



Evolutionary Economics

Hardy Hanappi

For my wife Edel, whose help and inspiration made this work possible.

Evolutionary Economics

The evolutionary revolution in the social sciences

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Bibliography

Introduction

The concept of evolution is as trivial or as complex as the theoretical structure, that it is embedded in. From its early popularization in the late 19th century till its current, almost inflationary, use in many sciences it has assumed different connotations, was modified to support political views from "progressive, anti-clerical" via "conservative social-darwinist" and back to "ecological entropy theories", "keynesian anti-equilibrium" or even "revolutionary, anti-equilibrium" again. All these different flavours of evolutionism show the persistent appeal of the basic idea as well as the difficulty to give it a clear and unambiguous meaning. It would be a valuable task to elaborate a historical account of the theoretical networks, which used the concept of evolution, to improve our understanding of contemporary fashions of evolutionism. This work takes a different approach. Instead of starting with the historical evolution of the concept of evolution to give a diachronic account, it uses Morris' distinction between syntax, semantics and pragmatics to develop a synchronic panorama of a subset of contemporary evolutionism: evolutionary economics.

To do so, the original sequence from syntax to semantics to pragmatics had to be changed. Part I starts off with semantics to narrow down the meaning of evolutionism and its key concepts in the social sciences. Whereas the distinction between matter and first life forms seems to be quite clear-cut and widely accepted in the scientific community, there have been recent attempts of sociobiologists to challenge the existence of a divide between the human species and other life forms. To defend the social sciences as a proper field of scientific inquiry, a border line between evolutionary theory in biology and in the social sciences is drawn in chapter 1. It shows the crucial importance of the concept of information, which is dealt with in more detail in chapter 2. In economic theory information enters the scene usually as a restriction on optimization programs of agents, that is, the agents have to acquire information. Since this acquisition is costly, the economic problem usually is seen as optimal amount of activity (search) and/or money to be spent on this purpose. As argued in chapter 2, mainstream economics mostly neglects the other side of the information phenomenon, the production of information, because it assumes, that all economically relevant information is contained in the price system - and prices are produced by the market mechanism. The evolutionary approach opens a wider view on information production, the language of prices is just a subset of relevant information processes. Chapter 3 tries to dig even deeper: the notion of "copy", used as verb and used as noun, is established as most elementary process, or product, in social systems. Despite its somewhat

speculative character, this chapter still is intended to contribute to answer the semantic question: What is the meaning of evolutionism in the social sciences?

Having dealt with the meaning of evolutionism in economics in part I, it is the aim of part II to show, how this concept could be fruitfully applied. As already briefly discussed, the major shortcomings of mainstream economics stem from an inadequate treatment of information processing activities in social systems. The use of models with economic agents, which use themselves full-scale models of their environment, evidently leads to the hotly debated field of artificial intelligence. Chapters 4 and 5 try to accomplish two things: First to give a critical introduction to some central features and methodological underpinnings of the AI-approach; and second to outline a research project, which uses AI-concepts in an evolutionary theory of socio-economic development. After this methodological preamble the following three chapters give a more traditional account of what could be done in economic theory to meet the methodological requirements developed so far. In chapter 6 merits and deficiencies of the "gaming approach" in economics are discussed. Two decades of experience with this approach at our institute proved to be very helpful for this chapter. Taking matters to a more general level, use and misuse of experimental economics are discussed in chapter 7. Again the critique of the opening chapters of part II proves to be very useful for an assessment of some implicit methodological individualism in experimental economics. Finally, in chapter 8, some applications of macroeconomic policy design are described to illustrate the range of pragmatic interference fostered by evolutionary theory.

Contrary to the usual view held in linguistics or mathematics the question of syntax comes up last. Whereas in these sciences an "order of derivation", as I would call it, prevails, proceeding from the rules of language (syntax) to their reference scheme or meaning (semantics) and finally to applications (pragmatics), in my context this order is upset. This is so, because evolutionism in the social sciences has only just been born, nothing can be derived from well accepted basic statements, since these basics do not exist yet. Its language has to be discovered and this "context of discovery" forces us to come up in part III with suggestions for the rules of language only *after* running through preliminary attempts to define our object of investigation, only *after* the description of examples of applications. Chapter 9 looks out for a legacy in the history of economic theory to root an evolutionary syntax. J.A. Schumpeter clearly is a central point of reference in this respect - both as an economic historian and as a business cycle theorist. His concept of innovation, of emergence of the radically new, is the correlate of the concept of design, dealt with in chapters 1 and 8. It is this feature of sudden and radical

change, a change hard to understand for mainstream thought of the old regime, that distinguishes the evolutionary view most strikingly from concurring paradigms. Chapter 10 of part III addresses questions of simulation: Is it possible to use simulated behaviour of economic agents to steer socio-economic development in rough times? Could simulations involving real economic decision-makers contribute to prevent catastrophes in making the feedback-loop between theory and practice substantially tighter?

With the exception of chapters 7 and 10 most of the ideas expressed in this work have been published, and exposed to critique, in several research papers in different scientific journals. To put them in their common context, and to include reactions and extensions proposed by colleagues nevertheless has lead to a whole which is more than the sum of its elements - at least this is my hope.

PART I

Semantics of evolutionism

Chapter 1:

*From nature to society - two types of evolutionism*¹

"Evolution" has become a popular concept. Since Darwins work on the origin of species there was of course always interest in the questions he dealt with, but there has not been such an upsurge of evolutionism since the turn of the century. The recent fashion sees Darwinian terminology swap over from biology downwards to microbiology and even chemistry, upwards to the humanities, social sciences and philosophy and sideways to the arts, and many types of non-scientific discourse. Although Darwin himself seems to have thought a lot about the complementary question, the destination of evolution, he rarely writes about human species². Being a careful biologist, always trying to stay with his hypothesis within limits set by the availability of empirical material, he nevertheless admits, that the person inspiring him was a social scientist: Thomas Malthus³. In a sense Malthus' view of a self-regulating mechanism for workers population in early capitalism, one of the first equilibrium concepts, could not only be used to demonstrate the inevitability of the current type of society, it also could be transferred to biological reasoning to do a much less ideological job: If contemporary species underwent a similar dynamic adjustment process to reach their current equilibrium, then the forces at work during this process can be stated like in Malthus. Surviving populations are selected by the conditions of their environment, by "*natural selection*"⁴. Darwins great innovation of course is, that his painstaking studies of animal behaviour lead him to the introduction of a second concept - *variation*. Since populations usually allow for a certain variability of their members, changing environmental conditions might in many cases find a fitting sub-group.

¹) The major ideas of this chapter have been published in [Hanappi, 1992a].

²) John Burrow writes in his introduction to a recent edition of "the Origin of Species": "Moreover he (Darwin) knew, of course, that he was touching an intensely sensitive subject - one which affected some of the most cherished ideas of his contemporaries: the truth of the bible; the superintending providence of God in the natural world; ... It was for this reason that he omitted explicit discussion of the origin of man, apart from one cryptic sentence ... " [Ch.Darwin, 1985, pp.15-16]

³) "In the next chapter the Struggle for Existence amongst all organic beings throughout the world, which inevitably follows from their high geometrical powers of increase, will be treated of. This is the doctrine of Malthus, applied to the whole animal and vegetable kingdoms." [Ch.Darwin, 1985, p.68]

⁴) In Darwins time the major debate was, if the enormous amount of different species were just made as they were by God (as says the bible), or if there has been an evolution leading from fewer common ancestors to contemporary populations. In this controversy Darwin clearly represents the modern, scientific position.

Together "variation" (mutation) and "selection" make up what could be called the minimum requirements for the so-called evolutionary method⁵. But is method all that is left as soon as evolutionary theory reaches beyond biology? To subsume all forms of life under a common concept is tempting but dangerous⁶. As Malthus' example shows the concept of a selection process easily lends itself to an argument stating that the current situation is "natural"⁷. Only with its complement "mutation", remembering of the never ending newly emerging problems entities are confronted with, the dynamic character of evolution is saved. Consider now some sociobiologists, who explain all phenotypic, human and social behaviour by mutations of genes, mutations being simply copying errors⁸. In such a setting fatalism is the only appropriate attitude towards real life problems: whatever appears on the stage of life must be at least a preliminary optimum, since it passed the tests by nature. Other authors are more cautious and admit that there probably are special features of human behaviour like language or the activities of the human brain in general, which might dominate the genetic influences⁹.

This is not meant to be a critique of theories describing the biological roots of the human species. Given the assumption that mans' social behaviour is a special field of inquiry worth to be dealt with under aspects different from gene mutations, I rather focus on the methods used by evolutionary biology and their appropriability for the social sciences. To do so, one first has to take a closer look on the two fundamental pillars carrying evolution¹⁰: mutation and selection.

⁵) "The simplest scheme of evolution is one that depends on two processes; a generator and a test. The task of the generator is to produce variety, new forms that have not existed previously, whereas the task of the test is to cull out the newly generated forms so that only those that are well fitted to the environment will survive. In modern biological Darwinism genetic mutation is the generator, natural selection the test." [H.Simon, 1981, p.52].

⁶) A good example is Hermann Hakens synergetics [H.Haken, 1983]. As soon as it is applied to economics it often runs into the trouble to be either just a label for complex dynamic models or, worse, to be simply naive (e.g. [H.Haken, 1981, pp.133-156]).

⁷) "There has been a history but there is no more", as a critic of Malthus cynically formulated. Implicitly it is often stated, that with the current type of society evolution has reached its climax.

⁸) The classic for the hard-core sociobiology approach still is Wilson [E.O.Wilson, 1975].

⁹) John Casti in a recent survey [J. Casti, 1989, pp.143-208] tries to give a fair trial to the aspirations of sociobiology. He draws the conclusion, that close attention to the empirical results of this research is important to find out "what is so special about man".

¹⁰) Sometimes the reinterpretation and adoption of game theoretic concepts to the needs of evolutionary biology is considered a third pillar (compare in this respect [J.M.Smith, 1982]).

Mutation

The first difficulty everybody is confronted with as soon as he starts to work with evolutionary concepts is, that these concepts can change their specific meaning if the field of application changes. This is more than the usual complaint about loosely defined concepts. Sometimes for quite different things the same name is chosen, which often is heavily loaded with ideological content¹¹. In many cases it is therefore important to follow tightly the *evolution of the meaning of concepts* when applied from low level structures in physics and chemistry via vegetables and animals up to social phenomena.

Mutation is an excellent example. Its meaning ranges from the effects of copy errors in DNA structures to the variation of sophisticated models in the decision centres of large firms. While for the first process a majority of researchers still assumes pure randomness, the second process probably is a very skilled "directed mutation". In between these two extremes there is the large leap forward from what we consider as "copying" to what we consider as "learning". Indeed the central point of neo-Darwinism is, that selection by environmental constraints is a substitute for learning¹². Stressing this point to refute any kind of higher level mutation sociobiology reveals its basic methodological grounding: The search for first principles rooted in micro-units and (if they are found) the rigorous derivation of all epiphenomena. In that way the universe could be understood as obeying the "basic plan" inherent in the micro-units. An appropriate name for such a research methodology is *microtheology*.

This critique should ring a bell in the ears of social scientists. Methodological individualism, sometimes called atomism, prescribes exactly the same methodological procedure. The only differences are, that the first principle now is called "economic principle", or simply "rationality", and that its micro-unit, the single human phenotype, is destroyed by sociobiology to its bits and pieces - the replicators. What atomism did to an integrated view of social development is done to it by sociobiology!

¹¹) Consider for example the title of Richard Dawkins book "The Selfish Gene" [R.Dawkins, 1989]. "Selfish" is a word usually used in the context of human behaviour. Using it for the tendency of replicants to produce as many copies of themselves as possible clearly is meant to provoke: If genes are the major movers in the world, then the notion of an ego, necessary to support "selfishness", should be rather ascribed to them. The constructed ego of phenotypes is only a derivation of these more fundamental egos. The ideological purport works back in the opposite direction: If even genes are selfish, then a society based on selfishness just reveals deeply rooted and inherited features, which cannot be changed.

¹²) But even if true in principle, this is only possible if the time for the selection mechanism to do his work is long enough, as Darwin himself never ceases to emphasize.

Taking the other route, and allowing for different readings of the concept "mutation" immediately leads to the question which general features do "directed mutations" possess.

Since they constitute only a subset of possible mutations, there must be a set of constraints selecting them. But, contrary to the view of microtheology, these constraints do not have to be part of a lower structured environment, vulgo "nature". Entities can create their own environments and the succeeding steps of their ability to do so structures the evolutionary process. It also structures what we, in retrospect, have to understand by certain concepts like "information", "language", "consciousness" and the like. Of course it is possible to call the constraints in the higher-level environment "information", of course it is useful to make the point that "information" must be stored in some lower-level hardware element usually called memory. But to answer the question what it is, that is called information, how it is processed, one must enter into the "language-game" of a certain level. It is possible to postulate that all memory, all low structured carrier systems, have limited capacity, limiting in the sequel the amount of information that can be stored. But again, to describe what information is relevant, is worth storing or urgently to process, can only be discussed at the level of the life-form considered. This is so, because it is the practice of the entity under considerations, that determines the answer to these questions. Unless one assumes away different entities in favour of a first principle and its derivatives, one is forced to go into the details of entity behaviour.

