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INDUCED TECHNICAL CHANGE, INDUCED
INSTITUTIONAL CHANGE AND MECHANISM DESIGN

by
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INDUCED TECHNICAL CHANGE, INDUCED INSTITUTIONAL CHANGE AND MECHANISM DESIGN

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Abstract:

In this paper I review the theories of induced technical and institutional change. I discuss the sources of the demand and supply of institutional innovation. The sources of institutional innovation are illustrated by changes in land tenure relations in Philippine agriculture, by the development of institutional design principles based on studies of small scale resource management systems and by the transition from command and control to market based systems of resource management in the United States. I introduce the concept of incentive compatible mechanism and institutional design. In a final section I elaborate a pattern model that maps the relationships among changes in resource endowments, cultural endowments, technology and institutions.

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Key Words:

Technical change; institutional innovation; land tenure; resource management; constructed markets; mechanism and institutional design; pattern model.

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A central premise of this paper is that the demand for social science knowledge is derived from the demand for institutional change.² If this view is correct then any claim by the social science disciplines and related professions for public support depends on a credible promise that advances in social science knowledge represent an efficient source of institutional innovation.

I first review briefly the theories of induced technical and institutional change. I then turn to a discussion of the sources of demand and the sources of supply of institutional change I also discuss the concepts of incentive compatible mechanism and institutional design. I end the paper with a discussion of some of the elements of a “pattern” or “appreciative” model of the relationships among changes in resource and cultural endowments and technical and institutional change.

1. Induced Technical Change

Modern interest in the effects of changes (and differences) in relative factor endowments and prices on the rate and direction of technical change was initially stimulated by an observation by Sir John Hicks: “The real

² This paper is a revised and extended version of V. W. Ruttan, 2006, “Social Science Knowledge and Induced Institutional Innovation: An Institutional Design Perspective,” *Journal of Institutional Economics* 2(3): 249-272. I also draw on Ruttan and Hayami (1984) and Ruttan (2001, 2003).

reason for the predominance of labor saving innovation is surely that ... a change in relative prices of factors of production is itself a spur to innovation and to innovation of a particular kind-directed at economizing the use of a factor which has become relatively expensive” (Hicks 1932: 124-125).

Hicks’ suggestion laid fallow until it was challenged by Salter in 1960: “At competitive equilibrium each factor is being paid its marginal value product; therefore all factors are equally expensive to all firms (Salter 1960: 16).

Salter went on to argue “the entrepreneur is interested in reducing costs in total and not particular costs” (Salter 1960: 43-44). In retrospect is difficult to understand why Salter’s criticism generated so much attention except that students of economic growth were increasingly puzzled about why, in the presence of substantial capital deepening in the U.S. economy, factor shares to labor and capital had remained relatively stable The differential growth rates were too large to be explained by simple factor substitution.

The debate about induced technical change centered on two alternative models-- a growth theoretic model and a microeconomic version. The most formally developed version was a growth theoretic model introduced by Kennedy (1964, 1966) and elaborated by Samuelson (1965). Kennedy cast his model in terms of changing relative factor shares because of the growth theory implications. By the early 1970s the growth-theoretic

approach to induced technical change was itself subject to severe criticism. Nordhaus insisted that the model as “too defective to be used in serious economic analysis” (Nordhaus 1973, 2008).

The second approach to induced innovation, built directly on Hicksian microeconomic foundations, was developed by Syed Ahmad (1966, 1967a, 1967b). In work published in the early and mid-1970s Yujiro Hayami, Hans Binswanger, Colin Thirtle, and I extended the micro economic version of induced technical change and tested it against the history of agricultural development in the United States and Japan and in cross country perspective (Hayami and Ruttan 1970, 1971; Binswanger 1974; Binswanger and Ruttan 1978; Thirtle and Ruttan 1987). Rather than attempting a detailed review of the econometric results I draw your attention to Figure 1.

/ insert Figure 1 about here /

By the late 1980s, in reaction to the Nordhaus criticisms and the emergence of new macro economic endogenous growth theories (Romer 1986; Lucas 1988), interest in induced technical change was beginning to wane. Interest was sustained, however, by agricultural and resource economists who continued to find the micro economic version of induced technical change useful (Runge 1999). Recent work on the theoretical foundation of induced technical change theory and its implications by

Acemoglu suggest a possible revival of interest by development economists (Acemoglu 2002, 2007).

The demonstration that technical change can be treated as largely endogenous to the development process does not imply that the progress of either agricultural or industrial technology can be left to an 'invisible hand' that drives technology along an 'efficient' path determined by relative resource endowments. The capacity to advance knowledge in science and technology is itself a result of institutional innovation – “the great invention of the nineteenth century was the invention of the method of invention” (Whitehead 1925: 96).

2. Induced Institutional Innovation

Institutions are the rules of a society or of organizations that facilitate coordination among people by helping them form expectations, which each person can reasonably hold in dealing with others (Hayami and Ruttan 1985: 94).³ In the area of economic relations institutions have a crucial role in

³ For a review of the role of institutions, and of institutional change, in economic development see Lin and Nugent (1995). There is considerable disagreement regarding the use of the term institution. A distinction is often made between the concepts of institution as an organization and institutional arrangements. In my own work I have found it useful to employ a definition that includes both concepts. This is consistent with the view expressed by both Commons (1950: 24) and Knight (1952: 51). This inclusive definition

establishing expectations about the rights to use resources in economic activities and about the partitioning of the income streams resulting from economic activity: “institutions provide *assurance* respecting the actions of others, and give order and stability to expectations in the complex and uncertain world of economic relations.” (Runge 1981b: xv).

Anticipation of the latent gains to be realized by overcoming the disequilibria resulting from changes in factor endowments, cultural endowments, and technology represent powerful sources of demand (inducements) to institutional innovation (North and Thomas 1970; Schultz 1975). The growing disequilibria in resource allocation due to institutional constraints generated by economic growth create incentives for political entrepreneurs or leaders to organize collective action to bring about institutional change (Olson 1982: 74). This perspective on the sources of

was also employed by Davis and North (1971: 8-9). In his more recent work North excludes organization and conflates the concepts of institution and culture. The distinction that I make between institutions and cultural endowments is that institutions are the formal rules and arrangements that govern behavior among and within organizations while cultural endowments are the informal codes of behavior that have evolved to influence individual and group behavior. Drawing on game theoretic concepts Hurwicz distinguishes between institutions and mechanisms. Institutions are defined as families of “game forms” or mechanisms. As an example, share tenure is defined as an institution. It includes the entire set of mechanisms (ie., game forms) in which the rental share ranges between 0 and 1. Institutions can be represented as a correspondence between game forms (mechanisms) and economic environments (Hurwicz 1996).

demand for institutional change is similar, in some respects, to the traditional Marxian view.⁴

There are supply side as well as a demand side sources of institutional change. Advances in knowledge in the social sciences (and in related professions such as law, administration, planning, and social service) can reduce the cost of institutional change in a manner somewhat similar as advances in the natural sciences reduce the cost of technical change.

