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MODELING INSTITUTIONAL CHANGE IN RURAL EGYPT

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The purpose of this paper is to outline a conceptual framework for the economic analysis of village institutions. As one component in the Egyptian village simulation effort, it treats village level institutions as well as the larger institutional environment with which the village interacts. Section I discusses the nature of and rationale for institutional research and briefly reviews some of the literature directly pertaining to rural development. Section II introduces the methodology of stochastic learning systems and discusses its use as a tool for modelling institutional change. Section III offers a preliminary list of questions to which this approach might be applied in the context of Egyptian village studies.

I. The Economic Study of Institutions

At one point or another, those attempting to understand a social process usually find it beneficial to identify the institutions through which the process unfolds. Across a wide spectrum of ideologies and approaches, the analysis, as some important juncture, depends upon an adequate formulation of the institutional structure and an understanding of the forces which shape and perpetuate that structure. For some research, institutional change represents the core of the concern; in other investigations, formulating institutional taxonomies, identifying institutional links, and pinpointing institutional constraints are essential preliminaries. In studying village

economies, institutions are of interest for both of these reasons.

In the economic sphere there are at least three unique classes or levels of institutions: the overarching set of cultural values which form a context for economic behavior, the set of laws and regulations which specify the rules of the game, and the contractual arrangements which are used to effect transactions. Although consideration of the first level (cultural values) leads to important questions in economic anthropology which at times concern us here, the primary content of our investigation focuses on the second (laws and regulations) and third (contracts) categories or strata. In particular, the formation and evolution of the institutional arrangements which mediate economic transactions at the village level and the interaction between regulatory behavior and village level choices constitute two related areas of investigation. Such institutional behavior affects the allocation of resources within the village and the overall productivity of the agricultural sector. Thus the institutional web becomes one important focal point for economic analysis: how are economic arrangements formulated, how do they constrain or facilitate the course of development, what policy options are consonant with existing or potential institutions, and how do institutions respond to exogenous shocks?

For economists, the very unique institution called a market plays a central role in theory and policy formation. The perfect competition case offers one point of departure for economic theory. In the Arrow-Debreu complete contingent commodities case, the market model reaches another conceptual extreme. Whatever the merits of such polar cases for the formulation of theory, the institutional context of many transactions falls far short of polar cases. Not only do we fail to observe a full set of contingent markets

but we also observe externalities, costly transactions, incomplete information, enforcement costs, and noncompetitive market structures. Thus, market analysis alone is inadequate, and the total economic picture cannot be sketched without also including nonmarket resource allocation. This portion of the picture becomes especially important when markets do not emerge or when allocation is bureaucratized. Both situations are plainly part of the economic milieu of village level allocation and production.

The approach taken in the present effort is to examine village level change through a study of the adaptive behavior of institutional arrangements and the regulatory framework which both shapes and is shaped by the actions of villagers. In the spirit of the "new institutional economics" [e.g., see Roumasset, 1978] we attempt to explain the existence and evolution of institutions through the use of conventional economic tools such as benefits, costs, and equilibria. In particular, we model both the village and the larger institutional framework as making choices with reference to the returns and risks of various options; furthermore, these payoff structures may be altered in response to such choices. That is, villagers may opt for particular institutional arrangements; however, if an agricultural authority, for example, is not content with the outputs forthcoming because of village level choices (or for any other reason), such authorities may attempt to alter the payoffs which villagers face. In turn, the response at the village level may register a new set of signals to the regulatory authority. Capturing this interaction is one goal of the present modelling effort. Other unique aspects of the present effort include incorporation of the probabilistic nature of institutional choice and the dynamic adaptive or learning behavior of the institutional structure. A systematic framework

for modelling institutional change in this manner is introduced in section II.

The economics of institutional change have received increasing attention during the past few decades. In part this has been an effort to alleviate the deficiencies of earlier work in institutional economics and to fill the void left by the rejection of the older methodologies. T.W. Schultz observed in 1968 that "It is currently a mark of sophistication in presenting economic models not to mention institutions. But for all that, it is a significant trait of contemporary economics that, despite this omission, it manages somehow to find support for institutional changes. It is a neat trick, but it cannot hide the fact that, in thinking about institutions, the analytical cupboard is bare." [Schultz, 1968, p. 1113.] Much of the recent attempt to fill the cupboard has focused on property rights and public choice. Some of the major contributions have been made by H. Demsetz and A. Alchian [Demsetz, 1967, 1969; Alchian and Demsetz, 1972], A. Downs [1957], and J. Buchanan and G. Tullock [1962]. In a similar vein, questions in the economic history of institutional change have been treated by L. Davis and D. North [1970, 1971].

