RURAL ECONOMY

Report of Discussions

Workshop on Applications of Complex Systems Science and Method to Agriculture, Rural and Environmental Issues
Westridge Park Lodge
Devon, Alberta
20-21 July 1995

Compiled by Steven Schilizzi and Leonard Apedaile

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PROJECT REPORT

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Table of Contents

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1 INTRODUCTION TO THE WORKSHOP

This workshop on complex systems has a history of several years of cooperative work by four of its members. It all started with the study leave from the University of Alberta of Peter Apedaile, at the Agricultural Systems Department of INRA in France with Steven Schilizzi. Herb Freedman and Mark Solomonovitch joined in a little later, when mathematics became an important part of the research program.

In 1990, the first workshop was held with the Agricultural Systems Department at Montpellier, France to address basic systems concepts. A poster presentation on dynamical systems was made in 1991 in Tokyo at the meetings of the International Association of Agricultural Economists. In 1993, some of the work was presented at the International Conference of the Society for the Advancement of Socioeconomics in New York. In 1994 a seminar was given at the University of Alberta on the ecological foundations of economic dynamics. In February 1995, a workshop was held with invited participants from the Agricultural Financial Services Corporation and Alberta Agriculture, Food and Rural Development.

Several published papers ranging from theoretical models to applications precede this workshop. A list is attached.

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2 HOW TO READ THIS SUMMARY

This Summary gets a little heavy in places. The heaviest places are marked so that the reader may skip them. Thus you can chose the parts of the summary you want to read.

You may wish to proceed directly to the last section reporting questions and answers. As promised, we have elaborated on the brief answers given hastily during the last hours of the Workshop. The answers reflect some of our work since the Workshop.

3 INTRODUCTION TO COMPLEXITY

Perhaps the major difficulty facing analysts of agricultural and rural development issues today is the complex nature of these issues. Complex problems normally cannot be addressed effectively with the "Cartesian" methods inherited during the industrial revolution from mechanical physics. Yet our formulation of questions, thinking and methods remain Cartesian. Examples: What would be the output response to a change in wheat price? What is the cause of the decline in subscriptions to crop insurance?

Cartesian method splits complicated problems into smaller parts and treats these parts as simple. Rules are established to re-combine the parts. Obedience to the rules and a degree of artisan skill usually result in recreating exactly the same complicated whole every time. (Ex: a bicycle, its parts and an assembly manual)

Cartesian (cause and effect) thinking has been very efficient for problem solving since the 1600's (Descartes, Newton) and lies at the roots of 20th century scientific and technological miracles. It is the basis of modern school and university education. Cartesian method and science have lead to the industrialization of agriculture and other rural activities. The current forms of economic behaviour and social structures which go along with this industrialization are referred to as 'Fordism'.

However Cartesian method may be reaching its limits. It addresses complicated systems effectively, but not complex systems. A useful distinction between 'complex' and 'complicated' lies in the predictability of outcomes. Outcomes of complicated systems (bicycle assembly) are predictable. Complex outcomes (exact path of the same bicycle and rider) are not. Consider the following.

Next paragraphs may be skipped

Complicated systems may be reduced to simpler parts for study and diagnostic work. Re-assembly, according to a learnable and finite set of rules such as an algorithm, involves additional learning conditioned by experience. Thus given a set of initial conditions, one can derive rules such that outcomes be predictable. Probabilistic or stochastic predictability is an extension of this principle to cope with random events, error or incomplete information.

Complex systems on the other hand cannot be taken apart and reassembled predictably to yield the same original whole, because the parts are themselves complex systems. They cannot be considered as simple. Worse still the parts often undergo modification as part of their interaction with other parts. Reassembling, adding, and aggregating do not recreate the whole. Therefore the whole cannot be predicted from the parts. Living biological, economic and social systems are typical of complex systems.

Resume reading for continuity

In summary, the difficulties with prediction for complex systems arise because each system and each part of a system co-evolves and self-organizes constantly. The rules of interaction among complex systems and their parts do not remain the same over time.

Thus perhaps the first step is to determine how much of a problem is attributable to complication and how much to its complexity. We think that in most cases we would find that questions for agricultural and rural economies involve rather more complexity than complication:

- Are hidden environmental costs swamping revenues?

- How are transaction costs related to value-added by rural and agricultural enterprise?

- Is there a low-revenue stability trap or trapping process inherent in agrifood processing (ex meat packing, canola crushing and ethanol) and intensification of agriculture?

- Is 'economic turbulence' related to sustainability issues, and does it mask economic information and inhibit predictions?

- Are sustained periods of either favourable or unfavourable agricultural terms of trade dysfunctional for the firm or a region?

- Can wealth transfers (income subsidies) substitute for retained wealth generation?

- Are some sets of rules less likely than others to induce economic or social problems for rural people, businesses and other institutions?

- Do impulses or external economic or ecospheric shocks to agriculture move equilibria around as well as destabilizing them, and can all outcomes be insured successfully?

- How does crop/income insurance improve the rate of economic recovery for farm business and the rural economy?

4 CONCEPTS AND LANGUAGE

Modelling economic complexity for agriculture is based on a 5-legged stool: Each leg is a long established collection of theory and evidence built in part upon on the heritage of Cartesian scientific method.

- Complexity theory (Prigogine)
- Non-linear dynamics theory (Poincaré)
- Ecology; Predation/Competition/Cooperation theory (Lotka, Volterra, Gause)
- Systems theory (Ashby, Von Bertalanffy, Emery)
- Economic theory (Samuelson, Arrow, Arthur)

Two out of the five stool legs have been most instrumental in our modelling of complexity issues: non-linear dynamics and economics. A new concept, "oikos", is added to these basics to tackle rules of economic change; economic, social cultural, personal, political and legal. Each of these three areas of theory are addressed separately now.

4.1 Non-linear dynamics

A dynamical system is formally defined by a set of difference or differential equations. Difference equations describe discreet or discontinuous processes and differential equations describe smooth or continuous processes.

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The following concepts are illustrated in the 'Cheat Sheet' of figures in Appendix 1.

A dynamical system is determined by a set of functions that depends on:

- dynamic variables which are a function of time.
- time itself.
- so-called structural parameters which do not explicitly change with time. In practice, parameters may also change with time, but "slowly" compared to the "fast changing" dynamic variables. They may change continuously or impulsively.
- A solution to a dynamical system can be represented as a time series, where variables are plotted against time, or in a phase space. Most of the figures on the Cheat Sheet use phase space. Phase space is defined by using each variable as coordinates to picture the solution to the system. Time is no longer explicitly visible.
- A manifold is a smooth curved surface or curve in some space defined for the purposes of analysing a problem.
- A trajectory, or orbit, is the mapping of a solution in phase space.

- Periodic trajectories are closed loops (or curves) in phase space.
- Periodic trajectories can be
  * stable : they form an attractor
  * unstable: they form a repeller
- An attractor is a sub-region of phase space where all nearby trajectories end up.
- A repeller is a sub-region of phase space from where all nearby trajectories diverge.
- An equilibrium corresponds to a particular solution of a dynamical system: one for which the values for the variables do not change over time. For autonomous systems, it is represented as a point in phase space.
- An autonomous system does not depend explicitly on time.
- Equilibria can be stable or unstable.
- Stable equilibria are: centres, stable nodes and stable focuses. The latter two are also called sinks.
- Unstable equilibria are saddle points, unstable nodes and focuses. The latter two are called sources.
- A limit cycle corresponds approximately to a periodic solution to the dynamical system. It is represented by a closed curve in phase space. If stable, all neighbouring trajectories end up on this curve. If unstable, all diverge from it (in two dimensions, both outwards and inwards).
- A system is structurally stable if a small change in the value of the parameters cause no qualitative changes in the trajectories.
- A bifurcation is an abrupt transformation of a robust system to another robust system with qualitatively distinct and different behaviour resulting from a marginal change in the value of a parameter.
- A qualitative change, or loss of structural stability, defines a bifurcation point. There are several types, for example:

  * a Hopf bifurcation changes the stability of a focus equilibrium and creates/destroys a limit cycle surrounding this equilibrium.

  * a saddle-node bifurcation creates a new equilibrium that subsequently splits into two different equilibria, one of which is a saddle and the other a node. In our model the node is stable and so becomes another attractor drawing trajectories to it from many of the original starting points. It may become a global attractor of the system.

All such bifurcations involve only one parameter. More complex bifurcations can involve two or more parameters.

- A homoclinic trajectory starts and ends at the same equilibrium. It takes an infinitely long time to do so.
- A strange attractor is an attractor other than an equilibrium or periodic trajectory. The trajectories captured by a strange attractor wander in seemingly unpredictable ways in a bounded region of phase space. These trajectories are extremely sensitive to initial conditions. In this case, predictability of system outcomes is lost very quickly, even though the system is deterministic. In our models the presence of strange attractors is evident for discernable and limited ranges of values of the parameters.

It seems that in complex systems, such as in biology, ecology or economics, (ex agriculture and rural) the appearance of strange attractors is quite common, and may be the rule rather than the exception.

Resume reading for continuity

4.2 Ecological interactional dynamics: predation, competition and cooperation.

The basic concepts from ecological dynamics stem from that of (partially) open systems, interacting with others. Three interactions are seen to be fundamental.