As a rule, phenomena like language, the experience of time and the closely linked question of self-consciousness, which are typical for humans, should first be discussed and defined in the context of humans, before they are grafted on other forms of life.

On its way to directed mutations, to more and more restricted choice sets, and this means to more and more "intentional" change, evolution is encompassed by successive regimes of information processing¹³. It is interesting to interpret this evolutionary steps as successive orders of the "copy"-operation. Whereas first-order-copy can be considered the elementary fact of a continuous self-consciousness, i.e. a "copy" of elements of running experience over time, second-order-copy can be viewed as all actions projecting first-order-copy on elements of the environment. In other words, copying the first-order-copy (self-consciousness) gives second-order-copies which

¹³) Evidently the following ideas are presented in an extremely compressed form.

usually are called "signs". A sign is what then can be stored on a physical carrier-system, in a memory. Common usage of signs immediately links individuals to groups. As soon as a stock of signs is accumulated new born individuals learn to see through the glasses of existing "knowledge". In this way "social knowledge" most of the time develops slower than new experience of new environments is to be processed by new generations. New emerging signs are either in line with "conventional wisdom" or, if a greater part of the existing knowledge has become obsolete for practical purposes, starts to cluster as a "new paradigm". This story of the growth of knowledge is not new, but fits excellently to my alternative to sociobiology, call it MMM-theory (non-linear, macro-micro-macro theory, to mention some desiderata).

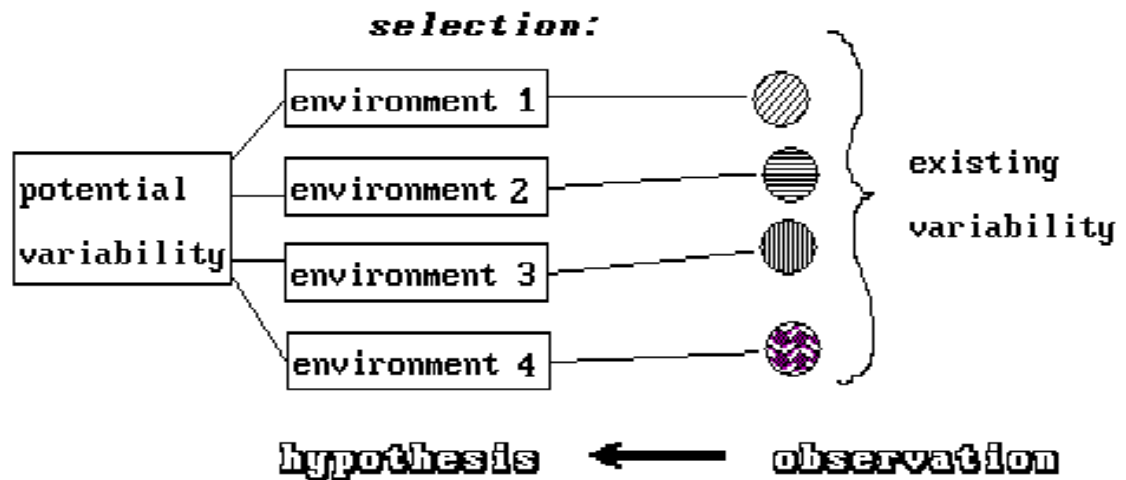
Future will show if the evolutionary process selected microtheology or a sort of MMM-theory as the next relevant paradigm for the social sciences.

Selection

Consider the asymmetric relation between mutation and selection: Variation might well be observed without the assumption of selection, but does selection make sense if there is no variation? Clearly there is no point to call a constraint on a set of homogeneous elements a selection. Either the selection process itself (the environment) must change, or there must be true variety in the elements. Excluding for a moment the first case, stable conditions might in the long-run lead to some equilibrium distribution of behavioural traits, either within each element or as relative size of elements with this feature in total population. This is exactly the content of Maynard Smith's "hawk-dove" example [J.M.Smith, 1982, pp.10-27]. Assuming now, that stable conditions actually prevailed for a long period, it is legitimate to consider the observed constellation as a good approximation to equilibrium. Travelling from one long-run stable environment to the next, different one, it is possible to study the relation between environmental constraints and behavioural traits. Moreover one could draw some conclusions about common ancestors of contemporary species¹⁴. The *results* of different selection processes are used to derive ex post the potential variability of a common ancestor, the starting point of mutations. Existent variability is used to make conjectures about selection processes, what Darwin calls "the struggle for life" (compare fig.1).

¹⁴) This is exactly the initial "experiment" of Darwin, his journey on the ship "Beagle".

Figure 1: Darwins method



Darwins strong hypothesis was the postulate, that for *different* environments the *same* selection process has been at work: survival of the fittest. This sheds some light on the relation between variability and selection in a classic example in biology. Let us switch to a quick comparison with the social sciences.

Most important in Darwins "experiment" are several special features. To name only a few: First is the stability of environmental conditions for a very long time. Second, and more or less logically implied by the first one, there should be no influence of the observed species on their environment. Third there should be no interference between environments. Fourth the choice of what is to be considered as a (preferably measurable) variable feature of an element should be unambiguous.

In Darwins case all of these requirements have been met to a high degree: Discovering areas more or less untouched by man accounted for the first. The observed animals did not shape their environment in a significant way (condition 2). Visiting islands, as he did, is probably the best way to exclude interference and eliminates problem 3. For point 4 again the type of object studied, animals, was favourable. The length of beaks, colour and behavioural traits are unambiguous, well-defined features.

Compare this now to "experiments" in the social sciences. To give an extreme example use three typical "species" of economies as empirically observed variety: a typical industrialized western country (OECD member), a typical eastern European

country (CMEA member) and a typical third world country (LDC). Starting with problem 4, it is much less unambiguous which variables should be taken as "representing a country"¹⁵. Condition 3 clearly is not met by most topics in the social sciences: There is interaction between evolving varieties. Condition 2, and as a consequence condition 1, *never* can be met by a social system, simply, as I will argue below, because it is a *social* system. Taking arguments together it is evidently not possible to draw conclusions about a common "ancestor system" or a common selection mechanism, like "only the strong (institutions: democracy, nomenclatura, dictators) survive". Examples from microeconomics (ancestor: entrepreneurial individual; selection: competitive markets) are less ridiculous but still misleading.

Let us now come back to the inverse question asked at the beginning of this chapter: Is variation possible without selection? The discussion in the last paragraph makes an answer much easier: Since selection comes into the picture only as an *ex post* hypothesis about historical processes, as a special postulate it has no necessity. But is it necessary to formulate *any* postulate at all? As my remark on conditions 1 and 2 above shows, for the human species my answer is: yes. This is exactly the defining characteristic of social systems. This point has to be dealt with more in detail.

Coming back to conditions 1 and 2 we now can state more precisely that humans adapt not only passively, but also shape their non-human environment¹⁶. Piaget has termed this human activity as *accomodation*¹⁷. Accomodation, as an extension of assimilation, also includes the *creation* of a new environment, the "information environment". Still this created information environment, sometimes called "culture", might be relatively stable for some generations, but then there might come a generation realizing, that it is no more adequate to help solve problems and should at least partially be revised - "cultural revolution". This type of use of information environments seems to be unique to the human species. Boiling down radically what these information environments do, gives "making hypothesis about past events to guide current behaviour". Hypothesis how to survive, that is about selection criteria, are elementary to all human groups. Since they are indispensable to humans, conditions 1 and 2 are incessantly violated and evolution theory in a strictly Darwinian sense is non-applicable

¹⁵) Economists usually prefer something like GDP per capita, but more biologically inclined scientists could opt for "maximum reproduction capacity" (population) showing that China is the leading nation.

¹⁶) This is not to be interpreted as a contradiction to animals, which also exert some influence on their environment. Nevertheless there seems to be a qualitative jump from their abilities to do so to human capacities.

¹⁷) As Piaget argues, adoption and assimilation show striking similarities in phylogenesis and ontogenesis [J.Piaget, 1983].

in the social sciences. I will label this type of theory adequate to describe "vegetable and animal kingdoms" as "evolutionary theory 1" (E.T.1) to distinguish it from a theory adequate to describe social systems¹⁸ (E.T.2). As recent discussions in astrophysics show, there might even be room for an E.T.0!

What happens according to E.T.2 ? Environment doubles into a low-structured physical environment and a highly-structured information environment¹⁹. In an analogous way selection hypothesis double into physical selection hypothesis and hypothesis about adequate information environments, into "bread questions" and "belief questions". Adequate information environments evidently should enhance "living"²⁰.

One last remark concerning the introduction of the concept "information environment" is important. An information environment, called system of second-order-copy before, installs bindings between individual members of the human species. Being a defining characteristic, this means, that E.T.2 always is a theory about clusters of interdependent individual entities *and their language*. What is to be considered an entity and due to which information processes it emerges, is part of the theory²¹.

Social Science as E.T.2

Historically social sciences were born with late merchant capitalism or early industrialization. A possible interpretation is to connect its emergence with the opening of the gap between the bourgeois individual (concrete: the merchant) and the "nation" (concrete: the government). Adam Smith is among the first to interpret this discrepancy. According to his argument the wealth of the nation is positively correlated with the wealth of the individual. Translated into E.T.2 this means the construction of a model where accomodation on the individual level - the force of the entrepreneur to shape all aspects of life according to his individual objectives - leads to accomodation on a national level - the wealth of nations. In much of his work he used what I previously called microtheology to derive his conclusions.

¹⁸) Proper use of language should restrict the application of the word "social" to human systems.

¹⁹) "Structure" in this context is to be understood as a synonym for negentropy.

²⁰) If adequateness means different things to different groups in society, then the strongest group usually produces a hegemonial information environment. Therefore in the language common to all groups some concepts will necessarily be distorted for some groups. This is the content of the debate on ideology. If in the middle ages religion redefined the notion of "life" to include "life after death", it contributed to prevent the poor to revolt against *their* life before death.

²¹) In contrast, sociobiology explains phenotypes as clusters of genes emerging and dissolving according to the rules of first-order-copy. If a virus is a better carrier system than man, then genes will use it and will abandon the human phenotype (example given by Richard Dawkins [Dawkins, 1989]).

It was Schumpeter, who in his epochal history of economic analysis [Schumpeter, 1955] points out, that in the 19th century indeed Marxian evolutionism seems to have inherited the basic socio-economic approach of the anglo-saxon classics. In grafting Hegels philosophical evolutionism on the classics Marx constructs his genuine brand of MMM-theory some years before Darwin publishes his pivotal book, which in its turn lead to the development of biological evolutionism²².

The 20th century really is the golden age of the natural sciences, the immense upsurge of biological evolutionism just being one example for the success of "science". As soon as the latter has matured to be formalized in a mathematical way, social scientists started to borrow its "evolutionary method" to participate in the prestige of the "exact sciences". Armen Alchian has been one of the first to restart the debate after World War II. His attempt to use the mutation-test-metaphor to generalize the neo-classical doctrine to include behaviour out of equilibrium and incomplete information [Alchian, 1950], after 30 years seems to have been a partly successful proposal: Firms indeed do not need to solve complicated optimization models to produce convergence to neo-classical equilibria²³. On the other hand his analogy between the survival of firms and the evolution of biological species did not prove to be a workable hypothesis. Some of the early counterarguments (see for example [Penrose, 1952]) indeed stress points similar to the ones that lead me to postulate E.T.2, namely the necessity of a notion of what I call information environment.

From the sixties onwards Sidney Winter, later together with Richard Nelson, appeared as the major proponent of a careful elaboration of the fruitful points touched upon by Alchian²⁴ (two outstanding examples are [Winter, 1971] and [Nelson/Winter, 1982]). It is this tradition of "fine tuning of realistic behavioural models", that induces most contemporary "evolutionary" economists to use a collection of typical ingredients of models as characterizing the label "evolutionary"²⁵. And it is this type of economic

²²) Schumpeter rightly states that *in the 19th century* biological evolutionism and marxian evolutionism (beside their anti-clerical foundations, G.H.) had nothing in common. A blend of the two currents only appeared in the "bastard-marxist" writings of the early 20th century.

²³) The discussion between the optimizing- and the satisficing-approach is elegantly resolved in an illuminating paper of Richard Day [Day, 1971]. It is interesting, that even the numerical algorithms used in numeric computation of optima usually provide a heuristic, which lends itself to a "satisficing" economic interpretation.

²⁴) He also draws on other early critics of the neo-classical theory of the firm like Williamson [Williamson, 1964] and Simon [Simon, 1955].

²⁵) A recent example for a vague definition of this type is [Dosi, 1991]. Ulrich Witt holds, that the common feature of evolutionary economists is their opposition to neo-classics [Witt, 1990] and lists

work, which seems to attract the majority of evolutionary economists. In many cases this first current of contemporary evolutionary economics tries to improve on topics somewhat neglected by neo-classics, e.g. technical progress.

The second current important for contemporary evolutionary economists has been provoked by Wilson's book on sociobiology. There has been a short but vivid discussion on the solution of the problem of (observed) altruistic behaviour (see [Becker, 1976, 1977], [Hirshleifer, 1977] and [Tullock, 1977]) and some years later, there have been some more elaborate books devoted to the new school (for example [Boulding, 1981] and [Foster, 1987]). This work also can be seen as a further attempt to clear the ground for a more general foundation of an evolutionary social science.