Economists concerned with rural development have been prominent in their efforts to use economic theory in the analysis of alternative institutional arrangements. The theory of resource allocation under share tenancy has received particular attention in recent years. A classic work is S. Cheung's The Theory of Share Tenancy [1969]. The determination of the terms of share contracts has been the subject of a considerable amount of mathematical model-building. D. Newbery and J. Stiglitz [Newbery 1975, 1977; Stiglitz 1974; Newbery and Stiglitz 1979] have provided theoretical treatments of sharecropping with emphasis on imperfect information and risk sharing. C. Bell and P. Zusman [1976, 1980] have considered these issues

in the context of a bargaining model in which the contract between landlord and tenant is the outcome of a simultaneous dyadic bargaining process. The particular issue of interlinked contracts in rural factor markets has been emphasized by P. Bardhan [1980 and Bardhan and Rudra, 1978] and has received particular attention in modelling efforts by A. Braverman and J. Stiglitz [1981] and P. Mitra [1980].

The dynamics of institutional change in the development process have been emphasized by Y. Hayami and V. Ruttan [1971] [see also Binswanger and Ruttan, 1978]. This line of inquiry examines the economic inducements to technical and institutional change. Particular emphasis has been given to the process of public sector research and to the institutional structure through which change is facilitated. In contrast to the view which sees institutions as constraints to technical change and development, Hayami and Ruttan argue that "institutional reform is appropriately viewed more as a response to the new opportunities for the productive use of human and material resources opened up by advances in technology than as a precondition for agricultural development." [1971, p. 258] In a more general sense, institutional change is portrayed as a significant element in the process of adaptation to changing economic circumstances. As costs and opportunities change, a society is faced with the challenge of altering its behavioral rules and patterns to fit new circumstances.

'Reform' may, of course, not be the word which would always apply to institutional adjustments. This would especially be so for any particular agent or group which finds itself worse off rather than better off after an adjustment. Such a case is illustrated in recent research by M. Kikuchi and Hayami [1980] on the compensation of landless agricultural labor in a Philippine

village. They report an institutional innovation which lowered the effective wage rate. Over time, as rice yields improved and labor became more abundant, the marginal product of harvesters declined. In the absence of a fully functioning labor market, wage adjustments were made through institutional change. The shift was from the Hunusan system (in which workers received one-sixth of the harvest) to the Gama system (which is similar to Hunusan but restricts employment by requiring workers to weed fields without compensation in exchange for the right to participate in the harvest). From 1959 to 1976, there was a shift from 0% to 83% of the farmers using such a system. Another example given by Kikuchi and Hayami illustrates that such economic adjustments are not always in favor of landowners. Because of land reform regulations and other social forces, landlords were limited in their ability to raise rents. As the marginal returns to land rose, many tenants captured the surplus through various forms of subrenting. For our purposes, the significant point of these two examples is that institutional change is often amenable to economic analysis.

In sum, the "new institutional economics" has shunned ad hoc and anecdotal explanations of institutional change in favor of economic theory. Thus, any institution which performs an economic function can be at least partially analyzed with the economist's "tool kit." Some institutional aspects of rural development, such as the terms of share constacts, have been the subject of rigorous modelling efforts; other aspects have not received as much attention. The intent of the present research is to expand the economic analysis of rural institutions by 1) considering a broader set of socioeconomic institutions, and 2) explicitly modelling the dynamic learning behavior of the institutional structure. An important tool for this modelling effort will

be the use of stochastic automata theory in structuring a simulation of institutional adjustment.