In the 1920's, Lotka and Volterra investigated the two system case (two interacting populations). The three interactions are then defined as follows:

For a fixed set of resources:

* competition is where both systems gain less by interacting than by not
* cooperation is where both systems gain more by interacting than by not
* predation is where both systems may gain by interacting, but one system gains more and the other less.

These definitions can easily be extended to more than two systems.

Competitive outcomes (or solutions of competitive dynamics) are of three types:

* one system always wins
* either one can win, depending on initial conditions (bi-stable case)
* peaceful coexistence

Predative outcomes are of two types:

* limit cycles
* stable equilibria

Cooperative outcomes depend on the type of mutualism involved:

* if facultative, both systems gain from heightened performance of the other.
* if obligate, the performance of one depends on the performance of the other

4.3 Oikos: The rules governing the system

The concept of "oikos" was first coined by two of the workshop members as a response to boundary problems: Where does an economy begin and end? How is the boundary of an economic system defined?

The first idea was to define the boundary of a human system where control by one system was superseded by the control of another. As a consequence, the important issues turned out to be those which lay behind the control processes: namely laws, rules, norms, and the enforcements accompanying them. The term 'oikos' was coined to avoid unwanted connotations and misunderstandings for bio-scientists, ecologists, economists, sociologists, anthropologists and other scientists entering into interdisciplinary collaboration.

Next paragraphs may be skipped

Oikos of a system is defined as the sets of rules, both institutionalized and non-institutionalized which differentiate the system from others. Examples of sets of rules are: families, firms, governments, property rights and entitlements, and markets. Institutions manage, reproduce, enforce, guard and change rules to determine the system boundaries.

Oikos governs the dynamic behaviour of a system. Behaviour means the solution or trajectories of system variables. Governance is a deterministic control over system relationships. Thus oikos governs a system's internal within-boundary dynamics.

Rules also govern system cross-boundary dynamics, namely, predation, competition and cooperation. Typical examples are trade agreements, anti-trust laws, level playing field rules, fair competition rules, and rules of cooperation.

Two 'orders' of rules may usefully be identified:

- 1st-order rules: Rules directly governing system behaviour, in particular, competition, cooperation and predation.

- 2nd-order rules: Rules that create/modify/abolish rules. 2nd-order rules drive self-organising processes.

'Rules' is a generic concept: It may include laws or norms. They may be recognized within habits or customs. Rules may also be formalized, through a law makers' words as regulations to be respected by the community. 'Enforcement' is inferred. Rules of enforcement and sanction form part of the oikos.

Rules range from rigid constraints on behaviour to flexible inducements which guide behaviour. Examples of constraints are: excise taxes, unconditional prohibitions, property right denials and no-access to resources. Examples of inducements or 'steering' rules are: rules defining reward systems, such as employee bonuses and promotions, indexing for subsidies, conditional insurance schemes or investment tax credits.

More generally, in the language of dynamical systems modelling, rules can be represented by fixed rates of change and parameters or by thresholds. The form of differential equations or other mathematical specifications also constitute rules. Special conditions, such as equilibrium conditions, may be represented by time-invariant or algebraic equations.

A distinction between general rules and special rules may be one way of identifying boundaries and sub-systems. Special rules are distinguished from general rules by the large number of conditional rules limiting their applicability.

The set of rules defining an oikos is described as 'incomplete' relative to another set in that it includes at least one subset of contradictory rules or globally inconsistent rules. This incompleteness is a central feature of system change.

- A system continues to operate with 'old' rules which don't completely deal with a current situation. There are time lags between defining a new rule, enforcing its effect, and observing changes to those system features the rule was made to govern;

- On the other hand, contradictions and global inconsistencies within oikos prompt change. Thus incompleteness may be viewed as inducing co-evolution of a system with its changing environment.

Resume reading for continuity

The usefulness of oikos lies in the following points:

1. Oikos governs predation, competition and cooperation:

* through predation, to maintain mutualism and system persistence

* through competition, to maintain efficiency in resource use

* through cooperation, to allow for switching between competition and predation. For example, two prey may cooperate temporarily against a predator.

2. Oikos governs system change.

Change may be the outcome of a response to non-predictable external shocks or disturbances. Oikos governs response and therefore this kind of opportunity for learning.

3. Oikos provides system memory for learning.

Learning facilitates co-evolution. Institutions exist for the formal (schools) and informal (apprenticeship) education and training. Oikos provides memory of the effects of the rules involved.

4. Oikos governs external influences and boundary conditions.

Rules determine the signaling, ordering and filtering of information generated by other neighbouring systems. Examples are movements of migrant farm labour, import protection policies, response to international interest rate movements, capital transfers and exchange rate behaviour.

5. Oikos defines the amount of uncertainty the system can cope with.

Agrarian systems cope with uncertainty by rules for redistributing income among community members. For example, industrialized agricultural systems rely on formal commercial insurance governed by contractual rules.

6. Oikos is the basis for non-random system change, setting the moving bounds for system behaviour.

In summary, the goal of oikos analysis is to link social and cultural behaviour to economic dynamics. A second goal is to find useful and tractable translations of rules within the mathematical language of the models.

Application of the oikos concept should improve decisions for agriculture and rural issues by a better understanding the behaviour of economic dynamics. It should also help identify, with some precision, institutional restructuring needed to address relevant changes.

5 PRACTICAL ISSUES IN COMPLEXITY

5.1 A commodity market and management consultant perspective

Several issues which were raised in this discussion are linked to complexity.

Appropriate information is needed for taking forecasts and making them useful to farmers. The problem relates more to over-abundance of information and "noise" than to lack of information. Screening and evaluating the relevance of information is needed to unmask the complexity of systems which comprise the environment to farm businesses.

Interactions among household enterprises are complex. Indeed the standard has become the multi-enterprise, multifamily business. Complexity arises at two levels:

- private decision-making
- public choice and policy

The two levels are related, especially through processes which involve a vision and anticipation of the future. The problem for farm and government alike is to participate successfully in the co-evolution of private and public decision-making. Participation may be driven by a need to manage (control), or at least to anticipate outcomes. This appears to be a system boundary problem.

The household itself must now be seen as a complex system. One or both spouses are in wage employment off the farm introducing the influence of another set of rules which may conflict with the farm family oikos. This family oikos may have to change to accommodate multi-activity and multiple sources of income and the rules and freedom of opportunity which go with it.

How does this complexity change family entrepreneurial behaviour? for example, investment and savings decisions, both at the business level and at the household level? How do these two economic levels interrelate with more open system boundaries? The family farm becomes a more open system with wider boundaries. Its relations with the rural community and the rest of the economy change. How can these new relations be best managed? How does the coevolution associated with managing these new relations restructure the rural community and agriculture's position in that economy?

In today's complex farm business, memory of past events is insufficient for the learning needed to deal with uncertainty. Reference is made to experience during the 1973-78 and 1981-82 periods, when grain prices were high. How do you devise appropriate institutions for enhancing memory, both at individual (farm household) and collective levels? Which types of institutions are needed?

Timing of pricing of commodities: when do you price? This decision requires understanding of system dynamics and time scaling.

How efficient is diversification as a stabilization strategy? The tendency in Canada has been to stabilize prices, commodity by commodity. Examples are marketing boards such as the Canadian Wheat Board, the GRIP program, red meat stabilization. This reductionist approach to simplifying the overall stabilization problem seems to introduce distortion to the process of successful participation of farms and government in the coevolution of public and private decisions.

5.2 Perspectives from an agricultural production economist

The context is research into improved decision-making tools for farm and government, and setting priorities for agronomic research. The emphasis is risk management.

The first question is how to make decisions faced with complexity?
An example of complexity is the biological and economic interactions between farm enterprises and between years over crop rotation periods.

There seem to be three approaches to this question.

1. Simplify... but not too much. Farming systems are also complicated. They need a lot of detail: biological, climatic, economic, financial. This is the traditional approach using data-rich models.

2. Accept complexity as a fact-of-life, along with its main consequence, limited predictability. Assume that stochastic methods capture much of the unknown. Probabilistic decision-making becomes possible and useful.

3. Assume the economic world is inherently unpredictable and undertake risk averting strategies accordingly. What kinds of management options are then available? What strategies? (Game theory has been popular but has been shown to have severe limitations.)

Are standard economic decision tools still adequate in a complex world? The answer seems to be yes. We first learn about how the world is and changes, then we devise and apply decision rules. The optimisation rule must be an outcome of, and linked to, some rule of system dynamics.

4. How does aggregation, for instance during production of statistical information, affect economic dynamics? More generally, how does any aggregation process influence the dynamics it represents? Is the implication that we should replace the standard deductive top-down approach by an inductive bottom-up approach to economic modelling?

5. In a current economic situation knowing something about its historical context, how can you know where you stand relative to categories of equilibrium and stability, or any other attractor?

5.3 Cooperative institutions: An historian's perspective

Complexity appears to be associated with the appearance and disappearance of cooperatives. The context of this observation is the study of cooperatives and cooperative movements in the late 1800's and early 1900's in industrialized states, particularly Germany.