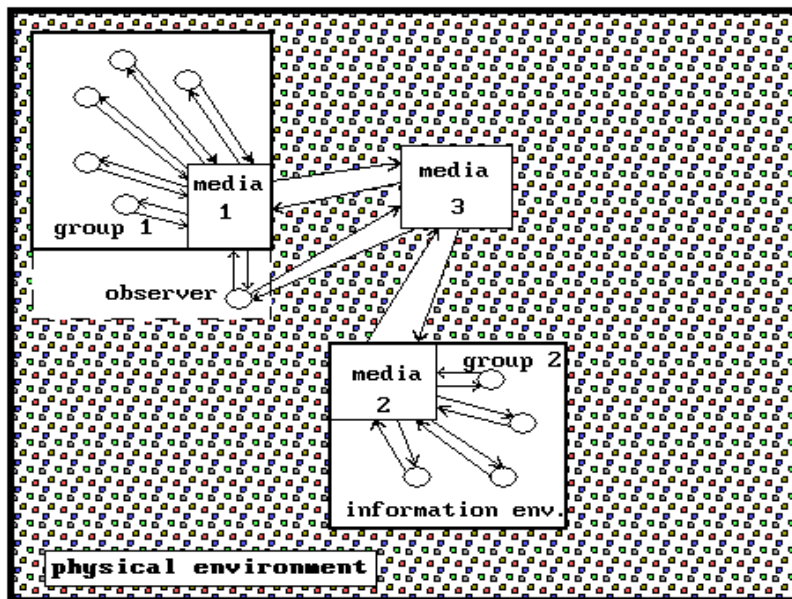
Again it is rather the common opposition to a too narrowly biological analogy, and not the positive content of the respective theory, which is shared. Almost needless to say, that most schools of thought with a long-run perspective, from a modernized Marxian evolutionism via Schumpeterian long-wave theories to institutionalism, qualify for a member in this second group of "grand theories", defending the social sciences as a special field of inquiry against sociobiologists, who consider it as just another province in the manifestations of gene selfishness.

Let me now tie the loose ends together and sketch a preview of a veritable E.T.2 (compare fig.2). Figure 2 of course incorporates more elements than figure 1 appropriate for E.T.1. First there are two environments of which one, the information environment, is constituted by a set of individuals and in turn feeds its normalizing power back on the group²⁶. There is a developing hierarchy of media in and between groups, which structures the information environment. The different media rectangles in figure 2 are just a symbolic reminder for this evolving complexity.

different groups sharing this common enemy. Again it is a set of heterogeneous elements, which is used for an extensional definition.

²⁶) Of course information is not the only constituent of groups. Simple physical production activities with division of labour are another one. But note that every other constituent is at least accompanied by information processes.

Figure 2: Methods of Evolutionary Theory 2



Second the observer is part of a system of observers, this is what the dotted rectangle, which associates the observer with group 1, should indicate. Each of his observing activities changes the system at least incrementally. An approach, which ignores the endogenous character of the observer is necessarily inappropriate for social phenomena²⁷.

Third, as time is experienced by entities, it is the information environment, which is relatively stable with respect to the physical environment to which it is "applied". It is the fund of applicable knowledge, which enables fast dynamic reactions to standard variations of the physical environment. But there is also a slow dynamic of adoption of the information environment to unknown aspects of the physical environment. Instead of still searching for inflexible "first principles", a final omnipotent information environment, modern social science could try to explore and incorporate these slow dynamics²⁸.

²⁷) This statement has far reaching implications. It means, that the researcher is not only "responsible" in some ethical sense for his product. His product is simply wrong, untrue, if it does not include his own role in the evolving process.

²⁸) Evidently this is where historians of economic thought might quite unexpectedly contribute to the most exciting future developments in economics. It is not surprising, that the eminent evolutionist Schumpeter spent so much time on this subject.

Fourth, there are some important consequences for formal modelling to be drawn from the first two characteristics. On the one hand any useful E.T.2 model must be dynamic. As explained in the last paragraph large information environments, built in the past, shape current behaviour with a short time lag, whereas this information environment changes only slowly²⁹. Two different adoption speeds can only be modelled in a dynamic setting. On the other hand at least some relations between the elements of E.T.2 models must be *non-linear*. Let me mention only two reasons for this characteristic:

Since social entities try to anticipate each others behaviour, they tend to build models of the models others use. In these models they must not neglect how the other one sees them and how far he knows how they see him. Without further restrictive assumptions this point of view leads to infinite regress if one tries to construct a true model. As a consequence information processing capacities (storage and processing) must be infinite to construct true models. Since physical capacities are finite, there are non-continuities in all models leading to non-linearity³⁰. There are two possible escapes from this trap:

- "Everybody knows everything": this is the program of the rational expectations school. Since the growth of knowledge is simply assumed away, the very characteristic of social systems in our sense (E.T.2) is excluded³¹.
- "Nobody knows anything": this is physics, Brownian motion of molecules, again missing the point of E.T.2.

The second argument for non-linearity stems from the simple fact, that at some stage of modelling, interaction with the physical environment has to enter, and there are many cases where the physical laws involved are non-linear³². Anticipation and strategic behaviour again propagate these non-linearities throughout the system. After the

²⁹) Clearly this only applies to the more basic elements of the social information environment, for high and abstract levels in the above mentioned hierarchy. Some price information in special markets might change pretty fast.

³⁰) A typical case would be to use anticipation via interdependent, game-theoretic reasoning only up to a certain level of complexity, a limit set by information processing cost versus gain of correct forecasts. Beyond this border line more or less blind but cheap guesses are used. The next chapter develops this idea.

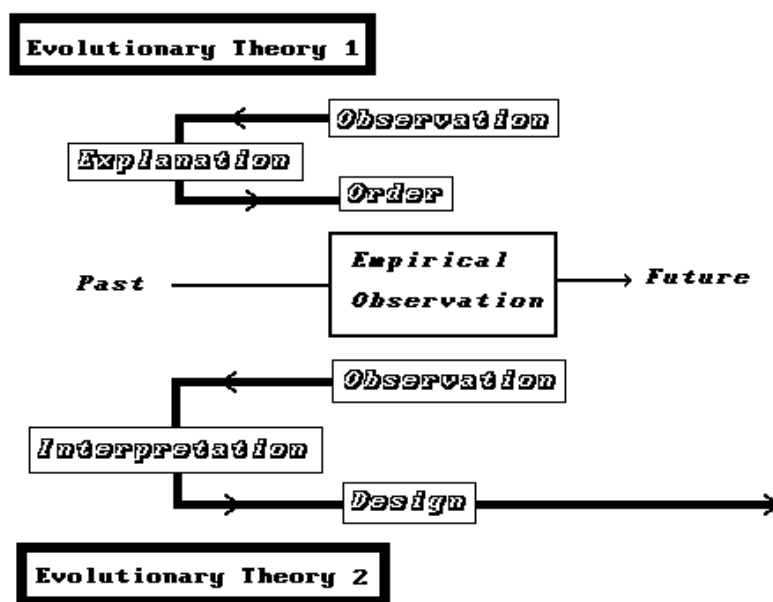
³¹) This critique does not apply to the question of stability and learning of RE-equilibria. It aims only at the overwhelming majority of RE proponents studying solely equilibrium positions.

³²) Again the finite character of physical resources, their exhaustability, might contribute to this non-linearity.

"Golden Age for mathematical economics" (Samuelson), there seem to be hard times ahead³³.

Finally there is a deep pragmatic difference between E.T.1 and E.T.2. As figure 3 shows, E.T.1 tries to explain contemporary observations as outcome of certain laws, which work out in the course of history. The objective of science is to find the master design³⁴, that lead to the existing order. If social science finds this plan, the contemporary state of affairs can be understood as rational, as obeying some extra-terrestrial first principles. Knowing them, mankind can participate in this order simply by obeying. This is where the conservative tendency in all naive transfers of E.T.1 to social science comes from.

Figure 3: Pragmatics



According to E.T.2 the objective of science is to design! Studying the past is not a search for a master design, but an interpretation. An interpretation, which is necessarily preliminary, and which is just a step towards a design of future (physical and

³³) My argument is similar to Dosi's [Dosi, 1991], but instead of expressing just a personal preference for a certain type of modelling, like he does, I think, that these ingredients of models are not open to different gusti. They are necessary.

³⁴) There is only a small but important step taken by this kind of science from the Masters design (Gods will) to a master design (eternal laws).

information) environments. Taking into account the endogenous character of the researcher, this amounts to policy design and this is exactly where the progressive bias in E.T.2 comes from.

Conclusion

There is need for evolutionary theory in the social sciences, but it must distinguish itself rather sharply from evolutionary theory in biology. Being aware of its place as an element in the evolutionary flow of societies it must lay emphasis on its role as a contributor to policy design. Its major competitor as a school of economic thought has been labelled microtheology. Whereas the latter school usually interprets observed constellations as the equilibrium outcome of competition, resembling in this respect E.T.1, evolutionary theory 2 starts with an essentially richer model in a state of disequilibrium³⁵. Although it is not possible to relate special formal tools with each school, the higher complexity, non-linearity and the dynamic character of E.T.2 models will more often lead to the use of simulation techniques. Numeric results produced by such models are good enough for E.T.2:

The major emphasis of E.T.2 is on *design* for future environments, and design needs preliminary but realistic forecasts instead of unobservable, eternal truths.

To deal with these pragmatic aspects of design it is necessary to explore what is to be understood if we talk about the information environment. This is the task of the next chapter.

³⁵) "Disequilibrium" is just another way to express the necessary frustration of expectations discussed in the last chapter.

Chapter 2:

What is information

A clear understanding of the concept of information is a necessary prerequisite for any discussion of economic topics. Information theory usually circumvents the problem by defining major concepts only with reference to the technical aspects of signal transmission. For these purely physical processes information theory can be worked out as a branch of probability theory. To grasp the crucial role of information processing in social systems this is completely inadequate. New formal techniques were needed to deal with the latter: that idea has been the starting point for Neumann/Morgensterns' path-breaking work on strategic games [J.Neumann/O.Morgenstern, 1942]. Since then game theory has become the most important tool in economic theory to model more sophisticated information environments.

The idea of the following models is to capture information processes in an even broader sense than usually done in economic theory. Information is not only considered as a "commodity", acquired at a certain cost (e.g. search cost) and yielding a certain additional revenue (e.g. savings due to additional knowledge about price dispersion), such that increasing marginal cost and decreasing marginal revenue determine optimal information processing. Indeed this type of models is only concerned with what I would call "optimal information consumption", with the optimal amount of data collection. Another strand of economic theory goes a little bit further, and discusses information as a typical public good: Once it is there, everybody is glad to use it, but there is no incentive for any single participant in the game to initiate its production. This type of work evidently uses the prisoners-dilemma-metaphor and in some cases provides arguments for a central agency (the state, the firm) to overcome it.

This paper goes one step further in specifying, what is meant by information production. To do so, very rigid and simple settings had to be chosen to arrive at any results at all.

Production of information: Distributional issues

Let us consider the following model: There are two entities, each one controlling one variable. It is assumed, that this variable can be measured by a scalar, which is normalized to stay in the closed interval $[0,1]$. This controlled variable is thought of as a kind of activity of each entity, leading to a certain, common result, a product. This product again is measured by a scalar.

This setting is substantially complicated if one assumes, that the entities know what they are doing¹. To be more precise, each entity uses a model of the production process, which just has been described. To keep matters simple, the two models are assumed to be linear. Since the basic task of this investigation is to describe information production, it is wise to allow for a divergence between the two models of the entities and to add even a third, still different model: the one that actually determines output². Thus the two models (subscript 1 and 2) and the real process (subscript 0) read

$$[1] \quad z_0 = w_0 + \alpha_0 u_1 + \beta_0 u_2 \quad (\text{world})$$

$$z_1 = w_1 + \alpha_1 u_1 + \beta_1 u_2 \quad (\text{model of entity 1})$$

$$z_2 = w_2 + \alpha_2 u_1 + \beta_2 u_2 \quad (\text{model of entity 2})$$

Output z_i is perceived by entity i as having been achieved by activity u_1 weighted with α_i , activity u_2 weighted with β_i and an uncontrolled influence summarized in w_i . Note that each entity, by definition, knows its own control variable, but has only a suggestion about the choice of control of the other entity.

Let us consider the most elementary case in which $\alpha_1, \alpha_2, \beta_1$ and β_2 are *positive* and entities use their respective control to maximize output³. It is clear, that both will set their control to unity, independent of the control of the other one. If output is perceived correctly and so is the control of the other, that is

$$[1.1] \quad z_0 = z_1 = z_2 =: z$$

¹) The question of a possible collapse of these difficulties in case of *complete* information of the entities is discussed later.

²) In other words, it is assumed, that the real production process can be described by a linear, deterministic production function.