II. An Approach to Modelling Institutional Adaptation

In order to study the adaptive behabior of institutional structures, we draw upon the theory of learning automata. Models of stochastic learning systems have been used most widely in engineering and mathematical psychology and have been given only scant attention by economists. The basic idea of a learning model is that a learner (automaton, system, or organism) has less than perfect information about an environment or situation and adjusts behavior on the basis of experiential feedback (penalties or rewards) from the environment. Our purpose here is to consider the feasibility of modelling the adaptive behavior of institutions using stochastic automata methods. Here the institutional framework is seen as a learning system which adjusts to environmental conditions. We also consider the more complex situation in which the environment itself (or some part of the environment) functions as a learning system. This section begins with a brief overview of the learning automata literature which is then followed by a discussion of possible applications to the economic analysis of village institutions.

The pioneering work on learning models in mathematical psychology was done by R. Bush and F. Mosteller (1955). Subsequent studies included treatments of the topic by P. Suppes and R. Atkinson (1960) and R. Atkinson, G. Bower, and E. Crothers (1965) extending the analysis to group interaction and game theoretic applications. Among these applications is a learning-theory approach to the behavior of oligopolistic firms which attempts to go beyond the static, deterministic models of conventional economic theory.

The treatment of automata models by engineers represents the largest body of literature on the subject and a substantial portion of this work has been done in the Soviet Union [see, e.g., M. Tsetlin, 1961; Ya. Tsypkin, 1971 and 1973; M. Tsypkin and A. Poznyak, 1977.] Tsetlin's work [1973] has included applications to biological systems. K. Narendra and associates have made many contributions to the literature including a major survey [K. Narendra and M. Thathachar, 1974]. K. Narendra also edited a "Special Issue on Learning Automata" of the Journal of Cybernetics and Information Science [1977] which contains an extensive "Bibliography on Learning Automata" compiled by S. Lakshmivavahan [1977]. K. Fu and associates have treated learning automata extensively within the context of adaptive control theory and pattern recognition [e.g., see K. Fu 1970 and 1971].

The general subject of stochastic learning systems has received rigorous mathematical treatment by M. Iosifescu and R. Theodorescu [1969] and M. Norman [1972].

A learning automaton model is constructed by specifying the automaton, $\{x, Y, p, A\}$, and the environment, $\{Y, x, c\}$, where:

x: input set of responses to the automaton from the environment (alternatively, the environment's output set)

Y: output set $\{Y_1, Y_2, \ldots, Y_S\}$ of actions or responses to the environment from the automaton (alternatively, the environment's input set).

p: the probability vector $(p_1, p_2, \ldots, p_S)$ associated with Y; $p_i(n)$ represents the probability of output Y_i occuring at time n.

A: the learning algorithm or updating scheme which generates next period's probability vector : $p(n+1) = F[p(n), Y(n), x(n)]$.

c: the penalty (or payoff) probability vector $(c_1, c_2, \ldots, c_S)$ governing the feedback to the automaton: $c_i(n)$ represents the probability (or distribution of probabilities) associated with the

possible environmental responses to the selection of Y_i at time n. If the environment is random but stationary, c_i is constant over all n.

A somewhat more involved model would distinguish between the internal states of the automaton and its outputs and would thus also need to include a rule for mapping states into outputs. We follow the frequent practice of assuming that this mapping is deterministic and one-to-one. Another common practice is to restrict x to be chosen from a binary set, $\{0,1\}$ or $\{-1,1\}$, or some other set of finite elements. This is often appropriate for situations where the feedback is of a yes/no or penalty/no penalty nature. However, in economic applications where the size or intensity of the reward or penalty is also of significance, x cannot reasonably be restricted in this manner. Although we will allow x to be any real number, when adjusting probabilities on the basis of x it will be necessary to introduce a procedure for normalizing responses in such a way that the input set is the interval $[0,1]$.