Historians have generally used three main approaches to address the question of how and why did cooperatives come about. More generally, they are interested in how change occurs in social and economic systems. The three main approaches are:

- functionalism: Powerful underlying forces are at work.

- individualism: Extra-ordinary individuals influence behaviour.

- hierarchies: Leaders, dominators, conquerors, elites etc define, impose and enforce their sets of rules on others.

These approaches taken together leave a lot unexplained. What appear most interesting in cooperative movements are the mutualistic processes which underpin the self-organization of cooperatives observed in the 19th and 20th centuries. Self-organization comes about through specific rule-creation, boundary creation and system control. For historians, however, such a view is but a working hypothesis.

The Gaia Hypothesis (Lovelock and Margulis) takes this argument of self-organisation one step further, by suggesting that members of an institution, alter their environment in the process of constituting and developing their system.

Detailed historical study of the German cooperative movement in the late 1800s and early 1900s lends support to the following statements:

1. Cooperatives are an innovation in symbiosis with the rest of the economy.

2. Cooperatives are a social feedback system, in response to the social and economic consequences of the swift industrialization of the economy.

3. Cooperatives develop because they are needed: they fill niches perhaps associated with the incompleteness problem referred to above in the process of rule change.

4. If successful, cooperatives spread according to a logistic law to every available niche, up to saturation of the social/economic/political need.

5. Cooperatives reflect patterns of mutual dependency.

6. Cooperatives redistribute profits, power, facilities and other social and economic attributes.

7. The spread of cooperatives is a system-stabilizing process (see # 2).

The 'success' or 'failure' of cooperatives in turn-of-the-century Germany clearly depends on their pre-conceived or post-conceived goal, a rather subjective attribute. Their development went otherwise than had been intended by their founders and initiators.

5.4 A rural policy maker's perspective

The context is the economics of cooperation in rural policy in Saskatchewan. How do you get constellations of collective action to change policy? How does cooperative action dissolve and break up? Conversely, why are there relatively few cooperative initiatives where economic opportunity is relatively abundant, such as in Alberta? Yet, why is collective action apparently so often a part of seizing opportunities?

The GATT and NAFTA agreements raise questions of complexity in the joining of economic systems, with implications for rural policy. The GATT and NAFTA are super-institutions to harmonize economic policy to increase trade and economic cooperation. They may also be viewed as institutional arrangements to legalize increased predation by economically stronger countries on the weaker. Do they fulfill both these roles of cooperation and predation at the same time, but at different levels of the economy? Do these dual roles of trade agreements promote economic marginalization of rural economies?

GATT and NAFTA-type agreements also exert influence on ideological values. Can we think of ideologies and systems of values, perhaps metaphorically, as competing among each other? Are we witnessing, with the fall of the ex-Soviet block, an out-competing of some ideologies by others? Is there less room today for competing ideologies than there has been in the past? What will the effects be on international and national institutions, as well as on agricultural trade, rural development and on global transactions?

How does a policy economist deal with complexity in practice? With intuition probably. The process of extracting policy decisions from complexity is not quite clear. Is it one of putting weights on different aspects of a complex problem, and on different outcomes? If so, then the possibility of decomposing a complex problems into distinct parts is implied. These weights implicitly or intuitively, hinge on values (ethos) which brings us back to the ideological issues in trade agreements. The weights become rules adding to the oikos. Or does the policy process, in the face of complexity reduce to new information and learning, especially information you do not even know you need?

5.5 A farm income assurance and disaster policy perspective:

The context for income assurance is the Canadian government's efforts to cushion farm income instability. It is assumed that stability and growth can and should be linked. These issues appear to be complex.

Government is in reaction mode. Income relief is provided after the event. Is this the best mode in terms of economic efficiency and public cost? Rather than reactive rules, should proactive (anticipatory) rules be used instead? If so, how?

If in reaction mode, how should the 'trigger' signal best be defined? Suppose the trigger could be more than a yes/no signal, taking on several values according to the intensity of the income hurt. Then, how could a payout policy be related to the 'intensity signal'?

Policies are defined at multiple levels of government and the agriculture and food industry. How consistent can/need these policies be?

Market-based devices for income assurance are generally thought to be limited to managing price or market induced instabilities. What if the efficiency of risk management tools depends on market responsiveness to the tools? More generally, do market institutions provide sufficient signals? Are the signals efficient but masked by economic turbulence, non-market rules, mis and dis-information, cushioning policies etc.?

Moral hazard appears to be a problem in insurance policies. However, maybe it should be considered as normal predation behaviour and dealt with by standard institutionalized means, such as contract law and justice systems.

What approaches could government take to improve its agricultural income insurance policies: new rules? New technologies? Acknowledgement of changing tastes and preferences.

For explicit reasons relating to re-election of political representatives, equity of income assurance payouts in space and time is an important issue. How can political equity considerations be addressed in an economically consistent way?

Government insurance schemes have evolved since the 1970's. How does the GATT-70 scheme compare to the previous NISA system in terms of the complex dynamic behaviour of the agricultural system? The whole farm approach seems an improvement on commodity-specific programs, but at what level of analysis and standards of economic achievement should it be implemented: regional, provincial, national?

Is risk-sharing among households and levels of government (GATT-70 scheme) the best way to accommodate shrinking government funds? How do you handle the equity problems inherent in the possibility that some farmers and not others have unilaterally invested in risk-reducing strategies without public funds?

In devising disaster insurance policies, how can historical evidence and memory be put to use to predict funding requirements? Is disaster-proofing economically viable at both private and collective levels? Are complex issues predictable?

The past 20 years have shown that farm insurance problems are not simple cause-and-effect issues: they involve complex interrelationships among several interacting subsystems, such as regions, commodities, farm wealth and technical capability categories, past policies, etc.).

5.6 A private crop insurance perspective:

The context for crop insurance, as opposed to income assurance, is private schemes designed for Canadian farmers. A long-standing question has been the relative benefits of whole-farm versus commodity specific insurance. Whole-farm enterprise insurance relies on covariances or co-occurrences of events and usually involves cross-subsidization of losses within each agricultural household. Historically, crop insurance has been cost-shared between farm and the two senior levels of government. Many farmers not buy insurance. It is not clear why. The whole farm approach appears to be a better scheme.

A related question is the target of insurance. Is the correct target specific individuals, specific crops, specific problems or perils (ex. hail). Targets can be optional too, enlarging the range of choice to fit the diversity of farmers' individual approach to risk. However, more and more farmers find it difficult to make these kinds of choices. They appear to have difficulty determining the implications of alternative coverages. They seem to have a feeling for the interactions at work, without having the means to quantify them. The insurance programs may be adding complexity rather than reducing it. There has been lobbying by farmers to replace all existing schemes by one single and simple program. Could improved and targeted education about insurance be a way out?

Lobby activity is pressing for firmly enforced rules against "big bad abusers" who raise the overall cost of insurance for everyone. This concern seems to imply an increased role for the State, a signal in contradiction to other signals arising from farmer focus groups.

These problems are related to pathological predation, free-ridership, and moral hazard. Pathological predation is defined as an extraction of benefits so as to place in jeopardy the willingness/ability of a prey system to sustain its contribution to the wellbeing of the predator system. In the case of human systems, the meaning of 'jeopardy' extends to violation of social norms and basic human rights. Pathological predation is considered to be extreme, unsustainable behaviour. It is more commonly called 'exploitation' and leads to economic marginalization and social exclusion.

What roles can focus groups, constructed to address the insurance question, fulfill beyond feedback and ranking? Do they have an oikos-fracturing role? Are they part of a process of defining new 2nd-order rules leading to the creation of new first order rules and change or abolition of old rules? [See the section above on oikos.] How do the answers concluded by focus groups hinge on the fact that they may be selected, or self-selected, with a bias relative to the actual characteristics of the population of farmers?

These issues raise several questions:

1. Can crop insurance be considered a structural parameter in agricultural wealth dynamics? If so, what would the effects of changes in insurance policy be?

2. What does crop insurance do to the agricultural system and its stability? How efficient is insurance in terms of both production and income stability?

3. What parameters other than insurance could be altered to increase stability, if stabilization is the goal?

Subsequent discussion suggests these questions could be modelled using an impulse model, with insurance levels as a parameter. Impulse modelling is scheduled for a subsequent year. However, its apparent importance may warrant a re-scheduling to next year.

5.7 The basic modelling perspective (see Appendix 2)

The perspective of the basic model is the interaction of agriculture with the rest of the economy and the ecosphere. The emphasis is on how agriculture can maintain a balance between its economic and its ecological relationships to remain sustainable. Market signals deal only partially with these relationships. Therefore a perspective, broader than market dynamics, has been adopted. Generalized behavioural dynamics of competition, predation and cooperation are borrowed from ecology. Each of these behaviours can be defined mathematically in ecological, in economic and in monetary terms.

The relationship between agriculture and the ecosphere is viewed as being primarily predatory. Agriculture preys on biospheric attributes to achieve its economic goals. Cooperative relationships are also possible and are free to become more important and sought for. These take the form of investments in ecospheric recovery and in research for a better understanding of the dynamics of ecospheric and economic relationships.