³) This will be assumed throughout the paper.

$$[1.2] \quad u_{21} = u_2$$

$$[1.3] \quad u_{12} = u_1,$$

then there still remain 3 unknown parameters for each entity, namely w , α and β . Suggestions about their respective size will be used in any bargaining process about the *distribution* of the common output. It is remarkable, that in this case, where controls are fixed due to the assumption of positive α_i and β_i ($i=1,2$), there still is some need for information processing. Entity 1 will try to convince 2, that α is big compared to β - and entity 2 will try the opposite. An inquiry in w is of minor importance in this case.

Let us denote the minimal share of output, that an entity i needs to sustain its activity by $z_{\min}^i$ and the remaining quantity for entity j by $z_{\max}^j$:

$$[1.4] \quad z_{\max}^j = z - z_{\min}^i$$

If $z_{\min}^i$ is considered to be exogenous, say it represents a condition of physical survival of entity i , then the distribution of output will in first instance depend on the relative coercive power of the two entities: the stronger one takes it all. But to exert power is costly and with information production getting cheaper it will prove advantageous to use it. Without loss of generality let us assume, that entity 1 initially has been stronger, such that

$$[1.5] \quad z = z_{\max}^1 + z_{\min}^2$$

Introduce the following notation:

[1.6] c_C^1 .. cost of coercion per period

c_M^1 .. cost of influencing the perception of entity 2

and assume that the original model of entity 2 has been

$$[1.7] \quad z = \beta_2 u_2 \quad \text{that is} \quad w_2 = \alpha_2 = 0.$$

In other words, entity 2 sees total output as its own product, only coercion forces it to accept its subsistence level $z_{\min}^2$. The model of the world proposed by entity 1 gives a different picture:

$$[1.8] \quad z = \alpha_{1M} u_1 + \beta_{1M} u_2 \quad \text{with}$$

$$\alpha_{1M} : \beta_{1M} = z_{\max}^1 : z_{\min}^2$$

That is, the prevailing distribution is justified as reflecting the respective contributions to the production process⁴. A possible formulation to introduce "information production", i.e. the modification of the model used by entity 2, is the following:

$$[1.9] \quad z = (1-\gamma) (\beta_2 u_2) + \gamma (\alpha_{1M} u_1 + \beta_{1M} u_2) \quad \text{with} \quad 0 \leq \gamma \leq 1.$$

In this formula γ indicates how far entity 2 believes in the model proposed by entity 1. If γ is zero entity 2 believes only in its original model, if γ rises it accepts an increasing amount of output as fair share for entity 1.

The last step to close the model is first to consider γ as an increasing function f of its cost c_{1M}^1 and second to assume coercion cost c_C^1 to be a negative function g of γ : The more entity 2 is willing to accept to distribute output according to the rules proposed by entity 1, the less coercion is necessary.

$$[1.10] \quad \gamma = f(c_{1M}^1)$$

$$[1.11] \quad c_C^1 = g(\gamma)$$

Given all these assumptions, the choice of γ will depend on the cost of information production relative to the savings in coercion cost. More traditionally one could argue, that for well-behaved functions, information production will be extended as long as marginal revenues from coercion savings exceed marginal information production cost.

As an example, specify functions f and g according to [1.12] and [1.13].

⁴) Note that [1.8] could be interpreted as logarithm of a Cobb-Douglas production function, with α and β as output elasticities of capital and labour. Neo-classical writers indeed used this formulation to discuss distributional issues.

$$[1.12] \quad c^1_M = k_0 \gamma^2$$

$$[1.13] \quad c^1_C = (1-\gamma) k_1 z^1_{\max}$$

Convincing entity 2 to let a small share for entity 1 is first cheap, but gets very hard as entity 2 approaches the subsistence level. This is where the non-linearity in [1.12] might stem from. In [1.13] the cost of brutal power are assumed to be proportional to the quantity acquired by entity 1 against the will of entity 2. Scaling parameter k_0 has to be smaller than $z^1_{\max}$, k_1 has to be smaller than 1. Both can be interpreted as measures of cost. Savings from increased influence in model 2 then are given as

$$[1.14] \quad s^1_C = \gamma k_1 z^1_{\max}$$

and the optimal mix of coercive and "ideological" power can easily be computed by setting marginal savings equal marginal cost:

$$[1.15] \quad k_1 z^1_{\max} = 2 k_0 \gamma$$

$$\gamma^* = (k_1 z^1_{\max}) / (2 k_0)$$

The higher the cost of coercion k_1 , and the lower the cost of information production k_0 , the more ideological power will substitute coercive power (the higher is γ^*). This is what one would expect. As a side issue the specification in the example also suggests more ideological power with lower subsistence levels.

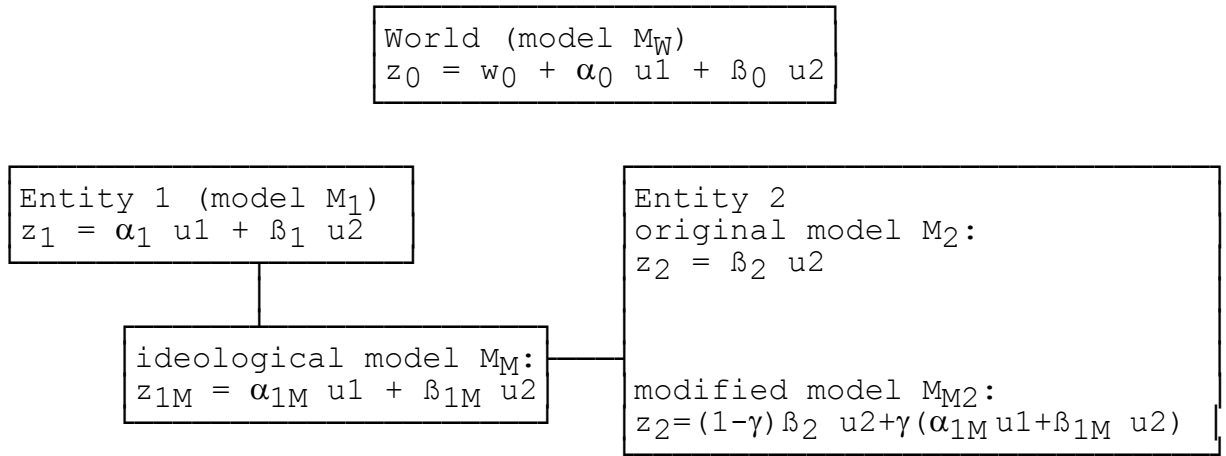
Let me briefly restate some implicit assumptions of this very small and rigid model. There is no conflict in activities u_1 and u_2 , both choose maximum activity and both know and appreciate, that the other one does. The problem is only the distribution of the common output. Just one of the two entities has excess to some kind of media enabling it to influence the model used by the other one⁵. Given a certain type of cost structure, this influence can be used to substitute coercive power. But that means of course, that there has been coercive power, a disequilibrium between entities, in the first place⁶. Finally note, that no use is made of the real model, there is no need for

⁵) Of course it is possible to extend the setting to model a "battle of ideologies".

⁶) This clearly is a deviation from the standard assumption of "(homogeneous) representative entities". Instead of formal beauty, this assumption draws on empirical observations, where slight advantages of an entity tend to develop into a situation of stable coexistence of strong and weak, that is, of basically

investigating actual parameters. There is also no need to investigate parameters used by the other one. Entity 2 has no reason to do so, since it has (by assumption) no access to media, and entity 1 has no need to know entity 2's parameters since they are constant anyway and do not influence optimal choice. So there is no information consumption in this setting, just information production of entity 1 in the model of entity 2. Scheme 1 gives a representation of the situation.

Scheme 1: A simple model of information production



Obviously the actual model (world) is irrelevant. And so is the question, if entity 1 believes in its own ideological model⁷, that is, if M_M is equal to M_1 .

Acquisition of Information: Learning Issues

Let me now try to relax some of the strong assumptions of this model to discuss different sets of problems. The following distinction helps to classify these sets:

Missing information of an entity can either concern the real process as represented by M_0 or the model applied by the other entity. In our first setting the essential point was, that entity 2 did not have the possibility to check the validity of its model - M_{M2} could be different from M_0 . Before allowing for other inequalities let us briefly check what happens if M_0 , M_1 and M_2 all are equal.

different entities. It is just a question of terminology to call the links stabilizing this coexistence "coercive power relations".

⁷⁾ Since there is no need (but some cost) for a "true" model for entity 1, it probably can be assumed, that M_M equals M_1 .

The first, very important point is, that one immediately recognizes, that there is a second level of knowledge: Do entities know what they, and what other entities, know? Even in our previous model, there was an implicit assumption, that, for example, entity 1 knows, that entity 2 knows the true sign of α and β ⁸. So let us consequently assume, that all entities know that they and all others know the true model. This is the case of rational expectations (without disturbance terms).

With optimizing behaviour as above the model can be solved - no information is produced or acquired, since, per assumption, all information is already given to all actors. The description takes on a quasi-physical character, with optimization rules substituting natural laws.

But where did all this knowledge come from? In the history of economic theory two answers to this question figure out prominently: introspection and learning.

Introspection means, that entity i expects, that entity j uses the same model as i ⁹, M_i equal M_j . Learning means, that there is some feedback from experience to model adjustment, M_i^t at time t is a modified version of M_i^{t-1} .

As mentioned above, a second qualification could be made according to the source of lacking knowledge: if M_0 or M_j or both are unknown to entity i . Scheme 2 gives a presentation of possible cases, combining alternate sources and knowledge generation.

Scheme 2: Possible Cases for Information Acquisition

	introspection	learning
$M_0 = M_1 = M_2$	case I	case II
$M_0 \neq M_1 = M_2$	case III	case IV
$M_0 = M_1 \neq M_2$	case V	case VI
$M_0 \neq M_1 \neq M_2$		case VII

⁸) It could be a side-effect of ideological influence to reassure a vague assessment of the sign of α and β .

⁹) Of course there are weaker forms of introspection, where, for example, only the type of model, but not its parameters, are assumed to be the same.

Cases I and II offer different justifications for complete knowledge. Case I states, that knowledge of the true model is an innate, natural feature of entities. Case II would suggest, that both entities had the possibility to learn the correct model to a degree, which makes their model indistinguishable from the true process. Implicitly this means, that there had been a stable true model for a time period long enough for feedback modifications of entities to work out to such a high degree¹⁰. Both cases are of no interest for my investigation, since there is no new information to acquire - everything is already known.

Case III is more interesting. Since the models of the two entities are identical and each entity knows this from introspection, it is possible to treat them as one entity with index 3. If control coefficients α_3 and β_3 used in M_3 (the entities' model) again are positive, then both choose controls equal unity. Now assume, that there is an approved institutional mechanism determining the distribution of the common output - distribution problems can be ignored. Entities 1 and 2 share a common believe system, model 3, that regulates their behaviour, choice of u_1 and u_2 . Problems can only arise, if M_3 does not reflect the true model M_0 and this fact can be recognized by the entities. The typical question now is, when and to which extent will information acquisition, investigation in M_0 , occur¹¹.

$$[2.1] \quad z_0 = w_0 + \alpha_0 u_1 + \beta_0 u_2 \quad (\text{world})$$

$$z_3 = w_3 + \alpha_3 u_1 + \beta_3 u_2 \quad (\text{common model of entity 1 \& 2})$$

First note, how a wrong model M_3 , that cannot be falsified, gives a rationale for "deviating behaviour". If observed, actual output z_0 remains close enough to predicted output z_3 , then there is no reason for model revision, although compensating changes in w_0 , α_0 and β_0 might have occurred. These changes could have been big enough to reverse the sign of one or both of the control coefficients. In a world of exogenously, rising productivity of the system, rising w_0 , falling α_0 and β_0 may hide this increase,

¹⁰) It can be doubted, if economic processes qualify for this condition at all. Contrary to biological evolution, social interaction usually is characterized by strong interaction and slow learning. Interaction between controls and true model, which leads to a change of the true model, can complicate learning substantially. On the other hand, to arrive at indistinguishable good approximations, learning should be "infinitely" faster, than any change of the true model.

¹¹) A deficiency of case III models is, that they assume different attitudes of the same entity towards similar information gaps. Knowledge of the other entities model is acquired by introspection, knowledge about the true model has to be acquired by learning. To justify the different approaches one must admit some prior knowledge about the difference between "nature" and entities.

leaving z_0 almost unchanged. Entities following traditional behaviour, setting controls at unity, will never detect what is going on. If control coefficients are already negative, an "irrational" sudden choice of zero-controls, a break from "successful" traditional behaviour, might yield extraordinary output increases. This probably will reinforce low controls and will finally bring about a readjustment of M_3 . If entities experienced this process several times¹², they will afford a certain level of seemingly irrational behavioural mutations to detect deficiencies of their believe system.

