrangements are relative to the size of the anti-commons problem.

One potential solution to the anti-commons problem is for the government to intervene directly in individual cases and try to improve efficiency by compelling specific firms to license or release their patents. Experts disagree whether government officials have the knowledge required for effective case-by-case interventions. Richard Epstein (2003) is one of those who conclude that regulators lack the necessary capacity. Other scholars hold contrary views. Epstein advocates an all-or-nothing approach to patent rights: a system of secure property rights free of government interference for some inventions and open access for others. But do we know where to draw the line between the two classes of inventions?

Finally, consider the very concept of for-profit biotech research firms that hope to survive by licensing or selling their products to other firms. Nelson (2008: 9–10) notes that in an earlier period industrial enterprises that were involved in conventional production and distribution of commodities successfully set up internal R & D departments, whereas the concept of specialized R & D firms did not catch on. Recent losses and outright bankruptcies of for-profit 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 US in support of biotech is quite uncertain'. Other scholars and investors do not share Nelson's subjective model – at least not until recently.

I now turn to my final theme: persuasion and competition among social models in the process of institutional change. An individual's social model contains a set of assumptions and relationships – theories – that he or she uses to interpret a complex environment. As people sometimes attempt to deceive others, the promotion of a particular subjective model can either involve honest exchange of ideas or deliberate falsification for personal gain. Let us 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, which was rationally ignorant about the new biogenetics industry. In Parliament, public opinion was needed to influence legislators voting on a bill authorizing the firm to operate a centralized electronic database containing the nation's health records. And direct public support was required to obtain blood samples from individuals as well as their general cooperation with the firm's research projects. In the war of models, the medical establishment emphasized why the firm's projects constitute an alarming threat to privacy; why it is technically impossible to securely encrypt medical data; and how the project would paralyze other medical research in the country. The opponents also described the database project as an attempt to steal the nation's genetic

heritage and its identity, 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; that there was link between the project and the country's unique history and heritage; and that the small island nation of about 300 thousand inhabitants could make a unique contribution to the welfare of mankind. Some of these arguments may sound simplistic but they were an important input in the evolution of biogenetic property rights in the country.

In biotechnology, the dialogue is not limited to propaganda. Scientists and other well-informed people have also debated, sometimes honestly, among themselves. I have already outlined serious disagreements about the prevailing social technology in the industry. Experts disagree with each other about: 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, and the overall viability of biotech institutions. And they do not only disagree, they try to influence policy. In the gray zone between the boarders of 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 traditional 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 standard theory of economic growth focuses on capital accumulation and leaves it in large part to fields outside the mainstream to study the economics of natural science, inventions, innovations, and technology leadership. The new economics of institutions complements these approaches by directing our attention to the social framework, especially to security of property rights and contract. Research into public choice and political economy suggests that many countries fail to accumulate capital and use best available production techniques because high transaction costs undermine collective action, prevent credible commitments, and enable rent seeking. The purpose of this paper is to draw attention to yet another issue in the growth process: incomplete knowledge about social systems. Growth theory, new institutional economics, political economy, and related fields usually assume that policy makers rely on correct social models and that they are 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.

The term institutional policy refers to attempts by authorities (rule makers) to modify social systems by adjusting various rules and methods of enforcement. These attempts often fail because rule makers lack knowledge of the social technologies required for making the desired reforms. Strategic responses by potential right holders and duty bearers aimed at influencing new rules complicate institutional policy. As subjective models guide all types of actors, persuasion has an important role in the process of institutional change, and social systems will malfunction unless there is some minimal convergence of subjective models. The paper's last section uses the evolution of property rights in modern biotechnology as an illustration of how incomplete knowledge affects the evolution of property rights in a new high tech industry. The analysis begins with Demsetz's (1967) insight that rising potential resource or asset values raise the demand for exclusive rights. I then introduce new complications. In addition to divergent interests of rule makers, right holders, and duty bearers, there are also differences in beliefs concerning social technologies and their effects, and competition among alternative subjective models often plays a critical role in the process of institutional change.

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