Likewise, the relationship between agriculture and the rest of the economy, dubbed 'industry', is viewed at a global level of analysis, to be potentially predatory. The model permits competitive and cooperative relationships as well. Predator status can switch between the agriculture and industry systems with changing terms of trade. The historic trend, however, has been predation by industry on agriculture. This historic relationship in turn is viewed as intensifying predation by agriculture on the ecosphere associated with erosion, soil loss, deforestation, water pollution, and reduced biodiversity. Thus, the model links, industry and the ecosphere through agriculture to explain the sustainability of agriculture, and perhaps of the rest of the economy too.

Predation seems to characterize the main system interactions as long as globally aggregated entities are considered. As soon as these are split into sub-categories, competition and cooperation also become important. The implications of each of the three types of behaviour are to be dealt with in the forthcoming "coupled model".

At this stage, "agriculture" can be considered either as a super-farm at a regional level or as the aggregate of all farms in a region. A plausible alternative is to consider farms as a group, as if organized within one institution such as a cooperative. An example is the Rice Farmers' Association in New South Wales, Australia.

Formally, the basic model is a system of three dynamic or differential equations, one for each system. The dynamic variables (see section above on Concepts and Language) are agricultural and industrial "wealth", and ecospheric "quality". The first two are measured in dollar (market) terms; it is not yet clear how the third may be measured in a manner consistent with the rest of the model. Total value concepts based on contingent valuation methods appear inappropriate. However, even market valuation for the first two may not be appropriate, given the great imperfection of markets (monopolies, externalities, public goods, etc.). Measurement problems have not yet been addressed (see below).

The dynamics of the interactions among these three systems hinge on a number of structural parameters. These are terms of trade and relative productivities between agriculture and industry, rates of degradation and rehabilitation of the ecosphere, economic recovery rates, the rate of industrial capital depreciation, and others. In current work the values of the parameters are considered to be determined exogenously and to remain constant over time. Later on, they will be allowed to vary or even made endogenous.

The basic model considers that the ecosphere can take care of itself, maintaining an equilibrium in spite of agricultural pressure. This simplification reduces the problem to two dimensions, agriculture and industry. Even with this simplified system, several types of interesting behaviour can occur, namely Hopf, saddle-point and homoclinic bifurcations. The two key parameters, on which these bifurcations depend, are the relative productivities of agriculture and industry, and the rate of industrial capital depreciation.

For more information on this model, the reader is referred to Apedaile, Freedman, Solomonovich and Schilizzi: "Equilibria and Dynamics in an Economic Predator-Prey Model of Agriculture" Mathematics and Computing Modelling, 1994, 19(11), 1-15.

6 INTRODUCING ECOLOGICAL DYNAMICS TO THE AGRICULTURAL SUSTAINABILITY PROBLEM

6.1 The Threshold Model: Investigates minimum safe standards

For a full account of this first extension to the basic model, the reader is referred to our 1994 document "Impacts of Recovery Rates and Terms of Trade on Strange Attractors and Predictability in Sustainable Agriculture", Staff Paper 94-06 of the Department of Rural Economy, University of Alberta, currently under review for publication in Ecological Economics.

We briefly summarize the key points.

This first extension of the basic model removes the assumption that the ecosphere is always in equilibrium. Now the ecosphere, including the agricultural resource base, can degrade through soil erosion, loss of organic matter and biodiversity, and pollution. Similarly, the ecosphere may rebuild its productive capacity, through deferred cropping (fallows), land amendments and improvements, reduced tillage, reforestation, etc. The question is: how do economic and ecological sustainabilities coexist and support each other?

Next paragraphs may be skipped

The differential equation describing ecospheric dynamics includes three parameters not found in the basic model: a degradation rate by agriculture, a rehabilitation rate through agricultural investment, and a productivity saturation level for the ecosphere. The quality of the ecosphere is considered to have a lower threshold, below which the ecosphere "crashes". This can be considered as a sustainability threshold, or a 'safe minimum standard' level. Students of resource economics may recall a similar concept introduced by Ciriacy-Wantrup and Bishop. Our model is different and more general. It is dynamic, not static, and does not rely on the game theoretical framework which is considered too restrictive. The important point here is that, when the ecosphere crashes, so can agriculture and industry. This is reminiscent of what has recently happened in some natural resource based economies, such as the Maritime Provinces in Canada due to over-exploitation (pathological predation) of marine resources).

Resume reading for continuity

One result of this model is that investing in ecospheric recovery appears to be as worthy as investing in agricultural productivity or support programs, to reduce the severity of rural economic downturns, low farm incomes or unpredictability. This latter problem is an outcome of the complex relationships between the resource base, agriculture and the rest of the economy, when ecospheric quality levels are too close to the minimum threshold. The model suggests several ways by which predictability may be improved:

- Improve terms of trade for agriculture. Warning: agricultural subsidies may not in general be a substitute for favourable terms of trade.
- Maintain recovery capability for the ecosphere, with particular attention to the balance between agricultural degradation and rehabilitation, by redirecting productivity research to research into recovery processes.
- Maintain a close relationship between productivity gains in agriculture and industry. This may or may not be less of a problem as both sectors become indistinguishable.
- Invest research dollars to quicken agricultural and industrial recovery rates.

These policy measures are partially substitutable, providing scope for strategic combinations and dynamic optimization and control methods to reduce instability in agriculture. The problem then becomes one of weighting expenditures, both public and private, among environmental conservation, insurance schemes, financing for economic recovery of agriculture and industry, and productivity research.

6.2 The Recovery Model: Replaces the safe minimum standard by an ecospheric recovery process.

This work is in progress with the support of Kenagra Ltd and Alberta Agriculture, Food and Rural Development. The idea stems from the recognition that imposing a threshold level on ecospheric quality levels is somewhat arbitrary and rigid. The ecosphere, instead of being completely passive, can regenerate autonomously from human's destructive actions. For example, micro-organisms are involved in regenerating organic matter and soil quality. Winds, birds, insects and water carry seeds and spores allowing for spontaneous restoration of biodiversity and reforestation. Water-borne pollutants do end up degrading, dispersing, or concentrating in localized wetlands, away from agricultural lands.

In the Recovery model the minimum threshold level was removed, replaced by an autonomous ecosphere regeneration parameter. The value can be positive for recovery, zero for no recovery, and negative for spontaneous degradation. Degradation is characterized as some economic production process. Physically, it has no meaning whatsoever. This is an important point to remember.

The four ecospheric parameters present in the model are distinct and different. These are:

- The autonomous ecospheric regeneration rate (epsilon): It measures the rate, usually positive but very small, at which, independent of any human intervention, the ecosphere restores its economically valued capacities.

- The ecospheric recovery coefficient (e): It represents the rate at which the ecosphere, after some shock or external disturbance, can recover towards its initial state. Ecologists have an equivalent concept called resilience.

- The ecospheric rehabilitation rate (u): This is a function of purposeful investment financed from agricultural revenue, additional to any autonomous restoration rate (epsilon). This parameter is one to two orders of magnitude (or 10s to 100s times) bigger than the autonomous epsilon. Investment in rehabilitation is made to accelerate or supplement the natural processes.

- The ecospheric degradation rate (v): This is a function of agricultural activity and production levels.

The three last parameters are amenable to change via learning processes, such as research, experimentation, education and training, and experience. The first one, epsilon, is not, but understanding how it works is.

An interesting outcome of this second extension to the model is that, the more the autonomous recovery rate for the ecosphere is positive, the more the opportunities for complex behaviour or turbulence are reduced. Consequently, predictability is improved. In other words, maintaining a healthy ecosphere gives it enough 'punch' and elasticity to buffer unpredicted changing economic circumstances. This is a good reason to invest in ecospheric recovery-oriented research and development.

6.3 The Hysteresis Model: Endogenizes the ecospheric rehabilitation parameter

The third extension to the basic model endogenizes the ecospheric rehabilitation parameter. The parameter is replaced by a function of agricultural wealth treated as an investment process signalled by 'low' condition of the ecosphere. An implicit trade-off is involved between agricultural wealth spent on increased production and that spent on ecospheric rehabilitation. The former is being viewed initially as a shorter term process than the second.

The idea is that investment into ecospheric rehabilitation increases if environmental degradation is high or increasing, and decreases, or ceases altogether, if degradation is low or decreasing. The concept is that of an 'effort function'. The simplest sort of effort is triggered by an on-off switch.

This work is just under way at the design stage. A 'smart' hysteresis module has been discovered and is under test.

Future work is being planned to endogenize other parameters. Candidates for endogenization are the other ecospheric parameters, degradation and recovery rates; agricultural and industrial recovery rates; industrial structural coefficients, and agricultural terms of trade.

6.4 The Coupled Model: Splits agriculture and industry into sub-categories

This work is just beginning. Even at this early stage, however, a whole new realm of interesting issues appear to be amenable to investigation.

The first issue is reinterpreting the variables. We now have two agricultural subsystems and two industrial subsystems. The ecospheric wealth variable could be sub-divided in two sub-categories. The two agricultural wealth variables could be set up to designate two regions or two types of activities, crops and livestock or industrial and artisan agriculture. More interestingly they could represent production agriculture and eco-tourism. Three subsystems may distinguish agriculture and fishing from off-farm pluriactivity. Industrial sub-sectors may designate downstream and upstream services closely related to agriculture, or manufacturing versus services, or rural versus metropolitan economies. As for the ecospheric variable, it could be redefined to represent government.