Assume now, that z_0 differs significantly from z_3 . Does it pay for entity 3 (entity 3 is now the community of 1 and 2) to acquire information about M_0 ? If it turns out, that a lower z_0 was caused by a decreasing w_0 , then information acquisition was useless - w_0 cannot be influenced by entity 3. If, on the other hand, it turns out, that a control coefficient changed its sign, then the cost of information acquisition might be outweighed by the increase in output, due to correct control. In the simplest possible formalization, this again is a trade-off between acquisition cost and expected output increase. Let us use the following notation:

[2.2] c_3^0 .. cost of acquisition of the true model M_0

z^+ ... expected additional output if α_3 is set to α_0

p_1 ... probability that α_0 has changed sign

p_2 ... probability that β_0 has changed sign

p_0 ... probability that w_0 has changed

To keep things simple, it is assumed, that the true model can be "bought" at a fixed cost c_3^0 . With the old, wrong model M_3 having positive control coefficients and the suggested true α_0 and β_0 being negative, expected output increase is

$$[2.3] \quad z^+ = p_1 \alpha_3 + p_2 \beta_3 ,$$

leaving us with [2.4] as condition for information acquisition:

¹²) Of course a model with two linear controls and one output is not rich enough for a meta-issue like this. To derive "optimal deviation levels" in a larger model unfortunately leads too far away from my main topic.

$$[2.4] \quad p_1 \alpha_3 + p_2 \beta_3 > c_3^0.$$

Evidently learning rules should allow for endogenous determination of probabilities p_1 and p_2 . But without variation in controls the observed deviation of output does not give any idea about the source of disturbance. Without any prior knowledge about the source of the forecasting error, each parameter (α , β and w) usually is given an equal probability of one third¹³. Revising parameters thus will always be just adding or subtracting a third of the forecasting error from each parameter. Starting with positive control coefficients this procedure might eventually lead to a change of sign of some of these coefficients. A simple learning rule would be to switch the corresponding control of these coefficients to zero. But is such a passive behavioural rule all that entities could do?

If environmental parameters provide a richer structure than the simple w_0 in our model, then the usual techniques of statistical inference can be applied to forecast output. From well-known future developments of some observed series not under control of entities, some conclusions about trajectories of endogenous variables can be derived. Take as an example the seasonal pattern of weather conditions, which in the medium-term, seems to be quite predictable: summer will come and will be hotter than winter. This fact might help to predict the supply of different types of fruit. The very essence of experiments is, to use *controlled* future series to do the same. In doing so, entities inject information into the system, that is, "information production" in a sense different from the one in the previous model, comes into play again.

The weak point in [2.4] clearly are the a priori probabilities p_1 and p_2 . Instead of taking them as given, one could describe a simple heuristic procedure, which is often used by decision-makers¹⁴ to learn (more about) these probabilities.

The first step is to change controls just strong enough to get an effect on output, without running the risk of causing severe damage¹⁵. Sensitivity borders and uniqueness of outcome in general will be different for different controls, leaving room for another, second level, optimal choice, the choice with which control one should start.

¹³) This assumption is known as "Bayes' suggestion of insufficient cause".

¹⁴) In many of my simulation experiments with economic policy games the inexperienced players followed this type of behaviour.

¹⁵) That is not always easy. As recent economic history shows, it proved to be risky to test the Marshall-Lerner-condition by a heavy devaluation. But with slight changes in the exchange rate, no clear trend could be detected. With more controls at the disposal of economic policy, the whole issue becomes very tricky.

Given certain probability distributions and parameter sets, again sub-optimal short-run choices of parameters, deviations, could be shown to be long-run optimal. To make this happen, forecasting errors in p_1 and p_2 must be reduced strong enough (helping either to avoid useless spending of c^0_3 , or indicate useful spending in time) to outweigh their cost of direct influence of the sub-optimal control on output.

Consider the following example. Let $u_1^{\min}$ be the choice of control u_1 , that leads to the smallest observable effect on output. In our case $u_1^{\min}$ should be smaller than 1, the traditional choice of u_1 . The expected direct loss of such a variation of control is

$$[2.5] (1-p_1) (u_1-u_1^{\min}) \alpha_3 =: c^V_3 \dots \text{expected direct cost.}$$

The expected direct revenue is

$$[2.6] p_1 (u_1-u_1^{\min}) \alpha_3 =: r^V_3 \dots \text{expected direct revenue.}$$

The expected net direct cost of an experiment therefore are

$$[2.7] c_{\text{net}}^V_3 = c^V_3 - r^V_3 = (u_1-u_1^{\min})\alpha_3(1-2p_1)$$

So for p_1 greater 0.5 expected net direct cost become negative and information should be produced anyway, at least as long as indirect effects of a better knowledge of p_1 are in any sense considered beneficial. If the a priori probability p_i of a control variable u_i happens to be greater 0.5, then experiments should be started.

But even with an a priori probability less than 0.5 experiments might be optimal, if some indirect effects of better knowledge come into play. These considerations lead into some kind of mean-variance analysis and open up a wide field of possible specifications.

But let me come back to the heuristic learning of p_1 . Call an experiment, where output increased with lower u_1 a positive event e_1^+ , strengthening the suspicion of a change of sign in α . In the opposite case the experiment is called a negative event e_1^- . After n experiments probability p_1 can be approximated as the sum of positive events e_1^+ divided by n . Given a certain trust in 'inherited views', measured as weight g_0 , this could lead to the following dynamic adjustment formula for period n ¹⁶

¹⁶⁾ It need not immediately jump to unity, since there is always the possibility of dominating simultaneous

$$[2.8] \quad p_1^n := g_0 p_1 + (1-g_0) ((\sum e_1^+)/n) \quad \text{with } 0 \leq g_0 \leq 1$$

To see how better knowledge about p_1 can be of indirect use, let us assume the simplest possible case: If it is possible for the entity to keep environmental influences constant¹⁷, that is w_0 is constant, then, since there is no random element in the model, one experiment is enough to be sure about the change of sign¹⁸. That is instead of the use of [2.8] it can be assumed, that from period 2 onwards p_1 jumps either to one or to zero. If the entity faces a planning period (an age) of T periods, expected total production with experiment in period 1, call it Z^E , will be

$$[2.9] \quad Z^E = T w_3 + p_1 \alpha_3 u_1^{\min} + (1-p_1)(u_1^{\min} \alpha_3 + (T-1)\alpha_3) = \\ = T w_3 + u_1^{\min} \alpha_3 + (1-p_1)(T-1)\alpha_3$$

Expected total production without experiment, Z^0 , on the other hand is given as

$$[2.10] \quad Z^0 = T(1-p_1)\alpha_3$$

The experiment should be carried out if Z^E is greater than Z^0 , which reduces to

$$[2.11] \quad \alpha_3 (u_1^{\min} - (1-p_1)) > 0.$$

As [2.11] shows, experiments might be useful even if a change of sign is improbable, that is p_1 is less 0.5, as long as observable changes in output can be induced by small enough changes in control, $u_1^{\min}$ close enough to unity, and environmental conditions including other controls can be kept sufficiently constant. Even if $(1-p_1)$ is big, that is α_3 is thought to be positive, $u_1^{\min}$ always could be closer to unity, making the term in brackets positive and as a consequence [2.11] is true.

The discussion of case III thus led to two basic fields of action: First, if observations of the environment are rich enough to support identification, econometric techniques can be used to discover 'laws', to find the true model. Second, in 'poor' environments under

influence of the other two variables, which could hide the true sign.

¹⁷) This is the way, the importance of 'laboratory conditions' enters this model. Evidently the social sciences face severe restrictions in this respect.

¹⁸) The absence of non-linearities in the model helps to avoid any optimization concerning the point of time when the experiment should be made. With finite planning horizons any time later than period one would simply reduce possible returns from better knowledge without changing the expected cost of the experiment.

certain circumstances experiments can be used to improve knowledge. In other words information acquisition might be supported by information production.

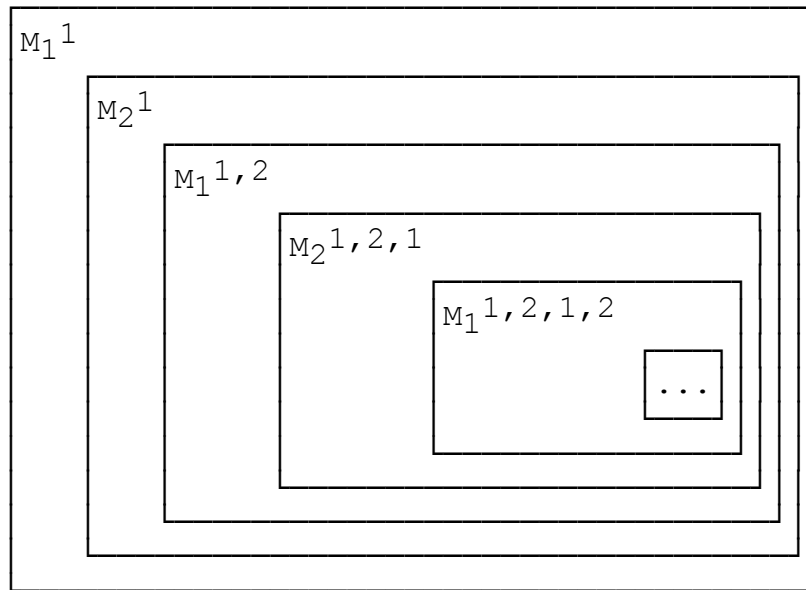
Let me turn to case IV now. The distinction between introspection and learning, made in scheme 2, only makes sense for existing knowledge. If models are identical, this answers the question, where the identity came from. If models are *not* identical learning is the *only* activity to partially overcome this basic ignorance¹⁹. The model in case III is an example of learning the true model M_0 . As an explanation for the existing knowledge, the fact that M_1 is identical to M_2 , 'intuition' was used. For this reason case III figures in column 1, which is 'intuition'. In other words columns distinguish only explanations of identical models. Now, in case IV, it has to be argued, that this identity has been the result of learning, while learning of the 'true' model M_0 is still going on. In other words, learning of the other entities model has been infinitely faster, than learning the 'true' model.

There are several reasons for such an assumption. Entities might use simple behavioural models, much easier to learn than a complex 'true' model. Furthermore entities might reveal these simple models as long as they consider communication as beneficial. Compared to the stability of this known behavioural roles of entities the true model could vary in a fast and unpredictable manner. All real world situation characterized by such a description fall into case IV. As we have already dealt with learning the 'true' model in case III, all we have to do now, is to specify a model describing learning of the other entities model, and to postulate, that this second learning process is much faster than the first one.

Why is it necessary at all to treat the other entities model separately? Why could the same decision-theoretic model dealing with the 'true' model not also be applied to the other entities' model M_2 ? There must indeed be an implicit assumption, that entity 1 somehow knows, that entity 2 is an entity, that it acts on the basis of model-building. Conceded this a priori knowledge, it immediately follows, that this model might contain models of other entities, other entities models of the own model and so forth. The whole modelling of modelling process leading to infinite regress, being only limited by the finite information processing capacity of entities. Scheme 3 depicts the situation.

¹⁹) This explains, why there is only learning if no identical models exist: case VII in scheme 2.

Scheme 3: Infinite regress in models of models



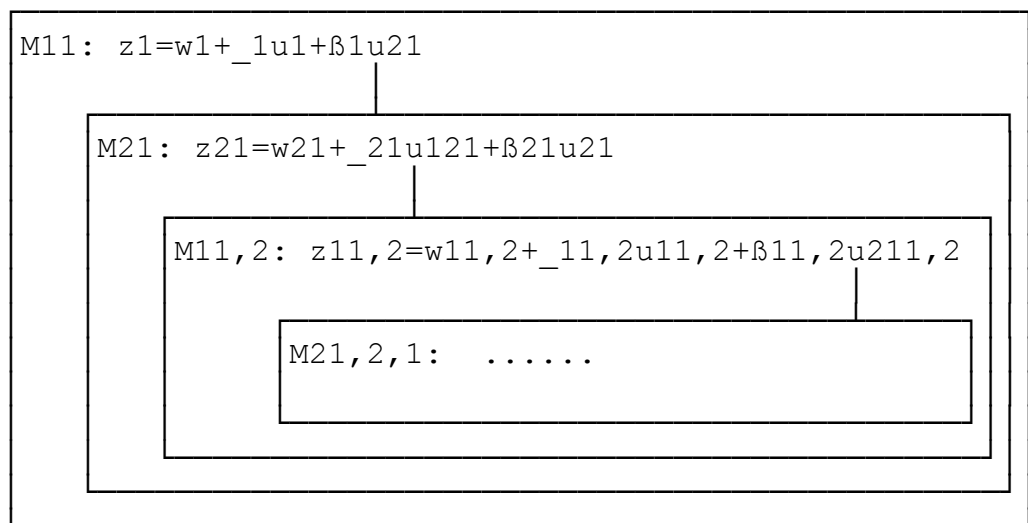
Each rectangle in the scheme represents a model with its name in the upper left corner. Subscript and superscript have the following meaning. Starting with the outmost rectangle M_1^1 means model of entity 1 (subscript) as seen by entity 1 (superscript). As argued above, this model includes a model of entity 2, presented in the scheme as the inscribed rectangle called M_2^1 , the model of 2 (subscript) as seen by entity 1 (superscript). Now if entity 1 anticipates the behaviour of entity 2 by the use of model M_2^1 , it has to consider, that entity 2 is doing the same thing, namely, that entity 2 uses a model of entity 1. This model has to be included in the model M_2^1 and is called $M_{11,2}$: A model of entity 1 (subscript) as entity 1 thinks, that entity 2 sees it (superscript). The further interpretation of inner rectangles goes along these lines. What is the upshot of this thought?