Advances in game theory have, during the last several decades, enabled economists and political scientists to bring an increasingly powerful set of tools to bear on the understanding of the processes of institutional change (Hurwicz 1960, 1973; Schotter 1981; Ostrom 1990; Aoki 12001). In spite of the power of these new tools I continue to find the application of standard neoclassical micro-economic theory to interpret the sources of the demand and supply of institutional change exceedingly useful.

⁴ “At a certain stage of their development, the material forces of production in society come in conflict with existing relations of production, or - what is but a legal expression for the same thing - with the property relations within which they had been at work before. From forms of development of the forces of production these relations turn into their fetters. Then comes the period of social revolution. With the change of the economic foundation the entire immense superstructure is more or less rapidly transformed” (Marx 1913: 11-12). For a discussion of the role of technology in Marxian thought see Rosenberg (1982: 34-54).

Insistence that important advances in the understanding of the processes of institutional innovation and diffusion can be achieved by treating institutional change as endogenous to the economic system represents a clear departure from the tradition of modern analytical economics.⁵ The scope of modern analytical economics is expanded by treating institutional change as endogenous.

There is general agreement that institutional change has and continues to evolve in response to long-term changes in resource endowments such as the pressure of population against land resources or a rise in the price of labor relative to capital. But there has been substantial disagreement within the social sciences about the role of purposeful or rational design in institutional innovation.⁶ Those holding an “organic” or “spontaneous order” perspective argue that the fact that the institutions of civilization have been created by human action “does not mean that man must also be able to alter

⁵ The orthodox view was expressed by Samuelson (1948: 221-22): “The auxiliary [institutional] constraints imposed upon the variables are not themselves the proper subject of welfare economics but must be taken as given.” Contrast this with the statement by Schotter (1981: 61): ‘We view welfare economics as a study ... that ranks the system of rules which dictate social behavior.’

⁶ Schotter (1981: 3-4) notes that in economics there have been, historically, two distinct interpretations of the sources of institutional change--“organic” and “collectivist.” He identifies the organic view with the work of Hayek and the collectivist view with the work of Commons. Hayek (1978: 3-22) uses the term “constructivism” rather than collectivist.

them at will” (Hayek 1978: 3).⁷ This organic view of the sources of institutional change is reinforced by a theory of the “unintended consequences” of institutional innovation that runs through the work of Adam Smith, Carl Menger, Max Weber, and Frederich Hayek (Lal 1998). In contrast the constructivist or design perspective holds that advances in social science knowledge can play an important role in the rational design of institutional reform and institutional innovation.

Much of my work with Yujiro Hayami on induced institutional innovation reflects an organic perspective. In other work, on the development of agricultural research institutions for example, I have employed both organic and constructivist perspectives (Ruttan 1982, 2001). I reject any demand to choose between the organic and constructivist perspectives. They should be viewed as complements rather than as alternatives. I also reject the ideological implication, advanced by some proponents of the organic approach that the unintended consequences of

⁷ Hayek was apparently referring to a statement by Karl Marx: “Men make their own history, but they do not make it as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly formed, given and transmitted from the past” (Marx 1936: 15). Hayek regarded the explanation of the unintended patterns and regularities which he termed constructivism because of the inability of social theory to anticipate unintended consequences (Hayek 1967: 96-105).

institutional change preclude the possibility of a rational or analytical approach to institutional reform and design.

3. Demand for Institutional Innovation

In some cases the demand for institutional innovation can be satisfied by the development of new forms of property rights, more efficient market institutions, or even by evolutionary changes arising out of direct contracting by individuals at the level of the community or the firm. In other cases, where externalities are involved, substantial political resources may have to be brought to bear to organize non-market institutions in order to provide for the supply of public goods. In this section I draw from agricultural history to illustrate how changes in factor endowments, technical change, and growth in product demand have induced organic change in property rights and contractual arrangements.

The agricultural revolution that occurred in England between the fifteenth and the nineteenth centuries involved a substantial increase in the productivity of land and labor. It was accompanied by the enclosure of open fields and the replacement of small peasant cultivators, who held their land from manorial lords, by a system in which large farmers used hired labor to farm the land they leased from the landlords. The First Enclosure

Movement, in the fifteenth and sixteenth centuries, resulted in the conversion of open arable fields and commons to private pasture in areas suitable for grazing. It was induced by expansion in the export demand for wool. The Second Enclosure Movement in the eighteenth century involved conversion of communally managed arable land into privately operated units. It is now generally agreed that demand for changes in land tenure arrangements was largely induced by the growing disequilibrium between the fixed institutional rent that landlords received under copyhold tenures (with lifetime contracts) and the higher economic rents expected from adoption of new technology which became more profitable as a consequence of higher grain prices and lower wages. When the land was enclosed there was a redistribution of income from tenants to landowners and the disequilibrium was reduced or eliminated.⁸

In nineteenth-century Thailand, the opening of the nation to international trade and the reduction in shipping rates to Europe following the completion of the Suez Canal resulted in a sharp increase in the demand for rice. The land available for rice production, which had been abundant,

⁸ There has been a continuing debate among students of English agricultural history about whether the higher rents that landowners received after enclosure was (a) because enclosed farming was more efficient than open field farming, or (b) because enclosures redistributed income from farmers to landowners (Dahlman 1980; Allen 1982).

became more scarce. Investment in land development for wet rice production for export became profitable. The rise in the profitability of rice production for export induced a demand for the reform of property rights in both land and man. Traditional rights in human property (corvee and slavery) were replaced by more precise private property rights in land (fee-simple titles) (Feeny 1982; 2002).

3.1 Land Tenure in a Philippine Village

Research conducted in the Philippines during the late 1970s by Hayami and Kikuchi has enabled us to examine a contemporary example of the interrelated effects of changes in resource endowments and technical change on the demand for institutional change in land tenure and labor relations (Kikuchi and Hayami 1980; Hayami and Kikuchi 1981; Hayami and Kikuchi 2000). The case is particularly interesting because the institutional innovations occurred as a result of private contracting among individuals—what Hayek termed “spontaneous order” and in more recent literature has been referred to as “Coasian bargains” (Hayek 1978; Olson 2000). The study is based on a rigorous analysis of microeconomic data from a single village over a period of about 20 years.