Each redefinition requires a change in the form of the equations. But the dimensionality of the system remains the same. The same framework allows for the exploration of a whole range of problems.

The main feature of the coupled model is that the number of interactions greatly increases. Competition and cooperation now come to the forefront between agricultural systems. Likewise between industrial systems. However, between agricultural and industrial systems, predation remains important, as well as cooperation. 'Industry' does not compete with agriculture because, by definition, it does not directly use biospheric resources. In all likelihood, the resulting dynamics become very sensitive to the values of the parameters describing the intensity of competition, cooperation and predation relationships. This sensitivity may have direct implications for policy.

The third issue, at this stage, is the possible introduction of explicit market structure and price signals. If so, the model outcomes may be compared to solutions based upon neoclassical and institutional economics.

6.5 The Impulse Model: Introduce a wild environment

This work has yet to begin. The idea is to explore the effects of sharp changes in the system environment on the dynamics of the model. When combined with the learning exemplified by effort functions, this model should enable us to explore the capacity of the system to change so as to deal with new disturbances or events. These results may have interesting policy implications, especially with regards to the opening global economy. Results in terms of stabilization or buffering policies may be expected. The design and function of crop and disaster insurance and income assurance should benefit from this work. An interesting issue is how this approach to uncertainty can be positioned with respect to the standard (problematic) probabilistic approach, which today drives agricultural insurance programs and risk management.

6.6 Reflective observations; Complicated, complex and aggregated

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The models, although exhibiting complex behaviour, are simple in design. Knowing that the world is both complex and complicated, how do we deal with complicatedness? How much further do we go in adding new parameters and sub-dividing categories into sub-categories, in the pursuit of the real world realism? Two answers to this question suggest themselves; a 'can' answer and a 'should' answer.

The 'can' answer is quite straightforward: Not much further. With the 'Coupled Model', we have already reached the limits of mathematical tractability.

The 'should' answer may be more interesting. A useful way to look at this is to ask how much 'richer' our models could be if made more complicated? How much more insight could be obtained? Our intuition is that richness very quickly levels off with complicatedness. Once you have multiple and strange attractors and a number of bifurcations, further complexity in the behaviour of the system may not be revealed with increased complicatedness. If this proves to be the case, then the issue of aggregation takes on a new meaning.

Aggregation is an underlying issue yet to be explored with our approach. If complicatedness and complexity are related, then Fisher's and Leontieff's classical works appear in a new light. Aggregation, as perceived in the standard manner, may be a dead issue. The 'aggregation problem' may well be an artifact of linear cartesian thinking. If the focus on complicatedness shifts to complexity, the aggregation issue might vanish altogether. It may not matter how many sub-categories of agriculture or industry are modelled, once it is understood that the important thing is to grasp the dynamics underlying the behaviour of the economy. One way to test this insight is to sub-categorise each of agriculture and industry into three parts, and compare the new qualitative information with that obtained from the two sub-categories model. The need to disaggregate may turn out to be a product of an inappropriate paradigm.

Having said this, micro studies of small 'sub' systems can still be expected to produce distinct quantitative information amenable to interpretation by decision makers immersed in their system detail.

7 THE EMPIRICAL ISSUE: FACING THE REAL WORLD WITH REAL DATA

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Research progress normally proceeds from conceptual thinking and curiosity about unsatisfactory explanations of a phenomenon, through to theoretical mathematical modelling. This is followed by numerical experiments and analysis. The last step is to confront these simulated results with real world evidence.

What evidence should we be looking for? Do our modelling efforts suggest any answers to this question?

Starting with the dynamic variables, the measurement units for ecospheric quality have to be defined. As mentioned earlier, social-value concepts, such as total economic value estimated through contingent evaluation methods, seem inappropriate. Ecospheric quality is both a physical and an economic concept. It describes the capacity of the ecosphere to contribute to agricultural economic wealth, mainly through production. Its value is 'objective' as opposed to subjective. This problem has not been thought through yet.

Agricultural and industrial wealth are more amenable to measurement in economic terms. The concept of wealth has to be refined in light of available data for each system under study. Currently, shares of GDP are used as proxy measures.

The structural parameters are only defined functionally so far. Measurement requirements have yet to be faced. Some however are more easily measurable than others. For instance, agricultural terms of trade can be derived from existing statistical data. So can relative sectoral productivities, once the appropriate productivity indices are designated. Total factor productivity seems to be the appropriate measure, but care must be taken with respect to 'land' as a production factor. The issue is not so much the quantity as the quality of land, raising issues analagous to those of the ecospheric variable.

In real life, the structural parameters, held constant up to now in our models, are likely to change over time, albeit slowly. Four possible approaches are being considered for this aspect of the dynamics. One is to average out the values over the period for which the data is available. The second is to track the values over time, after having simulated system behaviour with time-dependent parameters. The third is to replace the parameters with functions. The fourth, tried with some success in our experiments, is to stream actual historical values for the parameters into the numerical analysis.

The models are more sensitive to some parameters than to others. Results of experiments to date suggest the first parameters to be measured are agricultural terms of trade, relative productivities between agriculture and industry, and economic and ecological recovery rates. Other parameters may not be directly measurable, needing 'auxiliary' models to be estimated.

A second issue is what to check for once we do have relevant data. What relationship do we want to explore between our modelling efforts and the available historic record? The answer may seem obvious. Compare model output to available time series. Unfortunately, this is far easier said than done. For several reasons.

First, one must assume there lurks somewhere behind the data, some deterministic process reflecting our models' equations. If so, the number of hidden dimensions, or needed equations, is greater than just the three or four in the model. In this case, the additional relationships are undetectable, and the whole system may as well be considered random.

This problem reflects an important mathematical theorem. There is no way to distinguish practically between a high-dimensional deterministic system and a randomly driven one. One may as well use stochastic methods. Of course, this means that there are intermediary cases, where the number of dimensions is not very high, but still high enough to evade identification. Such systems are somewhere on a continuum between pure randomness (white noise) and strict determinism. Methods exist which allow us to know just where in between.

The implication for this research is a need to assume that a low-dimensional attractor is lurking somewhere in the data and use available methods to identify it. These methods should also suggest what the form of the equations should be. If none are identifiable, assume randomness.

The second reason comparisons of model outcomes to historical experiences is that in economics, and also in ecology, most data sets are quite short and of poor quality (missing values, inconsistency, etc.). However, methods have been devised to deal with this difficulty. One of them is the so-called surrogate data set method. The basic idea is: first transform the original data set by some randomizing process. Then compare the properties of both the original and the "randomized" data sets with exactly the same method. No or small differences in results will suggest either true randomness in the original data set, or high-dimensional dynamics. Typical data set properties tested for are so-called fractal dimensions.

This subject is still a young and increasingly active field of research. Things are changing drastically year by year. One possible breakthrough seems to lie in the generalization of one-dimensional time-series data analysis to multi- dimensional 'spatio-temporal' data analysis. This new approach would break some way through the dimensionality barrier which is such a curse in the social sciences.

Resume reading for continuity

8 SUMMARY OF IMPENDING PROBLEMS ON THE RESEARCH AGENDA

- Handle time-lags and delays in response functions.

- Deal with impulses and exogenous shocks. These may be random, with given probability distributions, or "surprises" (Casti, 1988), such as major technological innovations or institutional restructurings.

- Deal with spiraling trajectories and torus-shaped attractors: this is relevant to growth and development problems.

- Investigate the dynamics of shifting equilibria, especially in the outwards direction of greater wealth.

- If you really have dynamics, then parameters change too. This will need to be addressed.

- Scaling and data. Empirical studies. One troubling issue is the possibility that our models may implicitly contain differing time scales, some parameters changing very slowly and others much faster.

- Use of this work: not prediction or forecasting, but anticipation. This means using knowledge of system dynamics and future states to act now, basically on parameter values. This could lead both to constructive and destructive actions. An example of destructive action, in a competitive context, would be to trap a competitor in a low-level equilibrium trap, by controlling a key parameter. For example, the more he would invest, the more money he would end up losing, no matter what the predicted discounted benefits.

9 SUGGESTED FIELDS OF APPLICATION FOR THIS RESEARCH

- Insurance and income stabilization policies.
- Investment policies in predictable or unpredictable environments.
- Trade agreements strategies
- Market structure management
- Economic legislation
- Environmental policies
- ...

10 GENERAL DISCUSSION: TENTATIVE RESPONSES TO 16 QUESTIONS

10.1 Does the concept of Oikos incorporate cultural values?

It does, provided values translate into enforced rules governing behaviour. Culture, as expressed by the arts, celebrations and choice in general, may be viewed as manifestation of rules determining tastes and preferences. Enforcement, reinforcement and modification of values is a central focus of institution building and peer relationships.

10.2 Measurement of ecospheric quality: Much of the value of the ecosphere lies in the interactions among its components, including symbiotic effects. How are interactions taken care of in complexity work?