With physically limited information processing capacity, in a finite world, there must be limits to the infinite amount of memory and processing capacity, which such an infinite regress would need to be realized. So even in principle such a setting cannot be a realistic picture of the actual situation, if we accept the latter to be characterized by finite capacities. One way out is the assumption, that some models, in a strict mathematical sense 'almost all' models, are identical. This leads straight to the assumption of the rational expectations school, that all models are identical. But, as already argued above, with this assumption one loses the distinctive feature of social processes: information processing.

Another way out is, to admit just a certain depth of modelling modelling. This idea evidently leads to Herbert Simons' models of 'bounded rationality' [H.Simon, 1972]. Different types of boundedness give rise to different heuristics, the outcomes of these interdependent processes suddenly rely on the assumptions about information processing capacity. The inevitable loss in generality of the corresponding economic models, the loss of formal beauty, can only be balanced by the increasing relevance for economic action. More economically speaking, and quite apart from any physical constraints, the finite degree of sophistication of models, the boundedness, could be justified by the assumption of sharply increasing cost for greater depth while additional revenues peter out.

To get a better understanding of the information cost argument leading to boundedness, one can apply scheme 3 to model [1].

Scheme 4: Model [1] as seen by entity 1



Model M1 of entity 1 is augmented to model M11 in the following way. To explain the choice of control variable u_2 , set by entity 2, entity 1 uses a model of the model used by entity 2, call it M21. In this model appears the control variable of entity 1, u_1 , as entity 1 thinks, that entity 2 sees it: u_{121} . Entity 1 is aware, that entity 2 will use a model to explain this control variable u_{121} and anticipates this model as M11,2. This model again contains a control variable to be explained by another model M21,2,1, and so on²⁰.

²⁰) It is easy to see how complex matters become, if more than two entities and more complicated models are involved.

Since all these models are only anticipations of entity 1, they will in general differ from actually applied models, e.g. M21 will not be identical with M2. This is where the information problem, which we want to deal with, comes from.

The question is, does it pay for entity 1 to learn the true model M2. If both entities can be treated like one, as was the case in the previous model, this issue cannot be discussed. Let us furthermore assume, that the distribution of a common output, as discussed in the first model, is not the problem to be solved. There do exist generally accepted rules, specifying a well-defined amount of output for each entity for any given combination of controls. These rules are called payoff functions. It is important to appreciate the special flavour of such a setting. Entities are independent from each other as soon as controls are set. Each one can be sure to get its share. But by the choice of their control variable they influence their own payoff as well as the other entities payoff. To keep things simple, assume that each entity knows its payoff function.

[3.1]

$$z_1 = w_1 + \alpha_1 u_1 + \beta_1 u_2 \quad (\text{payoff function of entity 1})$$

$$z_2 = w_2 + \alpha_2 u_1 + \beta_2 u_2 \quad (\text{payoff function of entity 2})$$

The models in scheme 4, therefore have to be reinterpreted as payoff functions. Again a situation, where all control coefficients have the same sign, is not very interesting. Both entities will use their controls in the same way. If the sign of the control coefficients in M21 and M12 is correct, then it is pointless for the entities to acquire any information about the true model of the other one.

The more interesting cases evidently are those, which are extensively discussed in game theory. In particular the famous "prisoners' dilemma" (see for example [A.Rappaport, 1960]) can be considered as a special case of the framework given above:

In principle two additional sets of assumptions are necessary to define a "prisoners' dilemma" in the current context. The first set is a constraint on the coefficients α_i and β_i , the second one consists of assumptions about the identity of models.

The basic idea of a "prisoners' dilemma" is, that entities expect a payoff matrix of the following form:

Entity 1:

	u21=1	u21=0
u1=1	z1A, z2A	z1B, z2B
u1=0	z1C, z2C	z1D, z2D

With $z1C > z1A > z1D > z1B$ and $z2B > z2A > z2D > z2C$.

Entity 2:

	u2=1	u2=0
u12=1	z1A, z2A	z1B, z2B
u12=0	z1C, z2C	z1D, z2D

Again with $z1C > z1A > z1D > z1B$ and $z2B > z2A > z2D > z2C$.

Assume we start in point D. In this case a Pareto-improvement from point D to point A is possible but unlikely to happen as long as each entity has reason for mistrust. But even if A is achieved, a one-sided deviation from A would be beneficial for each party and anticipating such behaviour would lead to point D again. Point D is stable in the sense of Nash: For both entities the following statement is true. Given, that the other entity does not change its behaviour, there is no way to improve the own payoff.

Using the linear functions [3.1] the restrictions on payoffs translate into the following inequalities:

[3.2]

$$\alpha_1 < 0$$

$$\beta_1 > -\alpha_1 \quad (=> \beta_1 > 0)$$

$$\alpha_2 > -\beta_2 \quad (=> \alpha_2 > 0)$$

$$\beta_2 < 0$$

This is the first set of assumptions on linear payoff functions necessary to arrive at the classical "prisoners' dilemma". The second set assumes, that the models used by entities are known by both and are correct, in other words identical to the real world model. That is

[3.3]

$$M_{21} = M_{22} = M_{20} =: M_2$$

$$M_{12} = M_{11} = M_{10} =: M_1$$

Now assume without further loss of generality, that $w_1 = w_2 = 0$ and consider the decision problem of entity 1. [3.1] now reads

$$[3.4] \quad M_1: \quad z_1 = \alpha_1 u_1 + \beta_1 u_{21}$$

$$[3.5] \quad M_2: \quad z_2 = \alpha_2 u_{12} + \beta_2 u_2$$

Conditions [3.2] lead to a very suggestive interpretation. If entity 1 considers the second term of the right hand side of its payoff function as exogeneously given, then the negative sign of α_1 will always cause a choice of u_1 equal to zero. In other words, if the influence of the other entity is considered as an exogeneously determined "natural" event, like w_1 , then u_1 equals zero.

The special feature of this example of course consists of the possibility to improve on this outcome if entities are able to communicate in a way, that allows for a binding agreement. Since the damage that entity 1 causes to its own payoff by the choice of $u_1=1$ is less than the benefit it gains by entity 2 setting $u_2=1$ and since the analog argument is true for entity 2, it might pay for both entities to start cooperation. Instead of using only its own model M_1 entity 1 now can set u_{21} equal to u_2 , use M_2 to solve [3.5] for u_2 and substitute in [3.4]. This yields

$$[3.6] \quad z_1 = \alpha_1 u_1 + (\beta_1/\beta_2) z_2 - (\alpha_2 \beta_1/\beta_2) u_{12}$$

Again communication can be interrupted, if entity 2 thinks that entity 1 sets its control to zero ($u_{12}=0$) and entity 1 anticipates such a behaviour in maximizing its payoff only

with respect to the first two terms of the right hand side of [3.6]. The disastrous result would be, that the suspicion of entity 2 would prove true. This is exactly the story of the Nash-equilibrium given above.

Only if gain from cooperation is strong enough to guarantee that entities stick to their commitments, only then u_1 will be equal to u_{12} and [3.6] can be written as

$$[3.7] \quad z_1 = (\alpha_1 - \alpha_2 \beta_1 / \beta_2) u_1 + (\beta_1 / \beta_2) z_2$$

Using conditions [3.2] the first term on the right hand side of [3.7] now surely is positive leading to u_1 equal 1. Due to symmetry the same is true for entity 2.

The special features of the "prisoners' dilemma" allow for a most interesting interpretation, namely the evolution of language and cooperation as a result of output maximizing behaviour. Only in anticipating the other entities behaviour, using its model, and in communicating and creating trust, only with this whole variety of social actions, entities will be able to attain the Pareto optimum. Even if this optimum is reached for some period a single deviation of one partner might destruct it and might possibly drive the game to the less favourable Nash-equilibrium. Studying iterated evolutionary games of this type for large populations and setting appropriate limits to the survival of entities, simulation scenarios can be constructed, which select only cooperative entities as survivors.

Cooperation and communication are closely linked actions in this parable. Both concepts can be defined very precisely. *Cooperation* means, that entities choose Pareto-optimal control variables, though this choice is not optimal in the sense of Nash. *Communication* means, that cooperation evolves via the use and exchange of models, via "language", as the example above shows. Though the emergence of groups with cooperation and communication can be viewed as pure "survival of the fittest" for certain environmental conditions, it does not need "nature" to extinct the unfit as soon as communication techniques allow for some kind of enforcement of traditional behaviour. The deviating entity need not be punished by "nature" but by the group, whose rule-system it ignored. Traditional societies in the sense of Rostock [W.Rostock, 1960] are excellent examples for this metaphor.

Coming back to information cost arguments, it could be held, that the gain from the use of models, which in the example simply is the difference between Pareto-optimal payoff

and Nash-equilibrium payoff, must be greater than the total cost of setting up the more complicated model [3.7], store it, process it, that is, communicate it and agree upon cooperative behaviour. The last cost item sometimes is called contract cost. Now it is easy to see, why the infinite regress of scheme 4 will eventually stop. In the case of the classical "prisoners' dilemma" the use of more complicated models than [3.7] does not affect the gain from cooperation. It does not lower contract cost either. But it will increase information setup cost and storage cost. This net loss is the reason why it will not be carried out.

In more complicated situations, where entities and their contractional capacities are more structured, the optimal recursive depth of models can be higher. Clearly, it never will be infinite, since no final gain could exceed infinite cost.

Reconsidering scheme 2, one finds that models of the type just discussed belong to cases V and VI. Pure introspection, case V, only works if all entities have the same payoff function, or in a more economic jargon, if a representative entity is assumed. Since such assumptions are unrealistic, for any useful simulation model case VI seems to be more appropriate.

The full range of information production and acquisition comes into play if case VII of scheme 2 is the point of departure. What would a compressed model of an entity, which uses all major types of information production and acquisition look like. Let us just give a rough outline of such a model:

At its simplest stage an entity would only acquire information. Unexpected outcomes of its activities will motivate "research" to improve its performance. To investigate in the mechanics of real world processes has been summarized in the previous models by the use of variable w . Learning of w is a stylized way of describing the whole process of applied natural science. Thus the contribution of w consists not only of stochastically appearing "fruits of nature", but also of all well-understood physical processes used by the entity in a systematic way to enhance output. This type of knowledge will be labelled "technique of production". Physical laws used by techniques of production can only be discovered, that means acquired, they can not be produced.

On the other hand activities like "research" imply an entity, that consists of a greater number of human individuals. As argued above the inner structure of such an entity is characterized by cooperation and communication. All the evils of the purposeful

production of wrong or one-sided models, as described above, immediately enter the scene from within the community, the entity. Acquisition and production of information are no chronologically successive stages of information processing, they appear simultaneous.

Their common root, which in a certain sense is the root of the whole concept of information, is hidden in the process of copying. As physical laws are copied to formal relationships, which can be used to control the output via instrumental variables, so are behavioural rules within societies copied by its members to sustain living. Of course, environmental conditions for the latter change much faster than they change for physics, where some relationships only break down if time or space approach infinity. As history shows, rule-sets for societies are less stable. Traditional copying behaviour periodically becomes inadequate, social innovation is a permanently reappearing, common phenomenon. The next chapter tries to dig deeper, to highlight some special features of the concept of "copy".

Chapter 3:

Understanding understanding¹

In this chapter it is argued, that the concept "copy", used as a verb and used as noun, is of crucial importance for understanding understanding. To do so, it first has to be discussed why people try to understand, what the underlying pragmatics are.

As described in the previous chapter social entities build models. That is, they use mental representations of their environment to forecast future states of this environment. Let me restate the basic procedure: In order to achieve certain values for some variables, usually called goals, they set certain other variables which they control, usually named instruments. Given, that the relations between goals and instruments, postulated as a model, which probably uses some auxiliary variables, hold in the future, the future settings of instruments will ensure goal achievement. Figure 4 gives a schematical representation of this idea².