Between 1956 and 1976, rice production per hectare in “Laguna Village” rose dramatically, from 2.5 to 6.7 metric tons per hectare per year.

This was due to two changes in both resource endowments and technology. In 1958, the national irrigation system was extended to the village. This permitted double-cropping to replace single-cropping. The major technical change was the introduction of modern high-yielding rice varieties. The diffusion of modern varieties was accompanied by increased use of fertilizer and pesticides and by the adoption of improved cultural practices such as straight-row planting and intensive weeding.

Population growth in the village was rapid. Between 1966 and 1976 the number of households rose from 66 to 109 and the population rose from 383 to 464, while cultivated area remained virtually constant. The number of landless laborer households increased from 20 to 54. In 1976, half of the households in the village had no land to cultivate. The average farm size declined from 2.3 hectares to 2.0 hectares.

The land was farmed primarily by tenants. In 1976, only 1.7 hectares of the 108 hectares of cropland in the village were owned by village residents. Traditionally, share tenancy was the most common form of tenure. In both 1956 and 1966, 70 percent of the land was farmed under share tenure arrangements. In 1963, a new national agricultural land reform code was passed which was designed to break the political power of the traditional landed elite and to provide greater incentives to peasant producers of basic

food crops. A major feature of the new legislation was an arrangement that permitted tenants to initiate a shift from share tenure to leasehold, with rent under the leasehold set at 25 percent of the average yield for the previous three years. Implementation of the code between the mid-1960s and the mid-1970s resulted in a decline in the percentage of land farmed under share tenure to 30 percent.

The shift from share tenure to lease tenure was not, however, the only change in tenure relationships that occurred between 1966 and 1976. There was a sharp increase in the number of plots farmed under sub-tenancy arrangements. The number increased from one in 1956 to five in 1966 and 16 in 1976. Sub-tenancy is illegal under the land reform code. The sub-tenancy arrangements were usually made without the consent of the landowner. All cases of sub-tenancy were on land farmed under a leasehold arrangement. The most common sub-tenancy arrangement was 50-50 sharing of costs and output.

/ insert Table 1 about here /

It was hypothesized that an incentive for the emergence of the sub-tenancy institution was that the rent paid to landlords under the leasehold arrangement was below the equilibrium rent - the level which would reflect both the higher yields of rice obtained with the new technology and the

lower wage rates implied by the increase in population pressure against the land.

To test this hypothesis, market prices were used to compute the value of the unpaid factor inputs (family labor and capital) for different tenure arrangements during the 1976 wet season. The results indicate that the share-to-land was lowest and the operators' surplus was highest for the land under leasehold tenancy. In contrast, the share-to-land was highest and no surplus was left for the operator who cultivated the land under the sub-tenancy arrangement (Table 1). Indeed, the share-to-land when the land was farmed under sub-tenancy was very close to the sum of the share-to-land plus the operators' surplus under the other tenure arrangement.

The results are consistent with the hypothesis. A substantial portion of the economic rent was captured by the leasehold tenants in the form of operators' surplus. On the land farmed under a sub-tenancy arrangement, the rent was shared between the leaseholder and the landlord.

The sub-tenancy contract was an institutional innovation arrived at by voluntary agreements among farm operators, tenants and laborers. The land reform laws gave leasehold tenants strong protection of their tenancy rights. It gave them the right to continue tilling the soil at an institutional rent that was lower than the economic rent. But the laws prohibited tenants from

renting their land to someone else who might utilize it more efficiently, when they became elderly or found more profitable off-farm employment, for example. Sub-tenancy reduced such inefficiency due to the institutional rigidity in the land rental market resulting from the land reform programs.

The induced institutional innovation process leading toward the establishment of equilibrium in land rental markets occurred very rapidly in spite of the fact that the transactions between landlords and tenants were less than fully monetized. Informal contractual arrangements or agreements were utilized. The subleasing contract evolved without the mobilization of substantial political activity or bureaucratic effort. Indeed, the subleasing arrangement evolved in spite of legal prohibition. Where substantial political and bureaucratic resources must be mobilized to bring about technical or institutional change, the changes occur much more slowly, as in the cases of the English enclosure movements and the Thai property rights cases referred to at the beginning of this section.

4. The Supply of Institutional Innovation

The disequilibria in economic relationships associated with economic growth, such as technical change leading to the generation of new income streams and changes in relative factor endowments have been identified as

important sources of demand for institutional change. But the sources of supply of institutional innovation are less well understood (Olson 1968; Ostrom 1990). The factors that reduce the cost of institutional innovation have received only limited attention by economists or by other social scientists.

In the Philippines village case discussed earlier, land tenure innovation in Laguna Village was supplied, in response to the changes in demand generated by changing factor endowments and new income streams, through the individual and joint decisions of owner-cultivators, tenants and laborers. But even at this level it was necessary for gains to the innovators to be large enough to offset the risk of ignoring the land reform prohibitions against subleasing.⁹

The supply of major institutional innovations typically involves the mobilization of substantial resources by political entrepreneurs and innovators. It is useful to think in terms of a supply schedule of institutional innovation that is determined by the marginal cost schedule facing political entrepreneurs as they attempt to design new institutions and resolve the

⁹ Demsetz (1964) has pointed out that the relative costs of using market and political institutions is rarely given explicit consideration in the literature on market failure. An appropriate way of interpreting the 'public goods' vs. 'private goods' issue is to ask whether the costs of providing a market are too high relative to the cost of non-market alternatives. A similar point is made by Hurwicz (1972).

conflicts among interest groups (or suppression of opposition when necessary).