Interactions are acknowledged through the capacity of the ecosphere to respond to agricultural investment and to generate agricultural wealth. Ecospheric quality represented by 'E' in the models, is a quality variable measurable in terms of quantities of attributes, for example, organic matter in prairie soils, or designated pollutants in water. This focus on attributes is different from the focus on mass or volume of resources in economics. Degradation, rehabilitation and recovery parameters in the models relate to changes in attributes of the ecosphere as opposed to changes in the quantities of resources.

That said, measurement of 'E' is closely associated with the productive use of the ecosphere, a very narrow interpretation for now, which obviates the complexity of ecological relationships. Put another way, the measurement of ecospheric quality is viewed in terms of the productive value of attributes of the ecosphere in uses restricted to association with the value of agricultural output in the industrial economy.

This approach does not adequately reflect scarcity value captured and distributed through property rights and the rents that flow therefrom. In principle, land degradation in Nepal for example, is associated with rising land values, while at the same time, good soils are associated with relatively high land values. The former situation reduces the area of land suitable for cropping creating value in resource scarcity. The latter does not change the area which may be cropped, but is a feature in higher yields. That both circumstances change the scope of options for managing with uncertainty is not yet accommodated in the models.

10.3 What makes 'A', agricultural wealth, grow in the absence of industry, or when terms of trade are exactly equal? What drives that growth? Technology?

In the absence of industry, growth of agricultural wealth is transitory along an 'S' curve. Wealth reaches a steady state subject only to perturbation by external events. Agriculture is purely artisan. What tools there are, are fashioned by farmers. This situation is the limit case, now rarely observed even in the most remote traditional agrarian societies. Wealth grows slowly and temporarily at best, is highly concentrated in the hands of landowners and is precarious for land operators.

Perfectly equal terms of trade between agriculture and the rest of the economy is also rare. Furthermore it also is transitory. Market dynamics and economic policy ensure that equal terms of trade are rarely observed because it is so temporary.

However, the 'thought experiment' induced by this question is instructive at these early stages of interpretation of the model. The influential parameters for growth in these two limit cases are 'alpha', the agricultural carrying capacity of the ecosphere, 'beta' the extent of diminishing marginal returns in agriculture, and 'e' the ecospheric recovery rate.

Three other parameters 'u', 'v' and 'w', are also involved because agricultural wealth also depends on ecospheric quality. 'Mu' the relative productivity of agriculture and industry, acts as a scaling parameter.

Of these six parameters, only 'alpha' and 'u' the rate of ecospheric restoration or rehabilitation, can contribute to growth in agricultural wealth. Increases in agricultural wealth require a plough back into ecospheric recovery 'u'. Everything responsible for increases in agricultural wealth in the absence of industry depends on the quality of the ecosphere, carrying capacity and balancing rehabilitation and degradation.

Everything related to the ecosphere and carrying capacity is 'learnable'. A large part of what is learned, once applied, is called technology. Most 'technology' since the industrial revolution generates growth by expanding carrying capacity with industry. Without industrial substitutes for artisan agrarian practice and input, growth depends on intensification of water use and extending cultivation to new land.

Discussion during and after the workshop prompted new insight into the economic meaning of the model. It seems that the 'gamma' parameter, initially viewed in terms of an agricultural price index, may really be about growth and economies of size. These are technological issues.

Agricultural terms of trade determine the transfer of wealth between agriculture and industry. Wealth increases that used to accrue to landowners shifted to industrial shareholders as more and more of what used to be done on the farm shifted to factories. Instead of having to defer production with fallows to sustain outputs, industrial inputs enable continuous cropping and concentration of livestock production in small geographic areas.

Dominance of industrial agricultural systems globally, shape global terms of trade to the disadvantage of less industrialized systems. These latter systems are often found on marginal lands without the financial means of allowing the ecosphere to recover or to repair the damage of overgrazing, removal of crop residue and soil erosion. Growth is therefore stagnant and uncertain.

The model features another dimension to learning raised by the question about terms of trade. Terms of trade are about predation between industry and agriculture. In principle, equal terms of trade are interpreted as a 'predation-neutral' circumstance in which neither industry nor agriculture preys on the other through wealth transfers.

Predation, like technology is learnable. Predation may be seen as the way human behaviour takes advantage of technological opportunity to appropriate/generate wealth. In particular, the mutualism that prevents pathological predation and economic marginalization can be learned. It seems that learning about how far a relationship may be pushed, through and in the presence of technological change, and yet sustain its mutual advantages, may contribute to oscillation of terms of trade around neutrality.

Thus the distribution of benefits of growth have a lot to do with sustaining the relationships that underlie ecospheric recovery and the technology/industry/growth process itself. The models do go some distance in capturing the essence of this distribution/growth link.

10.4 How do gains from trade fit in a predatory model? What about surpluses generated, both consumer and producer?

At the present time, these issues are resolved exogenously to the models by the choice of values for the 'delta' and 'gamma' parameters.

The model is about changes in wealth, and does not address consumer or producer utility relative to willingness to pay or accept payment. Predation takes place through shifts in the appropriation of shares of rents inherent within value-added for each system.

Gains from trade are measured in terms of value added enabled by transactions. Gains are usually associated with specialization and economies of size. The usual problem of measuring value added applies to these models. That problem is pricing. The model is not a price determining model. Furthermore, theoretically correct measurement of value-added requires prices to be determined in perfectly competitive markets. Such prices would amount to predation-neutral outcomes represented by equal terms of trade, an unusual event explained above.

Further investigation is underway to understand the gamma/delta relationship in terms of prices and technology.

10.5 Do the models imply something about economies of scale?

Economies of scale mean economies of expansion of output keeping the proportions of fixed factors constant. The model provides for the possibility of economies of size, by allowing factor proportions to vary. There are no restrictive assumptions about economies of size built into the mathematical specification of the models. The models are configured to enable experimentation with economies, diseconomies and constant returns according to the choice of values for the 'beta' and 'eta' parameters. Negative values correspond to economies, positive to diseconomies.

10.6 What is the overall purpose of these models? What is wanted for agriculture?

The overall purpose of the models is heuristic. These are 'learning' models. Ultimately, with refinement and a lot more learning, they may become prescriptive, or even prophetic:

Their purpose is to learn how to resolve farm income problems and illuminate rural and agricultural development strategies.

The specific objectives for agriculture are to determine criteria for effective rules and institutional arrangements, including market institutions,

1) to understand what constitutes a sustainable share of value added between agricultural households, industrial firms and consumer households;

2) to understand how to sustain the persistence of agriculture, the ecosphere and industry combined; and

3) to reduce uncertainty about future wellbeing, especially for rural people, places and institutions.

10.7 If agricultural wealth has been artificially inflated over the past, how do we get back to reality?

In the absence of perfectly competitive markets at all points of transaction, upstream and downstream of agricultural households, it is not possible to know whether agricultural wealth has been inflated. Neither is it possible to know the 'correct' or 'reality' level for 'A'.

'Reality' is what is observed as opposed to what is deserved. 'Reality' is that both markets and politics determine terms of trade, that is to say, are the main determinants of predation in agriculture's relationships. The tradition in industrialized economies, based primarily on postwar economic affluence, is to enact policies for technological development, market conduct and intersectoral compensations at taxpayer expense as opposed to consumer expense.

What may be artificial is a matter of perspective. Systems theory views market behaviour, policies and business strategies as part of the self-organization of systems which affords them the flexibility to persist and sustain achievement of their purposes. In this context, changes of vision, perspective and perception are not artifacts.

10.8 Can these models help us use government money to ease transition out of agriculture?

These models do not yet include government money. In general terms, this question would be handled differently in our modelling approach than it would from a Cartesian cause and effect stand point. Most agricultural households mix and match off-farm income with agricultural income. In this way they constantly reorganize their economic activities and therefore the composition of their earnings, either in a long term process of disengaging from agriculture, or expanding their production capacity.

The question speaks to 'easing' transitions. The pain of transition has to do with cultural values attached to 'success' and 'failure', and in the recomposition of earnings in the direction of greater dependency on wages and welfare programs.

Rural economies have always acted as subsistence 'sinks' for the economy at large, and for agriculture in particular. 'Adaptation and transition problems' have more to do with failed education systems and marginalization into rural poverty, than with agricultural productivity and income issues.

10.9 Can these models help decide between constant insurance support vs. periodic support?

Yes, solutions to date suggest considerable new insight into 'instability' issues. Acknowledgement of multiple equilibria in the economic relationships of agriculture with the rest of the economy offers room for a greatly expanded economic analysis than the single market equilibrium approach to policy offered by standard static neoclassical economics.

Knowledge of the stability characteristics of these equilibria based on mathematical analysis provides clear distinctions between oscillation problems, the so-called 'periodic' problem, and equilibrium problems, the so-called 'chronic' low income problem. The solutions to the models indicate which parameters are most associated with each class of problem.

10.10 This modelling approach does not address the evaluation issue. How do you decide which is best among several possible outcomes? For instance, stabilization is one objective among others. Can this approach identify the trade-offs? Can the model help determine what has to be sacrificed for increased stability? How important is stability really as an economic goal?

The modelling approach does not suggest objectives, other than "more wealth is better". The approach does show the tradeoffs between stability and level of wealth. More significantly, the solutions and framework for experimentation indicate new approaches to modify the stability of outcomes for agriculture, so that the necessity of making costly tradeoffs may be reduced.