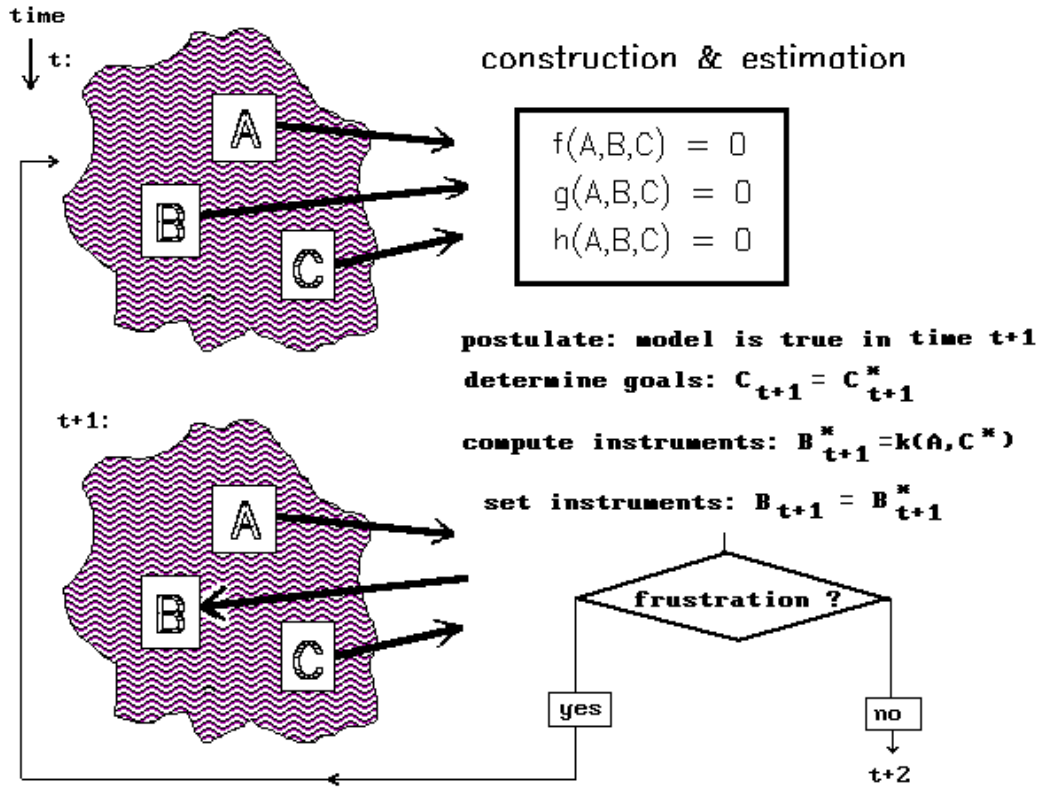
Let us translate this proposed process of model-building into the "language of copies" (I shall use the abbreviation LACO for this language). A model is a special type of copy of the environment. It does not simply double the environment allowing for an one-to-one relation, but condenses it to a threefold set of goals, instruments and auxiliary variables and their respective relationships. Only those parts are separated and included, which are thought to be *important*. As a consequence each such model has an in-built causation structure. Even if it consists only of interdependent goals and auxiliary variables, if there are no instruments to get hold of future developments, there still is the issue of complete impotence of the model builder, which might *cause* his retreat to

¹) The content of this chapter has been presented at the conference "Problems of Support, Survival and Culture" in Amsterdam, April 2-5, 1991 [Hanappi G., 1991a].

²) Though I do use mathematical models for all examples, this does not exclude any non-formal model-building from being covered by the argument. In my view mathematical languages are just a special subset of all languages. Their characteristic feature is to be deployed of all semantics to allow for an extremely rigid syntax. In other words, they only can be consistent, but never can give true statements in the synthetic sense. Since they do not strive for truth in the latter sense, they are extremely convenient for examples, where the methodological issue should not be confused with the truth of the sample statement.

metaphysical techniques³. The necessity of the causal character of models stems from the assumption that models are built to be applied⁴. I will return to this issue later.

Figure 4: Model-building



Turn now to the components of the model, the variables and their relations. Descartes invented the concept of a variable as a tool for formal arguments⁵. In LACO variables can be interpreted as inverted copies: A variable is a name for a changing value, its content. In a computer this name is an address and the value at that address is the current content of the variable. Both, address and content, usually are binary

³) This is the source of religion.

⁴) The way I define models emphasizes causality. Embedded in this overall causality are subsystems of auxiliary variables, systems lacking goals and instruments, whose dynamics therefore cannot be considered as causal. According to Mario Bunge these subsystems are characterized by a general determinism. Despite the validity of Bunge's distinction between causality and determinism for my view, I do reverse his opinion, that causal relations are just a subset of deterministic relations. In my approach non-causal systems are only auxiliary to higher-level causal systems (compare [Bunge M., 1959, pp.3-30])

⁵) Of course Descartes [Descartes R., 1980], as most inventors, only brought to the point what already was there. A new general concept usually just summarizes diverse existing practices. Scattered behavioural rules, known by different names, suddenly are seen under a common focus, enabling an immensely growing flow of exchange of experiences.

numbers. The essence of the whole exercise is, that one can use one of these numbers, the address, at different places of a program, or more generally speaking of an argument, without having to care about its changing content. So, while the content might assume many different binary numbers, these numbers will all be stored at the same address. This is possible since different values appear at the *same address* at *different times*. For a copy of a bit pattern the opposite is true: The same pattern is stored at *different addresses*, but at the *same time*. This is why I call a variable an inverted copy. While in a copy the address is different but the content is the same, a variable holds different contents at the same address, introducing the concept of time as a complement to space used in copying. Extending LACO one could say variables are copies over time: For each moment when the content is changed there is a contemporaneous copy of the same old address.

This whole story is used to describe the simultaneity of slow and fast moving processes. If "tree" is the name of a variable and "size" is a number describing the height of a certain tree, then the defining characteristic of the object, being tree for some decades, is retained even if its size changes continuously. The example shows, that in real processes the object described in a language as constant, as an address in a program, is just changing slow relative to fast changing special features, the "contents". This leads to the problem of the identification of variables.

Three types of variables have been distinguished: Instruments, goals and auxiliary variables. Whereas instruments and goals depend intimately on the subject of the whole action, the model-building entity, auxiliary variables are of a more technical nature. It is only the complexity of the real problem, that makes it necessary to insert them in between instruments and goals. Identification of instruments and goals should thus be somehow easier than identification of the auxiliary apparatus - at least if the entity under consideration, via *experience* and *introspection*, has access to its own *abilities* and *wishes*⁶.

At this stage of the argument two roads are open. On the one hand there appears the need for a more thorough discussion of the identification of auxiliary variables. In a sense this is the first step towards understanding of processes in the real world. Starting off with large samples of observables and assuming mostly linear relationships, this is the topic of several econometric techniques (principle components analysis, regression analysis, etc.) but also of "pattern recognition" as developed in computer science. On the

⁶) Chapter 5 will return to this point.

other hand the whole discussion shifts the role of the entity more and more towards the centre of the argument: It is not only the strong link between instruments, goals and the entity, that hints in this direction. The entire modelling process can be interpreted as a (higher level) instrument, meaning that even auxiliary components must be discussed under an instrumental perspective again closely bound to the nature of the entity.

Put in LACO, the first route is concerned with the ways in which copies, recurring patterns, can be detected in historical data records. The second approach tries to get closer to the concept of entity in stating, that variables, copies over time, are just copies of *consciousness*, which itself can be considered as a copy over time. Although there is a whole body of work along the lines mentioned as first approach, which badly needs a survey of achievements, the second route seems to be more innovative, even provocative, forcing me to concentrate on a defense and extension of this view. Perhaps a more elaborated view of the nature of copies might further our understanding of the emergence of auxiliary variables too.

Leaving the brain

There are many entry points for further discussion left open. The first one is the question of the selection of "*important* variables". What does the word "*important*" mean? Can we restate it in LACO? A second question concerns the duality between space and time as encountered in the explanation of variables. Is it really possible to dissolve Kants' transcendental a priori, time and space⁷, in a common LACOnic concept? What are the consequences? This leads to question three: "*What is consciousness?*", and further on to question four: "*Whose consciousness?*". Almost lost between these heavy weights, there is a seemingly easy one: "Considering whole models as instruments, is there a meta-model? Does this meta-model, like an enlarged copy of the original model, again consist of instruments (original models), auxiliary models and goals?".

Some preliminary answers to these last questions can be given, if one starts to be more specific about entities. Up to this point most readers probably will have thought "entity" simply stands for "human individual", "person". As I will argue in part II, it is important to subsume various types of actors (e.g. plants, animals, persons, production units, states, society) under this common header. If one accepts, that "models are built to be applied", then the nature of a model depends to a certain degree on the entity that is

⁷) Compare [Kant I., 1980 (1781)].

using it. Single citizens usually don't use large macroeconomic models for their everyday decisions. The information structures used as internal "models" in plants are radically different from market models used by firms - if one is ready to admit the name "model" for internal information structures of primitive forms of life at all.

Going up the evolutionary scale, model building is getting more and more complex⁸. As Erwin Schrödinger argued a long time ago, the size of an organism plays a distinctive role for its ability to perceive "laws"⁹. But it is not only the size of a model that counts: General Motors uses a set of models, whose size might well be big enough to match the requirements of a planning model for a small state like Austria. But is a state just a production unit? A state seems to be an entity, which covers more aspects of the life of its citizens than a single firm does. It is more "integrated", as I would call it¹⁰.

This can be made a general point: The further up the evolutionary scale, the stronger integrated the entity seems to be. Like all synthetic judgements this is only true in *grosso modo*. Moreover the most striking feature of this long-run process is its stepwise character, evolution seems to work itself through succeeding levels of relative stability. Many different single-cell organisms¹¹ are followed by organisms consisting of a huge number of cells. Animal species without strong inter-species links within a relatively short transition time gave way to human "societies", where language and culture pushed integration to a new level. From local groups of hunters via countries and states to hemispheres, there are now 5 billion people waiting for ever new steps of integration. For each stage of integration there has been its own type of consciousness of the entity, of intelligence¹² and understanding.

It might well be asked: After all this heterogeneity of entities, is there still room for common features? Let me use LACO again to stress three of them.

⁸) The hotly debated notion of complexity (see for example [Casti J., 1979] and [Blaseio H., 1986]) in this context only refers to the sharply increasing amount of variables and their relations, that enters the model.

⁹) According to Schrödinger, purposeful action based on "natural" laws could only be developed by organisms consisting of an immense number of atoms, because only in this way the irregularities described by quantum theory are levelled out. The emerging "order" in the brain enables to perceive order in the environment - quantum jumps are irrelevant for understanding understanding [Schrödinger E., 1944].

¹⁰) See [Hanappi G., 1989a] for an extended treatment of "integrated capitalism".

¹¹) The origin of life might even be backdated to "crystal genes", using a completely different carrier system (certain types of crystals) as all familiar forms of organisms. (see [Cairns-Smith A.G., 1985])

¹²) "Social Intelligence Support" emphasized in part II, aims at shifting cybernetic support towards more integrated entities.

As modern sociobiology¹³ rightly never ends to propagate (and wrongly tries to establish as only and absolute prime mover of all action): From crystal genes to mankind there is a tendency towards replication, towards the production of copies.

Second, "consciousness" can be described in a specific way common to all entities (compare figure 5). Drawing on my explanation of variables, and assuming that variables are just copies of the consciousness of the entity onto an external object, we are in a position to retell the story of the duality of time and space as a metaphor in LACO. Each rectangle in figure 5 represents a microstructure, say the smallest unit of a crystal, a cell of a body or a person in society. The number in the rectangle characterizes its specific state, the small number above the rectangle its location, its address. The just mentioned tendency towards the production of copies is represented as the growth of a horizontal row of rectangles with the same content, but different addresses. This is the dimension of space. Moving down a column shows different contents at the same address, a variable or, as just mentioned, the archetype of consciousness¹⁴. This is the dimension of time, which therefore is indissoluble twinned with consciousness.

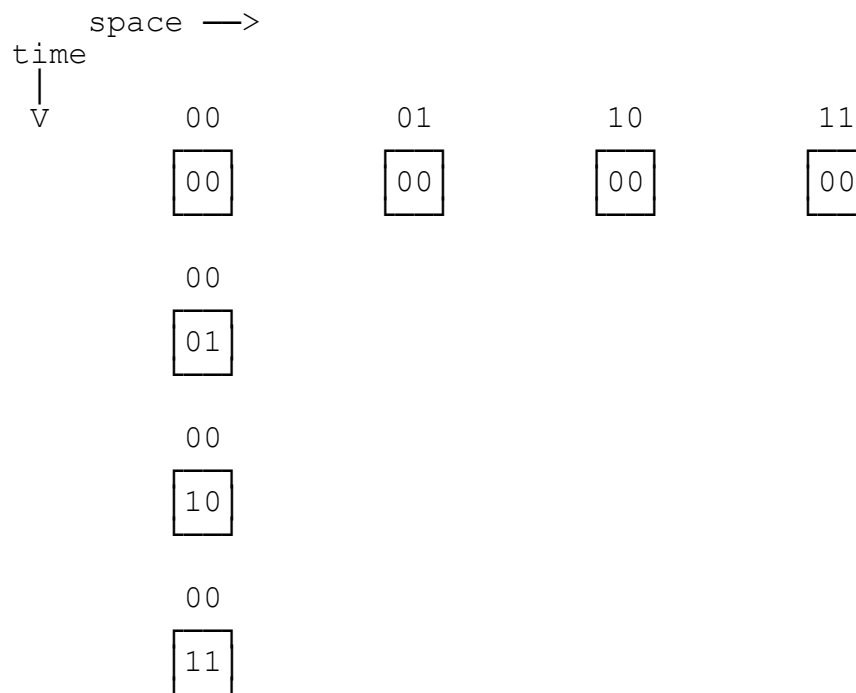
From a formal point of view it is evident, how consciousness can be derived from the tendency to copy: exchange address and content. Daring a little bit more interpretation, one could say, that a set of rectangles with the same content, a row¹⁵, assumes its content as its name, i.e. its address, and considers the different locations as its (spatial) content, vulgo its body. It is a question for (micro)biologists, and goes far beyond the scope of this book, if this metaphor makes sense for the explanation of the origin of life. Let me nevertheless expand it even more to say a few words on the concept of "memory".

¹³) In my view, this is the major general result to be found in sociobiological reasoning. (see [Wilson E.O., 1975])

¹⁴) In this very simplistic and rough form consciousness, the ego, only consists of "being the same" (address), while always changing (content). Curiously enough, the notion of contradiction seems to be closer to this archetype than the standards of formal logic.