To the extent that the private return to political entrepreneurs is different from the social return, the institutional innovation will not be supplied at all or at a socially optimum level. If the institutional innovation is expected to result in a loss to a dominant political bloc, the innovation may not be forthcoming even if it is expected to produce a large net gain to society as a whole. And socially undesirable institutional innovations may occur not only from the unintended consequences of institutional innovation but as a result of innovations that are designed to generate economic or political benefits to the entrepreneur or the interest group that may impose costs that exceed the gains to society (Tullock 1967; Krueger 1974; Tollison 1982).¹⁰

The failure of many developing countries to institutionalize the agricultural research capacity needed to take advantage of the large gains from relatively modest investments in technical change may be due, in part,

¹⁰ A referee for an earlier draft of this paper raised the question of whether it might be possible that errors in social science research might result in institutional innovations that make society worse off. The reviewer also raised the question of what mechanisms exist to discipline political entrepreneurs comparable to the market mechanism in economics. These important questions are dealt with in a vast literature in the field of public choice and political economy (Acemoglu 2005; Dalrymple 2006). I return to this issue later in this paper.

to the divergence between social returns and the private returns to political entrepreneurs. In the mid-1920s, for example, agricultural development in Argentina appeared to be proceeding along a path roughly comparable to that of the United States. Mechanization of crop production lagged slightly behind that in the United States. Grain yields per hectare averaged slightly higher than in the United States. In contrast to the United States, however, output and yields in Argentina remained relatively stagnant between the mid-1920s and the mid-1970s. It was not until the late 1970s that Argentina began to realize significant gains in agricultural productivity. Part of this lag in Argentine agricultural development was due to the disruption of export markets in the 1930s and 1940s. Students of Argentine development have also pointed to the political dominance of a landed aristocracy and to the rising tensions between urban and rural interests, that resulted in inappropriate domestic policies toward agriculture (de Janvry 1973; Smith 1969 and 1974; Cavallo and Mundlak 1982). The Argentine case would seem to represent a case where the bias in the distribution of political and economic resources imposed exceptionally strong constraints on the institutional innovations needed to take advantage of the relatively inexpensive sources of growth that technical change in agriculture could have made available.

Cultural endowments, including religion and ideology, may exert a strong influence on the supply of institutional innovation. They make some forms of institutional change less costly to establish and impose severe costs on others (Jones 1999; Tan 2005). For example, the traditional moral obligation in the Japanese village community to cooperate in joint communal infrastructure maintenance made it less costly to implement modernizing rural development programs than in societies where such traditions do not prevail. These activities had their origin in the feudal organization of rural communities in the pre-Meiji period. But practices such as maintenance of village and agricultural roads and of irrigation and drainage ditches through joint activities in which all families contribute labor were still practiced in well over half of the hamlets in Japan as recently as 1970 (Ishikawa 1981). The traditional patterns of cooperation have represented an important form of social capital on which to erect modern forms of cooperative marketing and joint farming activities. Similar cultural resources were not available in many South Asian villages where, for example, the caste structure inhibits cooperation and encourages specialization (Lal 1998; Ruttan 2003: 232-235).

Advances in social sciences that improve knowledge relevant to the design of institutional innovations that are capable of generating new income

streams or that reduce the cost of conflict resolution act to shift the supply of institutional change to the right. The research that led to advances in our understanding of the production and consumption behavior of rural households in less developed countries represents an important example of the contribution of advances in social science knowledge to the design of more efficient institutions (Schultz 1964; Nerlove 1974; Binswanger, Evenson, Florencio and White 1981). In a number of countries this research has led to the abandonment of policies that viewed peasant households as unresponsive to economic incentives. And it has led to the design of more incentive compatible factor and product markets and to institutions to make more productive technologies available to peasant producers.¹¹

4.1 Collective Action

Modest advances were made, beginning in the late 1950s, by students of what became variously known as the “new political economy” or the “new institutional economics” to explore the economic and political basis of collective action (Downs 1957; Olson 1965; Hardin 1968). The penetration of the political economy perspective into the traditional territory of political

¹¹ The international agricultural research system organized under the auspices of the Consultative Group on International Agricultural Research (CGIAR) represents a particularly impressive example of an institutional innovation that became an exceedingly powerful source of improvement in crop technology for developing countries in the tropics (Evenson and Gollin 2003).

science was initially welcomed (or at least not actively opposed) by many political scientists who found the new analytical tools drawn primarily from economics useful (Almond 1993).

The major implications drawn by the early practitioners of the new institutional economics were profoundly conservative: “Unless the number of individuals in the group is quite small, or unless there is coercion or some other device to make individuals act in their common interests, rational self-interested individuals will not act to achieve their common or group interests (Olson 1965: 2). The initial positive reception of this “zero contribution” inference was followed by a large critical literature. Elinor Ostrom has insisted: “Many people do vote, not cheat on their taxes, and contribute to voluntary organizations. ... Individuals in all parts of the world voluntarily organize themselves to gain the benefits of trade, to provide material protection against risk, and to create and enforce rules that protect natural resources (Ostrom 2000: 137-138).

Over several decades Ostrom and colleagues at the University of Indiana, Workshop on Political Theory and Policy Analysis, have brought together the results of a massive body of field observations, extensive laboratory evidence, and careful theoretical analysis to distill a set of principles that provide fundamental insight into the evolution of institutional

change and the design of institutional innovations (Table 2). The principles articulated in Table 2 are drawn, in large part from examples of “spontaneous order” arising out of individual and small group behavior. But the lessons drawn from this experience by social science research represents the foundation for a set of principles or rules for the design of incentive compatible institutions to enhance economic development at the community and regional level (Ostrom 1992; Boettke and Coyne 2005).

/ insert Table 2 about here /

4.2 Constructed Markets

In this section I present a case study of the contribution of advances in social science knowledge to the design of a contemporary institutional innovation at the national level. The case involves the design and implementation of an emission trading system to reduce the transaction costs of controlling sulfur dioxide (SO₂) emissions—an important industrial pollutant. Advances in economic knowledge led to an understanding of the very large cost reductions that could be achieved by designing a “constructed market” to replace the “command and control” approach to the management of SO₂ emissions.¹²

¹² This section draws heavily on Ruttan (2001: 511-516). For a retrospective perspective on the use of tradable permits see Tietenberg (2002).

The concept behind the design of a constructed market for the control of SO₂ pollutants is fairly simple. It is based on the realization that the behavioral sources of the pollution problem can often be traced to poorly defined property rights in open access natural resources such as air and water. A system of property rights and tradable permits for the management of pollution was first proposed in the late 1960s by Crocker (1966) and Dales (1968a, 1968b). The suggested institutional innovation did not emerge from its inventors in a fully operational form. Their proposals were followed by a large theoretical and empirical literature by resource and environmental economists (Bohm 1985). Design and implementation involved an extended process of “learning by doing” and “learning by using.”

Proposals to replace the command and control approach by Presidents Johnson and Nixon by effluent fees or taxes on pollutants were dismissed as impractical and characterized by environmental activists as a “license to pollute.” Beginning in the mid-1980s, however, a series of events conspired to make a more market oriented approach to reducing SO₂ emissions politically feasible (Taylor 1989: 28-34; Hahn and Stavins 1991; Stavins 1998). One was the predilection of President George H. W. Bush in favor of a market oriented approach to environmental policy. Another was the enthusiasm of Environmental Protection Agency administrator William

Reilly and a number of key staff members in the Executive Office of the President for validating Bush's desire to be known as "the environmental president." There was also bipartisan support in key Congressional committees for a variety of market based approaches to environmental policy.