The idea here is not to take existing tradeoffs as given, but rather to modify the tradeoff situation.

10.11 Does stability inhibit innovation, adaptation, evolution?

Get ready for a technical answer to this complex, and somewhat premature question for these models!

Stable equilibria are associated with attraction domains which require a major impetus, or change in parameter values for outcomes to escape into another domain. Thus stable equilibria are traps for the economy. Learning how to respond to trapping involves, among other things, innovation and adaptation, especially for the prey populations.

If parameters are close to their bifurcation thresholds, small changes can alter dramatically the equilibria, the stability qualities and the trajectories of wealth. However, we don't think that innovation and adaptation, in a marginal sense, lead to the kinds of change needed to break out of a stability trap. Rather, innovation and adaptation may be the response to, or corequisite of, a major investment, new uncertainty or reorganization needed to break out of the trap.

Evolution, or more correctly coevolution, involves far more than stability issues. It can involve unusual impulses which kick a system into a new attraction domain. It can also involve small structural changes in the values of parameters which define the relationships among systems. Structural change during the co-evolution process can strengthen or weaken stability.

10.12 Innovations with economic impact seem to occur in the recovery periods after downswings. Does this mean we need periodic downswings, or at least some oscillations in wealth for economic progress to take place?

This question cannot be answered directly at this stage in our modelling.

The oscillations in some of the solutions to our models are sensitive to both the predation relationship of agriculture and industry and the recovery parameters. Human systems playing the role of prey, like agriculture, may recover for three reasons; 1) because they learn how; 2) because nearness to extinction (bankruptcy) prompts effort, and 3) because supply-side problems associated with downswings change the agricultural terms of trade to weaken or even reverse the predation relationship of agriculture with industry.

It seems to be the fundamental nature of predator prey relationships to produce oscillations, larger when predation is stronger. Recovery is part of the process, otherwise the prey system could face extinction. Strong mutualism in predation relationships, including accurate signalling for performance problems within the prey system, should be expected to reduce the amplitude of oscillations. Accurate signalling is at the root of the debate over the role of markets in the economy.

The answer to this question is that learning about mutualism and recovery can probably shorten the relatively long time spent by each oscillation as it cruises through its low points. Economic progress is evident in upswings, but when the losses on the downswing are netted out, long term progress may be less evident.

Large oscillations are incompatible with human objectives for economic systems; namely to produce a secure and humane livelihood. Does historical evidence suggest that large oscillations steadily marginalize more and more people into a poverty system. Could such a system gradually evolve into a pathologically predatory system which can destroy the whole economy? If the answers are affirmative, then it is important to reduce the amplitude of oscillations and move the low points away from the threat of extinction. ....Or vice versa, for brinkmanship, or a conflictual strategy by an aggrieved party.

10.13 Insurance schemes based on moving averages will not work if you have turbulent non-periodic dynamics in agricultural incomes. How do we need to redefine what insurance policies are aimed at?

Our research program is just beginning to address these two questions. Results are not available yet. Certainly, moving average based insurance designs appear to be inappropriate when strange attractors are influential. Rather, the aim for program designers should be to adjust public policies to move agriculture away from the influence of turbulent unpredictable events. The problem lurking behind predictability, as opposed to stability, appears to favour the intensification of predation on agriculture. For example, upstream supply systems for supply managed agriculture. Insurance is about predictability.

10.14 Disaster aid programs are not stabilization policies. Do your models have anything to say on this?

The current modelling is ultimately directed at disaster questions. Hopefully there will be more to say in the future.

10.15 What is the aggregation level of your modelling; country, region, locality?

We have been working on the idea that the models are holonomic, that is to say, are applicable to system relationships at any convenient level of analysis. Since the workshop there has been considerable discussion about the meaning of aggregation in this context, but no conclusions yet.

We are thinking of applications at the level of the agricultural household, the Province, an ecosystem, and less developed economies.

10.16 Given the two price indexes of the model, why not allow the agricultural price index to depend on industrial wealth and the industrial price index to depend on agricultural wealth, allowing implicit market connections?

A lot more conceptual work is required before considering whether to endogenize price determination within the models. Steven Schilizzi has been having interesting discussions with Jean Marc Boussard in Paris on this issue since the Workshop. One question is whether supply/demand relationships leading to price/quantity determination under equilibrium conditions, are intrinsically static. A second question is whether the single equilibrium underlying market economics is just one 'level' within a complex set of alternative equilibria.

The suggested modification to the specification of the models seems premature in view of the fundamentals being discussed.

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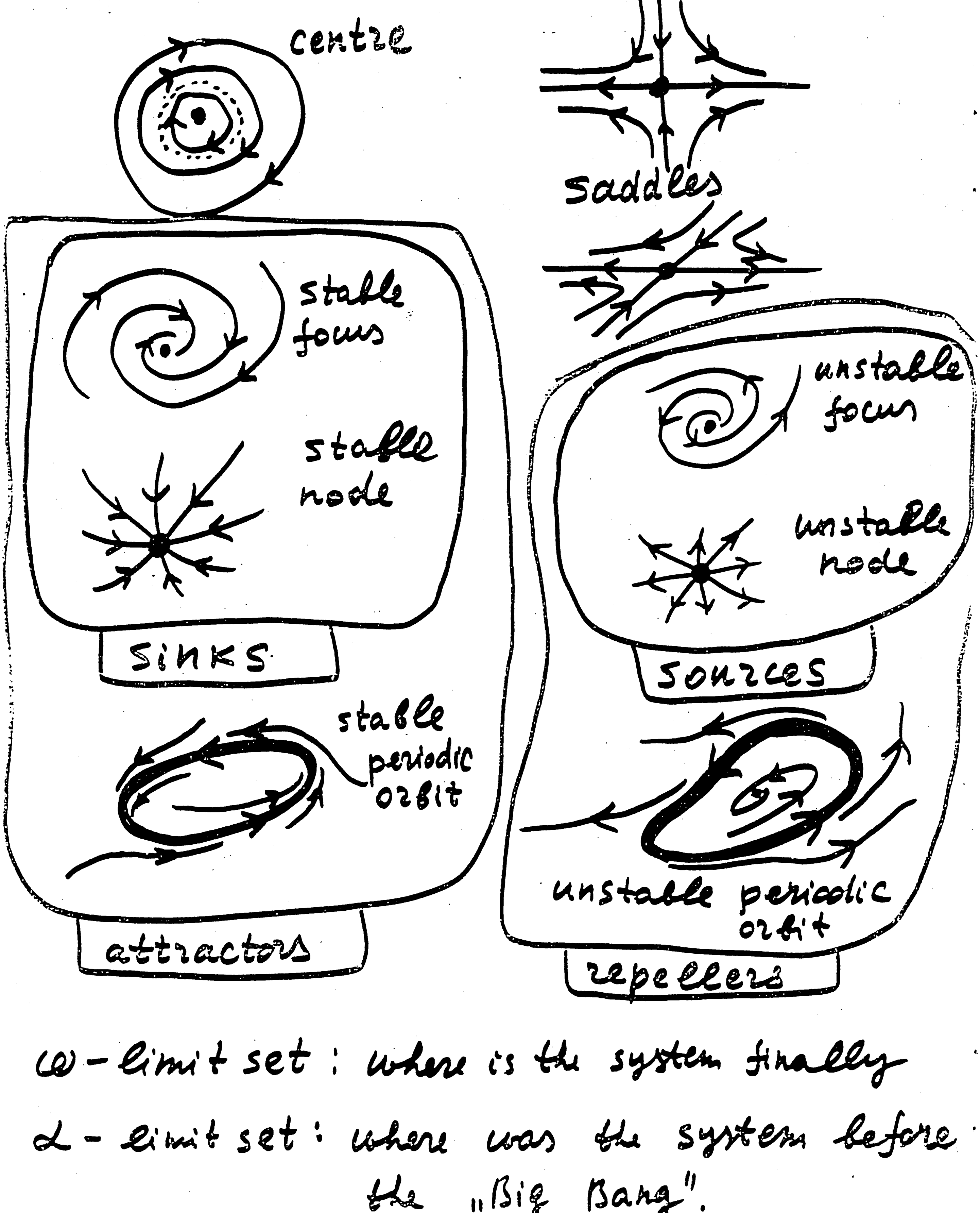
APPENDIX 1

COPIES OF OVERHEADS USED TO ILLUSTRATE CONCEPTS OF:

EQUILIBRIUM, STABILITY, and STRANGE ATTRACTORS

EQUILIBRIA, etc.

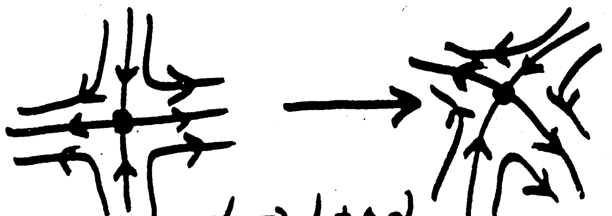


ω - limit set : where is the system finally

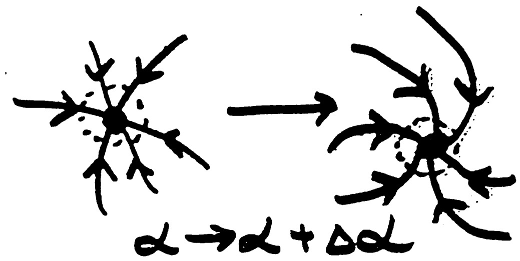
α - limit set : where was the system before the „Big Bang".