A simple schematic of the model is shown in Figure 1:

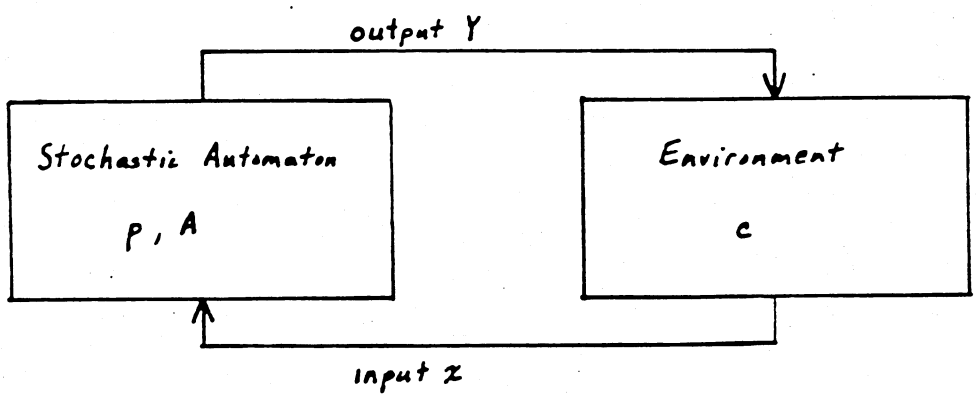

Figure 1

The performance of the automaton is said to be optimal if the limit as $n \to \infty$ of the expected value of its average penalty (reward) is minimized (maximized). It is said to be ϵ-optimal if this limit is within some arbitrarily small neighborhood of the optimal value. It is referred to as expedient if it performs better than an automaton which selects outputs in a purely random manner. And it is called absolutely expedient if the expected value of its average penalty (reward) is strictly monotonically decreasing (increasing).

The behavior of a learning automaton is characterized by changes in p, the probability vector. One may be interested in examining p directly and/or examining the properties of the transition probability matrix, M, with the typical element $p_{ij} = p\{Y(n+1) = Y_j \mid Y(n) = Y_i\}$. The specification of a reinforcement scheme yields a Markov process, and it is the convergence properties of this process which are of concern when identifying the asymptotic behavior of the automaton.

A key element in constructing a learning automaton model is the selection of a reinforcement scheme to be used for updating probabilities. The generalized linear reinforcement scheme for updating state or action probabilities as presented by K. Fu [1970] is followed here with minor modifications. For illustrative purposes, consider Y to be a set of institutional arrangements and $x_i(n)$ to be the payoff to the automaton when selecting Y_i at time n. The learning algorithm updates the probabilities of choosing the various Y_i. If the Y_i are to be selected in order to maximize the expectation of x(n), then the algorithm is as follows:

$$p_i(n+1) = \theta p_i(n) + (1-\theta)\lambda_i(n)$$

and

$$p_j(n+1) = \theta p_j(n) + \frac{(1-\theta)}{(s-1)}[1-\lambda_i(n)] \qquad \begin{matrix} j = 1,\ldots,s \\ j \neq i \end{matrix}$$

with $0 < \theta < 1$, $0 \leq \lambda_i(n) \leq 1$.

The values of the normalized performance index, $\lambda_i(n)$, are in [0,1] and are calculated, using an appropriate scheme, from the $x_i(n)$ values.

The automaton or learning system is seen as searching for or learning a pattern of actions by selecting from the set $Y = Y_1, Y_2, \ldots, Y_S$ in order to optimize the expectation of some performance indicator, x. The automaton is stochastic in the sense that each action, Y_i, has a probability, p_i, associated with its occurance. The learning algorithm is used to update those probabilities by lowering the probability of an action which registers an unfavorable performance and raising the probability of an action registering a favorable response. The convergence behavior of the automaton is of particular interest for identifying the nature of its learning capacity.

The application of the above mathematical framework to the evolution of institutions is straightforward. At least three possible cases will be of interest. Their differences relate to the nature of the random environment. In the simplest case, the environment is stationary; in a more complex case, it is nonstationary; and finally, another level of complexity is introduced if we consider two or more automata whose choices alter the environment for the other automaton(a).

An example of the first and simplest case might be the choice of contracts where the elements of Y represent a set of discrete alternative contractual forms. In the absence of fully functioning markets in which smooth, continuous adjustments of contractual parameters can be made, adjustment may be effected through a shift in institutional arrangements. Comparative statics could be used to study the impact of a one-time shift (e.g., a land reform, the building of a dam or new water system, a natural catastrophe, etc.) which altered the payoff structure associated with various institutional arrangements. Such situations are represented by the behavior of an automaton operating in an environment which has shifted from one stationary configuration to another.