Within the environmental community the Environmental Defense Fund (EDF) began to differentiate itself from the rest of the environmental community by advocating market based approaches as early as the mid-1980s. In 1989 EDF staff began to work closely with the White House staff in drafting an early version of proposed legislation. The credibility of the effort was enhanced by the fact that EPA Administrator Reilly, formerly president of the Conservation Foundation, was a "card carrying" environmentalist. Executives of several major corporations, influenced by subtle lobbying by the EDF commented favorably on the emissions trading proposals.

The design of the SO₂ emissions trading system advanced in the Clean Air Act of 1990 drew on earlier EPA experience. The EPA began experimenting with emission trading permits in 1974. The early programs included the elimination of lead in gasoline, the phase-out of chlorofluorocarbons and halons in refrigeration, and the reduction of water

pollution from nonpoint sources. The early programs had a mixed record. They were typically grafted onto existing command-and-control programs. The difficulty of converting from command-and-control programs encountered substantial transaction costs. These experiences did, however, provide important lessons for the design of more market oriented trading programs in the 1990s.

The Clean Air Act created a national market for SO₂ allowances for coal burning electrical utilities. The commodity exchanged in the SO₂ emissions trading program is a property right to emit SO₂ that was created by the EPA and allocated to individual firms. A firm can make allowances that had been issued to it available to be traded to other firms by reducing its own emissions of the pollutant below its own base line level. In 1995, the programs first year, 110 of the nation's dirtiest coal burning plants were included in the program. The affected plants were allowed to emit 2.5 pounds of SO₂ for each million British Thermal Units (Btu) of energy that they generated. During Phase II, initially projected to begin in 2000, almost all coal-burning plants were scheduled to be included and allowances for each plant to be reduced to 1.2 pounds per million Btu. Utilities that "overcomply" by reducing their emissions more than required may sell their

excess allowances. Utilities that find it more difficult, or expensive, to meet the requirements may purchase allowances from other utilities.

Emission trading has been even more cost effective than originally anticipated. Prior to initiation of the program the utility industry had complained that reducing SO₂ in amounts sufficient to meet the projected target (down from about 19 million tons in 1980 to 8.95 million tons in 2000) might cost as much as \$1,500 per ton. By the late 1990s allowances were being sold in the \$100-150 range. The decline in the cost of abatement has been due in part to technical changes in coal mining and deregulation of rail transport that have lowered the cost of low sulphur coal to mid-western power producers. It has also been due to technical changes in fuel blending and SO₂ scrubbing that was induced by the introduction of performance based allowance trading. As a result benefits substantially exceeded early estimates (Joskow, Smalensee and Bailey 1998).

The successful experience with SO₂ emissions trading illustrates a very important principle in inventing new property rights institutions to manage formerly open access resources. In a now classic paper Coase (1960) argued that when only a few decision makers are involved in the generation of externalities, the two parties, if left to themselves, will voluntarily negotiate a new institutional mechanisms—rules and payments—

that result in a reduction of the externalities to an acceptable level. However important the Coase theorem might be for understanding the small institutional innovations in the Philippine village case presented earlier in this paper, it has little relevance to most contemporary large scale externality problems.

The important externality problems that concern society today—such as SO₂ pollution, ozone pollution or the greenhouse gases responsible for global climate change—typically involve large numbers of polluters and even larger numbers of persons affected by the externalities. In contrast to the evolution of a “natural market” government must establish the conditions necessary for a “constructed” market to function. In the SO₂ case it was necessary for an outside principle, the U.S. Congress, to define the size (or the boundaries) of the resource, in this case the maximum tons of SO₂ emissions, and to establish the trading rules. The social science effort involved in the design and implementation of the institutional arrangements and mechanisms to confront such problems requires the mobilization of large economic and political resources.

5. Mechanism Design

The case studies presented in the previous two sections (4.1 and 4.2) represent important early examples of incentive compatible institutional design. They did not draw on the emerging mechanism design literature. Beginning in the late 1950's Leonid Hurwicz and several colleagues began to direct their attention to the design of mechanisms and institutions.¹³ The results of this effort have been truly revolutionary! In 2007 the Nobel Prize Committee awarded Hurwicz and two colleagues, Roger P. Myerson and Eric Maskin, the Nobel Award in economics. The Award committee noted that mechanism design theory began with the work of Leonid Hurwicz in 1960. However, the theory became relevant to a wide variety of applications only after Hurwicz introduced the key notion of incentive compatibility in 1972 (Nobel Prize Committee 2007: 2).

As noted above, the orthodox view in economics, articulated by Paul Samuelson, 1970 Nobel awardee, held: "The auxiliary (institutional) constraints imposed on the variables are not themselves the proper subject of welfare economics but must be taken as given" (Samuelson, 1948: 321-322).

¹³ Hurwicz distinguished between two types of normative analysis. One is to take the organizational structure as given while considering alternative policies within such a structure. The other is to take organizational structure itself as the variable. "It is this latter type of choice that we have called the designers point of view" (Hurwicz 1972: 37).

Friedrich Hayek, 1974 Nobel awardee, held that institutional change emerged out of organic processes, which he termed “spontaneous order” (Hayek 1978: 3). The concept of incentive compatible mechanism design removed the ideological, disciplinary and ethical blinders that had limited the scope of a more analytical and institutional economics. Hayek had feared the unintended consequences of efforts by the market socialists to substitute planning for markets. Samuelson viewed the normative judgments involved in institutional reform as outside the scope of the discipline of economics. Hurwicz, in contrast, insisted that the design of institutional arrangements was a central issue for economics. He laid the foundations for what the *Economist* termed the “intelligent design” of incentive compatible institutional arrangements (*Economist*, 10/20/07).¹⁴

In later work Hurwicz has addressed the question of the feasibility of achieving Pareto optimality in both classical and non-classical environments.¹⁵ It has been long recognized that in non-classical environments economists are confronted, in attempting to design mechanisms and institutions, with problems of incomplete information,

¹⁴ For a more complete and accessible discussion of the mechanisms design problem see Runge and Ruttan 2008.

¹⁵ “Classical environments are characterized by absence of external economies or diseconomies of scale, imperfect divisibility of goods, and convexity or the relevant sets and functions describing preferences and technology” (Hurwicz 1972: 38).

economies of scale, technical change, missing markets, non market resource allocation and other sources of imperfection. As noted above in such environments government or some other authority must often be called in to design and enforce reasonably “incentive efficient” mechanisms (Sandeep and Maskin 2003).