STRUCTURAL STABILITY

(Robustness).

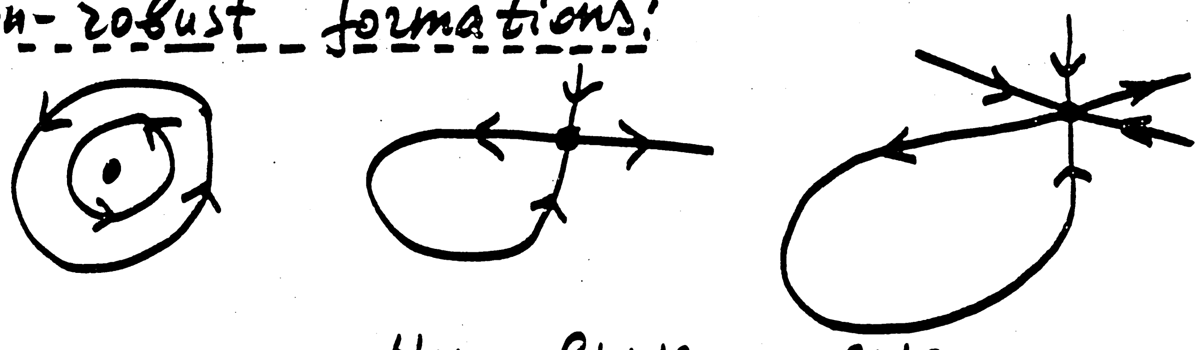


$\alpha \to \alpha + \Delta\alpha$



$\alpha \to \alpha + \Delta\alpha$

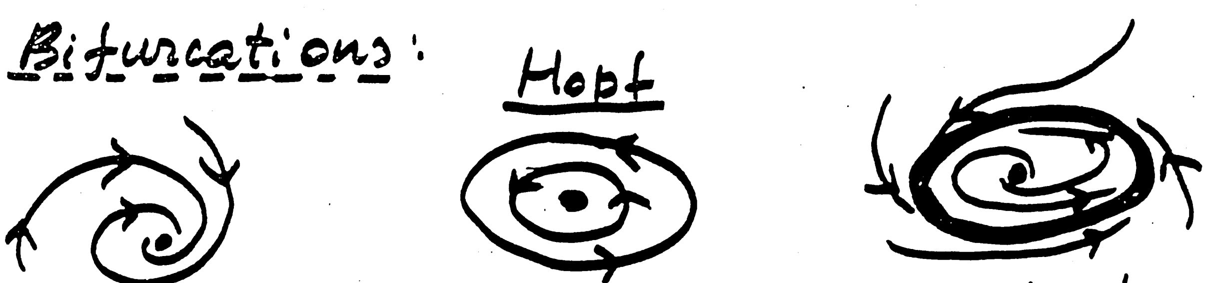
Non-robust formations:



Homoclinic orbits

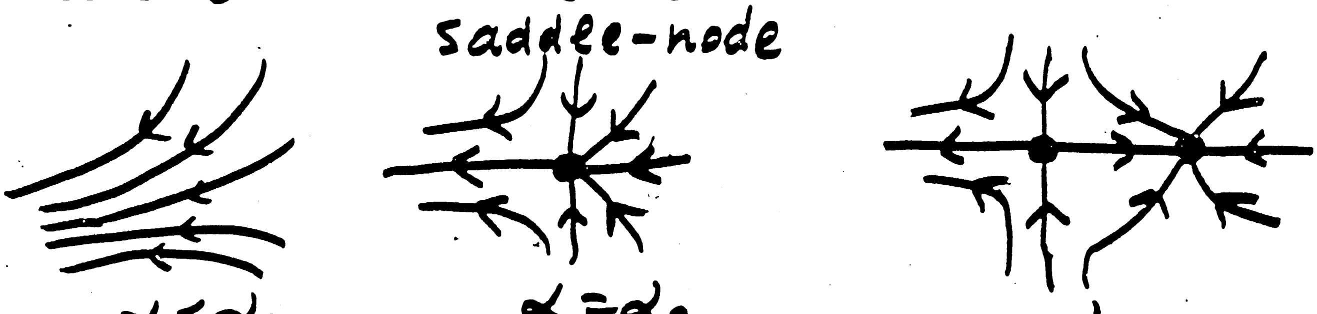
Bifurcations:

Hopf



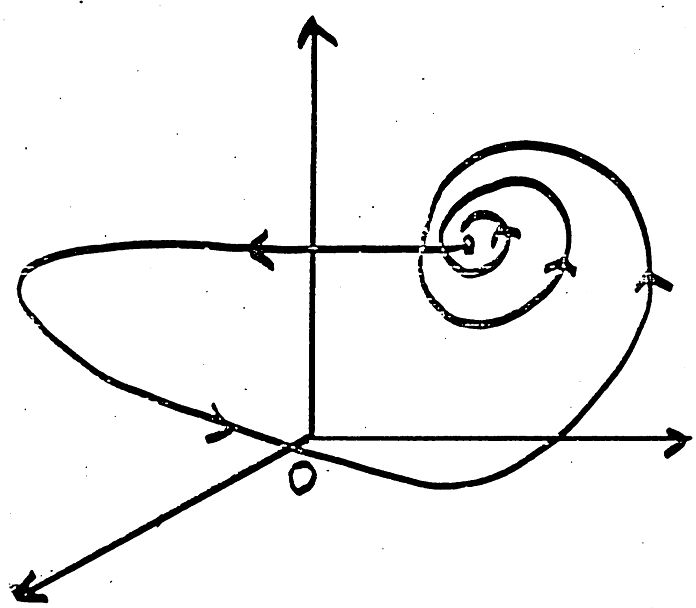
$\alpha < \alpha_0$ $\alpha = \alpha_0$ $\alpha > \alpha_0$

saddle-node

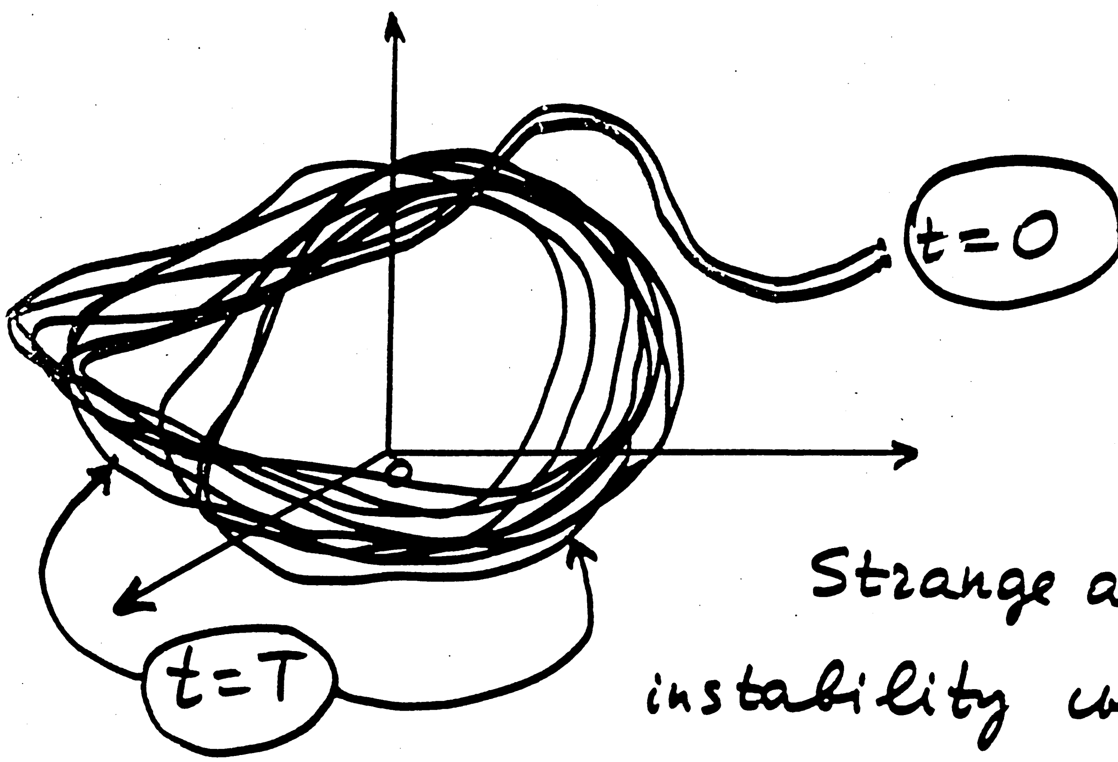


$\alpha < \alpha_0$ $\alpha = \alpha_0$ $\alpha > \alpha_0$

STRANGE ATTRACTOR.



Homoclinic orbit near saddle-focus



Strange attractor: instability with respect to the initial conditions.

APPENDIX 2

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