If the environment is non-stationary, the model is less tractable analytically but still offers a reasonable structure for simulating institutional change. Such simulations might offer insight into the ability of various

institutional structures to adjust to changing circumstances and could thus serve as one systematic approach to analyzing the significance of institutional rigidities (or lack thereof).

An especially challenging modelling problem materializes when we try to account for situations in which the environment may change in response to an automaton's behavior. One option is simply to regard the environment as nonstationary. However, this approach seems unsatisfactory if there exists a causal link between the environmental change and the automaton's behavior. Such is clearly the case when government is part of the environment and regulatory behavior is changed in response to the adaptive behavior of some group. Schematically, this situation is represented in Figure 2 where

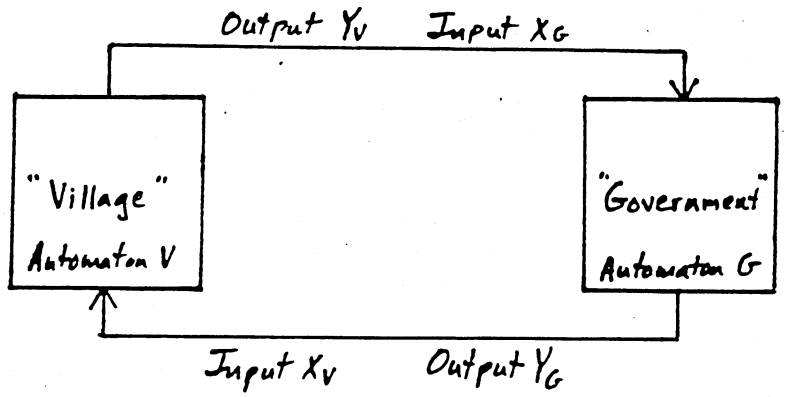

Figure 2

"Automaton V" represents village level adjustments in response to "Government" while "Automaton G" represents government regulatory adjustments in response to the "Village." The basic diagram shown in Figure 2 serves as a point of departure for constructing schematics of more complex versions of the model. Two examples of circumstances which require modification of Figure 2 are discussed below.

First, outputs may not be synonymous with inputs. For example, one output of interest may be a farmer's choice of contract while the relevant input into the automaton representing regulatory behavior may be some measure of agricultural productivity related to this choice of contract. In some cases, more involved information circuits might be accomodated by the insertion of a translation or evaluation step into the basic loop; in other cases, multiple loops or flows of information may be required.

Second, a larger issue involves the correct specification of each automaton's environment. If one automaton is not synonymous with the other automaton's environment, the diagram must reflect the more complex nature of the decision environment. For example, since regulatory behavior is by its very nature a pluralistic process, the modelling of government choice will usually need to encompass a larger decision environment than that implied by Figure 2. Likewise, village level choices are made with reference to government actions plus a host of other factors. Thus, in Figure 3 the dotted lines are used to indicate the partial nature of the diagram. Flows through other relevant environmental elements could be represented in a similar fashion but, for simplicity, are not shown here.