In a remarkable paper published in 1981, “Incentive problems in the Design of Non-wasteful Resource Allocation,” Hurwicz developed the proof of an “impossibility theorem” (first conjectured by Samuelson), that even in an informationally decentralized classical economy it is impossible to design mechanisms or institutions capable of achieving Pareto optimality.¹⁶ One constraint is the presence of private information. A second reason is that the operation of the mechanisms themselves employ scarce resources. Thus a first best Pareto optimality is generally not achievable. This negative result is extremely important because it focuses the attention on the comparative costs of the operation of the mechanisms and institutions. It also opens up the issue of the implications of new mechanism and institutions designed to improve welfare by generating new income streams (by reducing transaction costs, for example) and by introducing new mechanisms that improve the distribution of income (Hurwicz 1972: 43).

¹⁶ For a more formal treatment see Mass-Corell (1995: 858-869).

Hurwicz and his colleagues have established a foundation for a new and more powerful institutional economics. Their work challenges the conservative underpinning of Hayek's concept of spontaneous order, it breaks through the disciplinary constraints of neo-classical theory, and it challenges the relevance of Pareto optimality in normative economics (Runge and Ruttan, 2008).

6. Toward a More Complete Model

In Figure 2 I present in graphical form the elements of a pattern model that maps the relationships among changes in resource endowments and cultural endowments, and changes in technology and institutions.¹⁷ The model goes beyond the conventional general equilibrium model in which resource

¹⁷ Fusfeld used the terms 'pattern' or 'Gestalt' model to describe a form of analysis that links the elements of a general pattern together by logical connections. The recursive multi-causal relationships of the pattern model imply that the model is always 'open'--'it can never include all of the relevant variables and relationships necessary for a full understanding of the phenomenon under investigation' (Fusfeld 1980: 33). Ostrom uses the term *framework* rather than *pattern model*. "The framework for analyzing problems of institutional choice illustrates the complex configuration of variables when individuals ... attempt to fashion rules to improve their individual and joint outcomes. The reason for presenting this complex array of variables as a framework rather than a model is precisely because one cannot encompass the degree of complexity within a single model" (Ostrom 1990: 214). Richard Nelson (2006: 195-212) views economic growth as driven by the co-evolution of physical technologies and social technologies (or institutions).

endowments, technologies, institutions, and culture (conventionally designated as “tastes” in the economics literature) are given.¹⁸ In the study of long-term social and economic change the relationships among the variables must be treated as recursive and dynamic (Harsanyi 1960).

/ insert Figure 2 about here /

An important advantage of the pattern model outlined in Figure 2 is that it avoids the necessity of choosing between a materialist conception of human action, in which agents mechanically respond to changes in resource endowments, and an idealist conception of human action, in which agents respond only to subjective changes in cultural endowments (such as religion or ideology). A second advantage is that it helps us to identify our areas of ignorance.

Our capacity to model and test the relationships between resource endowments and technical change is relatively strong. In spite of recent advances in induced innovation theory and in mechanism and institutional

¹⁸ In economics the concept of cultural endowments has traditionally subsumed under the concept of 'tastes' which are regarded as 'given'--that is, not subject to economic analysis (Stigler and Becker 1977; Jones 1995; Ruttan 2003: 33-67). I use the term *cultural endowments* to capture those dimensions of culture that have been transmitted from the past. Contemporary changes in institutions, for example, can be expected to “harden” into the next generation’s cultural endowments.

design our capacity to model and test the relationships between cultural endowments and either technical or institutional change is relatively weak.

The model is also useful in identifying model components that have entered into attempts by other scholars to account for secular economic and social change. I illustrate below with several examples.¹⁹

Historians working within the Marxist tradition often tend to view technical change as dominating both institutional and cultural change. In his classic book, *Oriental Despotism*, Wittfogel (mistakenly) viewed the irrigation technology used in wet rice cultivation in East Asia as determining political organization (Wittfogel 1957). In terms of Figure 1 his primary emphasis was on the impact of changes in resources and technology on institutions (C) and (B). A serious misunderstanding can also be observed in the neo-Marxian critiques of the 'green revolution' in rice production in Asia (Cleaver 1972; Hayami and Ruttan 1985: 336-45). These criticisms focused attention almost entirely on the impact of technical change on labor and land tenure relations. Both the radical and populist critics emphasized relation

¹⁹ Induced innovation theory should be viewed as a diagnostic tool. Accurate prediction is not an appropriate test of the theory. If, for example, an increase in population pressure against land resources fails to induce the expected innovation in property rights institutions the appropriate response is to augment the model. Thus in my own work I employ induced innovation theory not to predict the effects of changes in resource endowments, technology, institutions and culture but rather as a guide to a “dialogue with data” and as a guide to mechanism and institutional design.

(B). But they tended to neglect the effects of rising population pressure against land (relationships A and C).

Economists such as Coase (1960) and Alchian and Demsetz (1973) identify a primary function of property rights as guiding incentives to achieve greater internalization of externalities. North and Thomas, building on the Alchian-Demsetz paradigm, attempted to explain the economic growth of Western Europe between 900 and 1700 primarily in terms of changes in property institutions (North and Thomas 1970: 1-17; Field 1981). The population decline in the fourteenth and fifteenth centuries was viewed as a primary factor leading to the demise of feudalism and the rise of the national state (line C).

Mancur Olson (1968, 1982), in an attempt to explain the more rapid growth of Germany and Japan relative to the United States and Britain, in the first several decades after World War II, emphasized the proliferation and rigidity of institutions as a source of economic decline. He also regarded broad-based encompassing organizations as having incentives to generate growth and redistribute incomes to their members with little excess burden. These distributional coalitions make political life more divisive. They slow down the adoption of new technologies (line b) and limit the capacity to reallocate resources (line c). The effect is to slow down economic growth or

in some cases initiate a period of economic decline. In a more recent work Greif (1994) has emphasized the differential impact of the collectivist cultural endowments of Maghrebi traders and the individualistic cultural endowments of Genoese traders on the development of commercial institutions in the Mediterranean region in the eleventh and twelfth centuries.

The impact of differences in resource endowments on the international diffusion of institutions has recently been explored in a series of important papers (Engerman and Sokoloff 2002; Acemoglu, Johnson and Robinson 2001; Levine 2005). A common conclusion is that where the disease environment was not favorable to settlement European states established extractive colonies (such as the Spanish in Mexico and Peru, Britain in the Gold Coast and Belgium in the Congo. Where the disease environment was favorable they established settler colonies. Where extractive colonies were established legal institutions were adopted that favored the extraction and transfer of resources to the metropolitan country and after independence to the new ruling elites. In settler colonies, in contrast, legal institutions that favored the rule of law and encouraged investment were established. These differences in legal culture and institutions continue to explain substantial differences in per capita income and income distribution, (lines F, D and C).