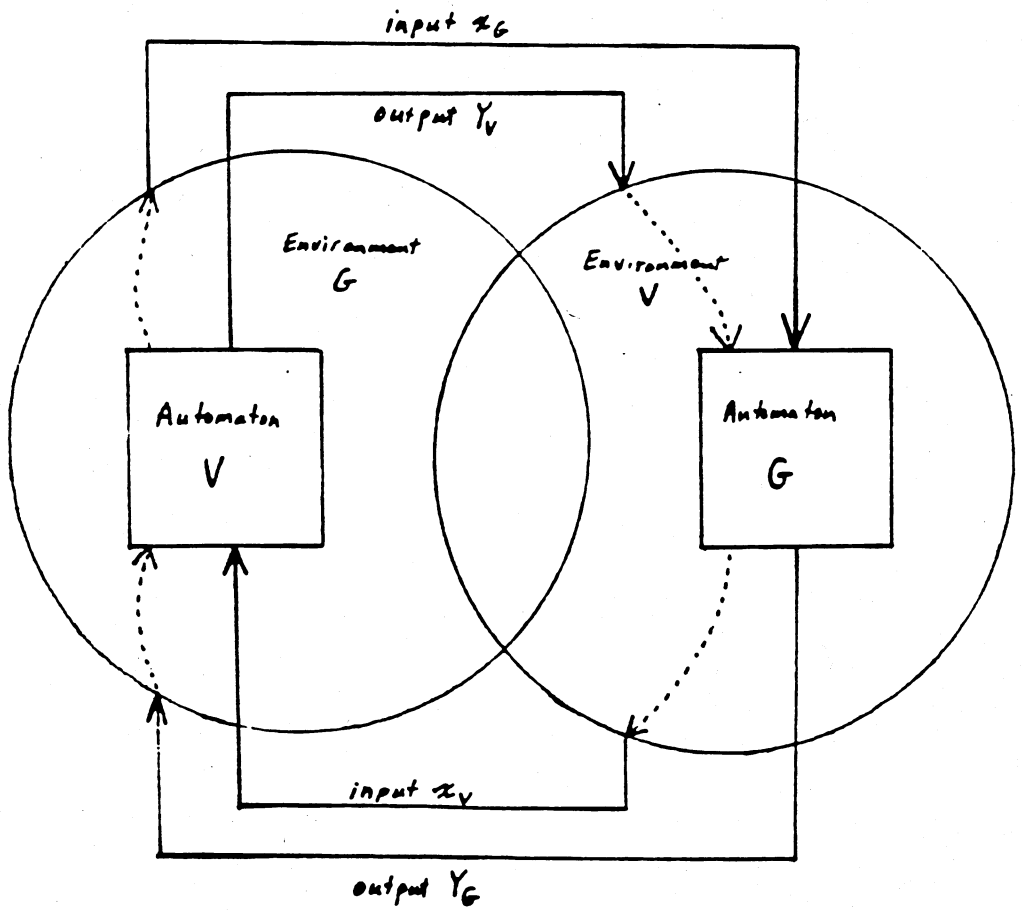

Figure 3

The overlapping of the two environments symbolizes that they are not likely to be mutually exclusive sets; to cite extreme examples, a natural disaster or a military invasion of the countryside alters the environment for both villagers and government.

The situations represented by Figures 2 and 3 above do not seem to have been treated in the automata literature. Attention has been given to games between automata [e.g., V. Krylov and M. Tsetlin, 1963; R. Viswanathan and K.S. Narendra, 1973.]; however, these models always assume that the gaming automata are making choices in response to the same environment. Rather than such a gaming situation, the pattern presented above suggests a two-stage process in which V updates action probabilities given the environment implied by G's last period choices, G updates given the most recent feedback from V, etc. A slight variation in this pattern of stages is obtained if G's decision period is of a different length than V's; for example, V may go through two or more updating sequences for each of G's if G's decision period is longer.

Another modelling problem relates to the treatment of risk within the learning automata structure. The problem can be illustrated with a simple example. Consider an automaton which chooses between action Y_1 which has a certain payoff of 100 and action Y_2 which has an equal chance of a payoff of zero or a payoff of 200. Both results have the same mathematical expectation and with an updating scheme like the one outlined above, the limiting action probabilities would be equal ($p_1 = p_2 = .5$); that is, the automaton will be indifferent between Y_1 and Y_2. Yet, such risk neutrality is obviously not a reasonable behavior to impose upon a population for which there is good reason to expect risk aversion to be an important element in choice-making. One solution is to use utility as the performance indicator and model the automaton

as an expected utility maximizer. Another approach is to introduce a more complex learning algorithm which might incorporate either or both of the following: a) in a lexicographic fashion, it could dramatically reduce the action probability of any alternative which registered a payoff below some specified threshold, b) extreme values could be weighted in a systematic manner and outlying responses would lead to disproportionately larger reductions in action probabilities.