A potential criticism of the pattern model approach depicted in Figure 1 is that it does not stipulate the mechanisms through which changes in resource endowments, for example, induce changes in technology or institutions. However it is not too difficult to visualize some of the most important mechanisms that mediate the relationships among changes in resource endowments, technical change and institutional change. The market represents a “master mechanism” for translating the uncoordinated behavior of individuals into system level coordination (Headstrom and Swedberg 1998: 3).

7. Perspective

What are the implications of the theory of induced institutional change for research on the contribution of social science knowledge to economic development? In my research with Hayami and Binswanger on the direction and rate of technical change we were able to advance significantly our knowledge by treating technical change as largely endogenous—as induced primarily by changes in relative resource endowments and the growth of demand. We were also able to interpret the advances in knowledge about the role of changes in the economic environment on the rate and direction of

technical change for the design of research systems and the allocation of research resources (Ruttan 1982; 2001).

In this paper I have presented a theory of induced institutional change. I argue that the theory has advanced our understanding of the process of institutional change. It suggests that substantial new insights have been obtained by treating institutional change as a response to changes or differences in resource endowments, technical change and cultural endowments. But, as in the case of technical change, my concern goes beyond advancing our understanding of the process of institutional innovation. It is essential for the social sciences to advance our understanding of the historical processes of social and economic development. But that is not sufficient! If social science knowledge is to be valued by society it must also advance the knowledge to successfully intervene in the process of development—to reduce the cost of the "trial and error"—that has been the constant companion of the historic “organic” processes of institutional innovation. A functional goal of the social sciences (including economics) is not just to understand human behavior but to evaluate proposals for institutional reform and to design new and better mechanisms and institutions (Myerson 1999: 1069).

Beginning in the mid-1980s I initiated a program of research and writing designed to explore in greater depth what development economists should learn from scholars in the other nomothetic social sciences—anthropology, sociology and political science—working in the field of development. My book, *Social Science Knowledge and Economic Development* (Ruttan 2003) grew out of that effort. A consistent theme in that book and in this paper is that advances in social science knowledge represent a powerful source of economic growth and more broadly of economic development. Advances in social science knowledge represent a high payoff input into economic development. This position falls squarely into the tradition of Enlightenment political philosophy. The U.S. Constitution was an early, and magnificent, example of this design perspective.

The design perspective stands in sharp contrast to the organic or evolutionary perspective. Hayek, for example, has argued that improvements in institutional performance are the result of a process of collective learning that has passed the slow test of time and are embodied in a people's language, culture and institutions. This accumulated knowledge is built into ways of learning and has a powerful impact on both the present and the future. Since collective learning occurs at the level of the community rather

than the individual there are severe constraints on the rational design of policies and institutions. But there can be no presumption that the institutions that emerge out of the process of social evolution, unguided by advances in social science knowledge, will result in efficient trajectories of cultural, social, or economic development (Hayek 1967, 1978; North 1994). Spontaneous order is not enough!

In closing I would like to emphasize again that the work on incentive compatible mechanism and institutional design initiated by Hurwicz has widened the scope for social scientists to contribute to institutional analysis, design and implementation. It challenges the adequacy of concepts of spontaneous order, organic and evolutionary approaches to the analysis, design and implementation of institutional change. It breaks through the disciplinary constraints of neoclassical theory and erodes the relevance of Pareto optimality in normative economics. It has not yet, however, provided us with an application “tool kit” for mechanism and an institutional design. The concept of incentive compatibility is, however, an exceedingly powerful intellectual concept. It may be even more powerful as metaphor than as an analytical concept.

The pattern model outlined in this paper is built on recursive relationships among changes in resource endowments, technology,

institutions and culture. Successful institutional innovation will almost always be culture specific. It involves more than simply institutional (or technology) transfer. Advances in social science knowledge can open up new and productive opportunities for institutional innovation and design that enhance development. In the induced institutional innovation model there is no role for simple resource, technological, institutional or cultural determinism. The dialectical relationships among changes in resource and cultural endowments and technical and institutional change influence the rate and direction of social, political and economic development. And the feedback from these changes becomes the sources of change in resource and cultural endowments.

Finally I would like to emphasize that the complementary relationship between mechanism design theory and the theory of induced institutional innovation. Designers are not free to ignore the long term secular shifts in resource and cultural endowments. Nor can they ignore contemporary changes in technical and institutional environments.

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TABLE 1. Factor shares of rice output per hectare, 1976 wet season

	Number of plots	Area (ha)	Rice output	Current inputs	Factor shares ^a					
					Land			Labor	Capital ^b	Operators' surplus
					Landowner	Sublesor	Total			
-----kg/ha-----										
Share tenancy land	30	29.7	2,749 (100.0)	697 (25.3)	698 (25.4)	0 (0)	698 (25.4)	850 (30.9)	288 (10.5)	216 (7.9)
Leasehold land	44	67.7	2,889 (100.0)	657 (22.7)	567 (19.6)	0 (0)	567 (19.6)	918 (31.8)	337 (11.7)	410 (14.2)
Subtenancy land	16	9.1	3,447 (100.0)	801 (23.2)	504 (14.6)	801 ^c (23.2)	1,305 (37.8)	1,008 (29.3)	346 (10.1)	-13 (-0.4)

Source: Yujiro Hayami and Masao Kikuchi, *Asian Village Economy at the Crossroads, An Economic Approach to Institutional Change* (Tokyo: University of Tokyo Press, 1981, and Baltimore: Johns Hopkins University Press, 1982), pp. 111-13.

^a Percentage shares are shown in parentheses.

^b Sum of irrigation fee and paid and/or imputed rentals of carabao, tractor, and other machines.

^c Rents to sublesors in the case of pledged plots are imputed by applying the interest rate of 40 percent crop season (a mode in the interest rate distribution in the village).

Table 2. Institutional Design Principles

Elinor Ostrom and colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University have articulated eight design principles drawn from their research on self-organized resource management regimes.

The *first* design principle is that the presence of clear boundaries and rules ...enables participants to know who is in and who is outside of a defined set of relationships and thus with whom to cooperate.

The *second* design principle is that the local rules-in-use define the amount, timing, timing and technology of harvesting the resource: allocate the benefits proportional to required inputs; and are drafted to take local conditions into account.

The *third design* principle is that most of the individuals affected by the resource regime can participate in making and modifying the rules. Resource regimes that use this principle are both able to tailor better rules to local circumstances and to devise rules that are considered fair by participants.

The *fourth* design principle is that ... resource regimes select their own monitors, who are accountable to the users or are users themselves and who keep an eye on resource conditions as well as on their use.

The *fifth* design principle is that the resource regimes use *graduated sanctions* that depend on the seriousness and context of the offense. By creating official positions for local monitors a resource regime does not have to depend only on willing punishers to impose personal costs on those who break a rule.

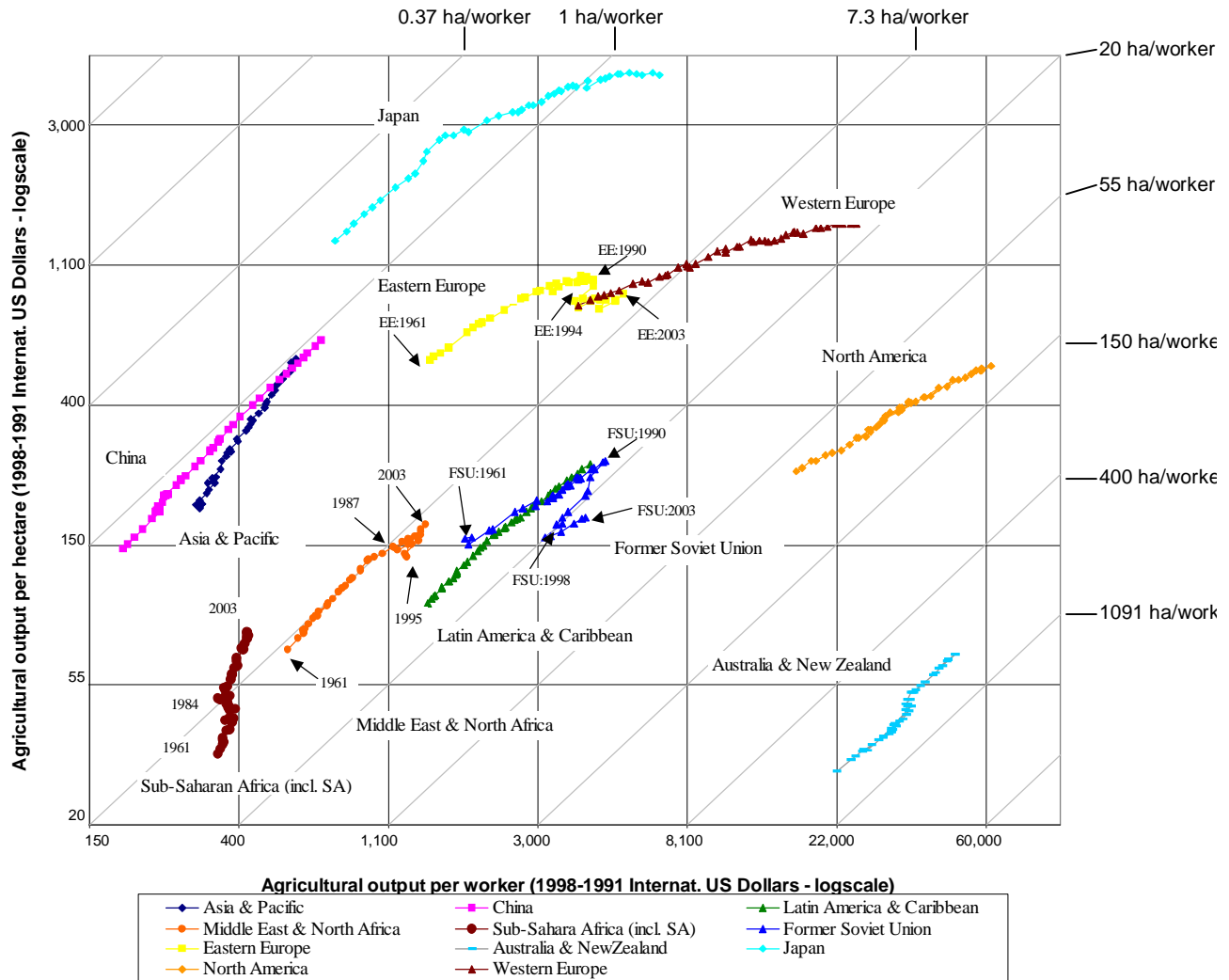
The *sixth* design principle is the importance of access to rapid, low cost, local arenas to resolve conflict among users or between users and officials. By devising simple, local mechanisms to get conflicts aired immediately the number of conflicts that reduce trust can be reduced.

The *seventh* design principle is that the capability of local users to deliver an ever-more effective regime over time is affected by whether they have minimal recognition of the right to organize by a local, regional or national government unit.

The *eighth* design principle that characterizes systems when common pool resources are somewhat larger is the presence of government activities organized in multiple layers of nested enterprises. Among long enduring self-organized regimes, smaller scale organizations tend to be nested in ever-larger organizations.

This table is adapted from the institutional design principles articulated in Elinor Ostrom, “Collective Action and the Evolution of Social Norms,” *Journal of Economic Perspectives* 14 (2000): 237-58. The institutional design rules developed by Elinor Ostrom drew heavily on her research on the design and management of irrigation systems. See Elinor Ostrom, 1992, *Crafting Institutions for Self-Governing Irrigation Systems*, San Francisco: ICS Press. The design principles were most fully articulated in Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*. New York, Cambridge University Press, 1990.

Figure 1. Global Agricultural Land and Labor Productivity, 1961-2003



Source: Pardey, P.G., J. James, J. Alston, S. Wood, B. Koo, E. Binenbaum, T. Hurley and P. Glewwe. *Science, Technology and Skills*. Background Paper for the World Bank's *World Development Report 2008*. St. Paul, Rome and Washington D.C.: University of Minnesota, CGIAR Science Council and World Bank, 2007.

Notes: Workers are economically active in agriculture. Land is the sum of area harvested and permanently pastured. Output is value of production farmed by weighting a time series of commodity quantities for each country by a 1989-1991 average of commodity-specific average of international prices. All productivity trajectories start in 1961 on left/bottom and end in 2003 on right/top, unless indicated. Diagonal lines indicate constant factor (land to labor) ratios.

Figure 2. Interrelationships between changes in resource endowments, cultural endowments, technology, and institutions. (From Yujiro Hayami and Vernon Ruttan, Agricultural Development: An International Perspective, rev. ed. [Baltimore: Johns Hopkins University Press, 1985], 111.)