III. Applications: Institutional Questions in Rural Egypt

The following is a list of institutional issues for further study. At this preliminary stage, the list is, more than anything else, an inventory of questions. The aim of these questions is to serve as one element in the process of identifying the relevant institutional content to be included in our village simulation. This process depends on both an accurate reading of the past and an anticipation of the forces which will impinge on villages in the future. Among the potential issues for consideration are:

1. Government. As the joint report of the Egyptian-U.S. Agricultural Sector Assessment Team [USDA, 1976], put the matter, "there is an attempt to direct from Cairo almost every phase of agricultural operations on individual farms, as well as operations in marketing channels." [USDA., 1976, p. 14.] A wide array of price controls, quotas, and regulations are found in the agricultural sector. Cooperatives function more as administrative agencies for government policy than as instruments for farmer coordination and agricultural efficiency. What are the underlying economics of such an institutional framework? What institutional changes emerge as the costs and benefits to 1) farmers, 2) govern-

ment organizations, and 3) the larger society, vary over time? To what extent do official pronouncements and plans conflict with unwritten rules which call for preserving the existing order? [see R. Meier, 1980, especially p. 10.]

There are two ways in which a desire to maintain existing relationships might enter the modelling framework presented above. First, the adjustment parameter, θ, can be set at a very low level; that is, even when the underlying economics induce change, the movement toward a new institutional configuration would occur only vary gradually. One indicator of the costs of this sluggish adjustment would be provided by the difference in the average value of the performance indicator for any given period compared with its expected value as $n \rightarrow \infty$. A second approach is to specifically model the survival of existing arrangements as the goal of a particular organization or set of agents. In this case, performance indicators would be chosen which reflect the survival of existing institutions as a goal in itself; departures from the prevailing order would register penalty signals; and the dynamics of the system would be analyzed with regard to its ability to meet such (institutional) survival goals.

2. Investment. Related to the above issue of government behavior is the matter of agricultural investment. Observers of the Egyptian economy frequently comment on the low proportion of investment going into the agricultural sector and furthermore on the fact that the bulk of this goes to new lands rather than into programs to increase productivity on the old lands. If a policy shift in this regard occurs, what impact will it have upon village structure? How does the existing institutional structure of old lands villages discourage such investment?

3. Water. Water availability is not presently regarded as a constraint in Egyptian agriculture. Yet, with mounting pressures from population growth and industrialization as well as the prospects for the Sudan using increasing proportions of the Nile's water for its own agricultural expansion (an issue discussed at length by J. Waterbury, 1979), the era when water is regarded as a scarce resource in the Nile Valley and Delta may not be far off. Will medium term shifts in economic and demographic variables create conditions under which water becomes a commodity rather than a right? There is good reason to believe that the institutional structure which now regulates water use will not remain unchanged in the coming decades. What shape will these changes take? How will national policy and rural practices adjust to allocate this vital resource?

4. Land. Agricultural land is already a scarce resource in Egypt and several forces are at work shifting the underlying economics of land ownership. Considerable amounts of land are being lost to urbanization; current estimates put the annual rate at anywhere from 30,000 to 75,000 feddans. On the demand side, emigrant remittances seem to be adding to the upward pressures on land prices. Several land related issues emerge:

a. Will owners contemplating the future sale of land withhold it from production for fear of government regulations requiring that tenants share in the proceeds from sales of agricultural land?

b. Are the increasing pressures on cultivated land, as some observers suggest, leading to an increase in landowner incomes through a reemergence of sharecropping and per crop rents in place of annual rentals?

c. What institutional variations emerge in new lands agriculture? (Studies of new towns in the energy boom areas of the western United States indicate that socioeconomic institutions are likely to be both inadequately developed and subject to great stress. Established patterns and arrangements are not transferred intact and unimpaired to new settlements.)

d. What lessons can be learned from a retrospective assessment of the evolution and impact of land reform since 1952?

5. Labor. Rural unemployment rates reported for Egypt are quite low. Although the statistics indicating relative tightness in rural labor markets are subject to a number of interpretive questions, they are dramatic enough to lead one to wonder about the adjustments that take place when rural male laborers emigrate to jobs in Arab OPEC countries. In particular, would this induce greater labor force participation by females? If so, how would traditional notions about the roles of women enter the picture? This last question involves at least three issues: How does tradition constrain change, at what point do long-standing notions give way to economic pressures, and finally, a problem for researchers, how do strong social norms affect the availability and reliability of data on such changes?

The above, being a very tentative and preliminary list, will of course go through much revision as the study progresses. Some not-so-pertinent questions will be eliminated and others (e.g., the impact of housing shortages on reinforcing the extended family, the affects of bread and fuel subsidies, the phenomenon of commuting rural-urban migrants, etc.) may be added to the list.

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