¹⁵) Remember Schrödingers remark on relative size, mentioned above. Only beyond a critical number of copies "lawful" behaviour can be expected. But relative size is only a necessary condition. Does there exist a *sufficient* condition for the reorganisation of a bunch of copies into an integrated higher level entity? The pragmatic role of necessary conditions is passive, they refer to the results of conventional growth, whereas the role of a sufficient condition, at least for higher organisms, will be active: If the micro-units are able to use their instruments to meet this condition, they will pass to the new stage.

Figure 5: Time and space copies



Imagine a set of micro-units, a "body", in an environment which influences it different at its opposite sides. Since there is always interaction between units at the border of the "body" and the environment, this imprint of the outside on the microstructures may have different effects. Either it destroys the structures or hinders their tendency to replication or it furthers this tendency. If there is a positive influence on one side and a negative one on the other the different speed of growth by copying will move the "body" in the "positive" direction¹⁶. But the positive imprint on some outer micro-units means a slight change of structure which via faster copying now is propagated in the new growing areas. Of course there still will be some part of the "body", whose structure corresponds to an older environment. One could say it "remembers" the old environment in the form of its reaction (in this example its copying speed) to it. If environment changes often enough, but soft enough to prevent extinction, then there will be different strata of units with slightly different structure representing different "experiences", archetypes of memory. Jumping back to the human brain for a moment recent neurophysiological research underlines the view of memory as a library of basic reactions to environment¹⁷. Of course there must have been a long way from

¹⁶) Such a process of positive influence usually is described as a metabolism to extract neg-entropy from the environment.

¹⁷) "Neural Darwinism" as propagated by Edgar Edelman and Israel Rosenfield claims to give "a new view of the brain", which is very much in line with my metaphor (compare [Rosenfield I., 1988]).

archetypical "memories" to the ability of a human baby to maintain variables¹⁸ as described by Piaget [J.Piaget, 1970]. And again the real work is to trace things back to the physical, atomistic processes - and to the specific evolutionary twists that provoke new levels. Nevertheless there seems to be something to the proposed metaphor.

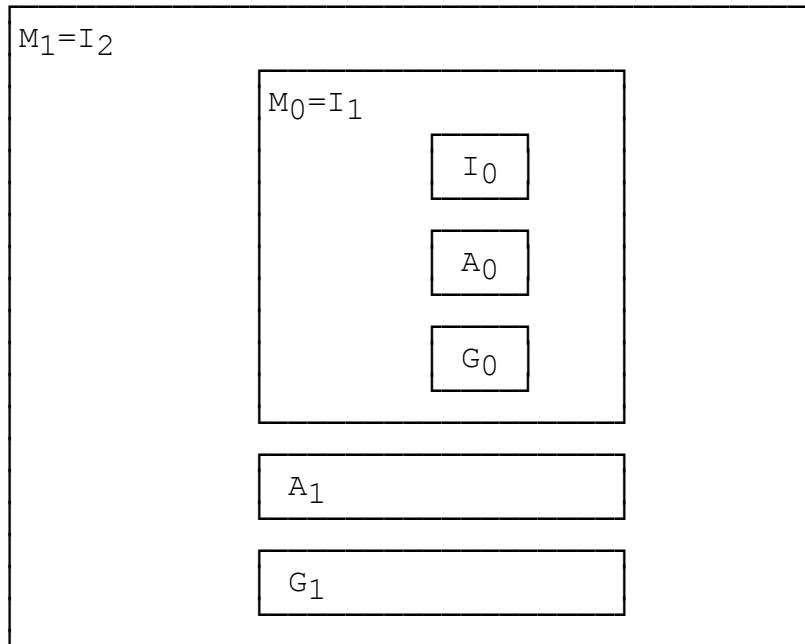
The third reason for a general concept of entity is to discuss goal driven processes from a more general point of view. As touched upon earlier, the entire model-building activity can be interpreted as an instrument in a more general setting. As represented in figure 6 model-building at level 0, called M_0 , is an instrument at level 1, called I_1 . M_0 consists of instrumental variables I_0 , an auxiliary model A_0 and goal variables G_0 . This is by now familiar. But talking about the whole process M_0 as an instrument I_1 means to construct a model M_1 . Again this meta-model should consist of three components:

- A set of instruments, where model-building is just one of them. Other instruments could be direct, affective controls of environment.
- An auxiliary model of the world, which could, but need not¹⁹, contain A_0 as a subset. A_1 should cover all links between I_1 and G_1 . Since both sets usually should be larger than on level 0 it follows, that A_1 probably will be much larger than A_0 .
- A set of goals that the model-builder of M_1 ascribes to the model-builder at level 0. If G_1 is not equal to G_0 , then model-builder 1 assumes, that model-builder 0 has goals he is not aware of (G_1 greater G_0) or tries to achieve things which are not really goals (G_0 greater G_1).

¹⁸) These LACO-variables now contain perception-reaction contents: The baby smiles if it sees fathers face.

¹⁹) One might as well suggest, that the entities building M_0 use "wrong", or at least different models of reality.

Figure 6: Model components



I_i instruments at level i

A_i auxiliary models at level i

G_i goals at level i

M_i models at level i

Thinking of the evolution of ever more integrated entities one might well suggest that M_1 is the model of a micro-unit and perhaps again just an instrument I_2 with respect to the higher level entity. In a similar way one could dig deeper in the structure of I_0 . What we get, and figure 6 shows it, is a set of zoomed copies, where one can find the same (threefold) structure in an element (Instruments) at all levels²⁰. As an algorithm such a structure is called recursive, and, as anybody acquainted with compilers knows, it is usually solved by a transformation into sequential copies. The most important thing for a programmer is, that these copies should not be exact copies to avoid infinite regress. There must be a stop condition met in one of the (recursive) copies after a finite recursion depth. So there must be something changing from copy to copy (stop condition true in all copies does not make sense), but it still must be copies. We had a situation like this just before, when discussing memory: micro-units must maintain their

²⁰) The perception of self-similarity (zoomed copies in LACO) in nature has been one of the starting points for fractal geometry. There seems to be some congruence to ideas presented here. As Heinz-Otto Peitgen, one of the prominent proponents of fractal geometry once remarked, recursive procedures might be the clue to explain the enormous storage capacity of human brains. In his lectures he uses a simple recursive model of copying machines to explain the basics of fractals [H.-O. Peitgen, 1986].

general structure to stay parts of the "body", but at the same time they must be able to absorb perception-reaction experiences as slight changes of this structure. Perfect copies without memory correspond to infinite regress in recursions, to never ending loops of the same story. So the idea of memory, as well as the idea of finite self-similarity leads to the concept of mutation.

Leaving the mirror

In a small paper called "On Mirrors and other Phenomena" Umberto Eco discusses the question if mirrors are signs, if they are capable of semiosis²¹. He concludes, that they are not, simply because they do not interpret, they just produce exact, bijective copies. In other words, mirrors (exact copies) are in general not useful for model-building²². They lack the threefold, self-similar structure of the model-builder as shown in figure 6. Looking back to the beginning of this chapter, it can be seen, that this point was made implicitly, when I insisted that models consist only of those components of the environment, that are thought to be essential. "Essential", translated in LACO, means again, that the structure to be modelled must be copied into the model - but slightly modified: Only those aspects are included that memory and current environment select as useful in the sense of instruments-goals and perception-reaction. As a consequence models are not exact copies, they are mutations. As the evolutionary view, presented in chapter 1, has it, all mutations are subjected to survival tests by the environment. Models as mutations are no exception to this formula.

Where do these mutations come from? One of the more recent, and more exciting findings of recent research in biology is, that it is not only the environment (plus some probability distributions), which is responsible for mutations. First it has to be stated, that there is room for a certain level of mutations, for an average deviance. This room has been "selected by nature" to be appropriate for flexible response to changing environments. Indeed, even the emergence of different sexes has been

²¹) In the context of this book semiosis can be taken to mean "usage as a model". For a more precise definition see [U.Eco, 1990].

²²) In Axelrod's famous computer tournament for iterative prisoners dilemma games [R. Axelrod, 1984] "tit-for-tat", a simple strategy based mainly on copying exactly the opponents past behaviour, turned out to be the all-time winner. It is remarkable that simple copying can solve an information problem that emerges from a specific pay-off structure in such a superior way. In my view these experiments shed more light on the origin of language (exchange of copies in LACO) than on the evolution of cooperation (in the everyday meaning of the word), since informational isolation of the players is an in-built assumption of the game. Two deaf and dumb prisoners try to speak via their actions, and this physical language turns out to be a kind of LACO for a certain, problematic incentive structure. In any case the setting of the experiment seems to be too archaic to induce mutations.

explained that way [Smith J.M., 1982, pp.123-139]. Given this necessity, more developed entities started to initiate their own mutations. Perhaps this is a possible explanation for the attractiveness of alternate social systems, for the arts, for many types of seemingly irrational, deviant behaviour in modern cultures²³.

Conclusion

Despite this overwhelming importance of *modified* copies, there seems to be one moment in the life of a human individual, where a simple mirror assumes the role of sign. As Eco, referring to Lacan, states, the baby that is not aware of its own body uses its first encounters with a mirror to assemble it from its components²⁴. Does this observation hold if we consider more integrated entities like the global society. Is there also a time in the early stage of this entity, where a mirror, a faithful collection of all the abilities of the new entity, would help to constitute it²⁵. I am inclined to support this view. Of course, human babies can grow up without mirrors, as early life forms developed without intentional mutation. But what an acceleration in qualitative improvements occurred, when this stage was overcome.

Let alone this immediate task, the use of LACO, in my view, has been quite useful. Of course LACO itself, as any language, can be considered as a special tool-set for model-building. Another model, another mutated copy, increases flexibility in times of terminological crisis, which is good, but at the same time has to stand the tests of applied research in the concerned fields, which is a challenge for the future.

Understanding understanding can be accomplished, if it is possible to specify the stepwise evolution of copying processes. To do so it needs "overlapping specialists" from all fields concerned. The (opportunity) cost of "overlapping knowledge" is high, but, as the history of science shows, the gain is invaluable.

²³) In chapter 2 such seemingly deviating behaviour has been "rationalized" as "making experiments". Now it can be seen, that what might look irrational at level 0 in figure 6, perhaps makes perfect sense at level 1.

²⁴) This is why he calls a mirror a "phenomenon at the margin".

²⁵) Some will be reminded of the complementary remark of another famous man, who said, that an *aging* society could be lead to break-down if it looks in a mirror.

PART II

Pragmatics - methodology

Chapter 4:

The Crisis in Artificial Intelligence¹

In part I evolutionism in the social sciences, labelled E.T.II in chapter 1, has been approached from different sides to give at least a vague idea of its meaning. Several conclusions have been drawn. The distinctive feature of social mutations has been found to be their ability to be partially directed by design (chapter 1). Since any design needs information processing, chapter 2 took a closer look at the emergence of information. Using stylized models of optimizing economic agents, the development of a common language as part of cooperation can be shown to be economically superior² given certain types of environments. This proposed genesis of information processing is tightly wound up with the genesis of social entities characterized by their inner structure of cooperative production. Chapter 3 tries to enrich this idea and to extend it in two directions.

On the one hand a very strong hypothesis is put forward, namely, that a certain type of operation, copying, is most basic for the understanding of all epiphenomena of life - including information processing. Mutations are just copies with more or less directed little errors.

On the other hand a trend towards larger and more integrated social entities can be found in the historical record. The birth of a new entity coincides with its awareness of its elements, concerning information processing this is the birth of new concepts. In this sense the two extensions are linked³.

Mainstream economic theory has been criticized profoundly because of its use of stylized, representative economic agents. Evolutionary theory, E.T.2, extends this criticism in pointing at alternatives: Models of social entities have to be substantially richer. They have to include how these entities perceive themselves, how they perceive their environment, how they perceive other social entities, how they learn and how their

¹) The major part of this chapter has been published in [Hanappi G./Grechenig T., 1988].

²) The analytical notion of Pareto optimality can easily be transformed in a synthetic judgement. Either natural selection, selection by market forces or a designing entity can be postulated to explain the current state of affairs. In my view each explanation is appropriate as dominant force of certain historical periods.

³) It is a striking fact, that copying processes dominate our lives as soon as we have the copy concept at hand to realize them. Indeed, I hope, that many copies of this book are sold to propagate this concept.

whole information processing is restricted by their finite capacities. This program goes far beyond the scope of traditional economics. It rather reminds on the questions investigated by a young sub-discipline of computer science: artificial intelligence.

The recent boom in the popularization of artificial intelligence concepts via books, software and other media has been accompanied by a remarkable amount of rather disappointed statements of the major specialists in the field. Not only well-known sceptics like Weizenbaum and Dreyfus, but such eminent promoters as Marvin Minsky seem to doubt at least the speed of the accomplishment of the unfulfilled promises of earlier research⁴. As I will argue below, these doubts indicate a problem which is rooted even deeper than these critics assume, namely in the very basic concepts used by artificial intelligence research. Nevertheless I do not share the generalistic view, that A.I. research has to fail anyway, because "it is trying something impossible", because there are things, that simply cannot be modelled. Some current impasses can be shown to be rather irrelevant by reformulating the theoretical apparatus appropriately. To demonstrate this, let me start with an extremely parsimonial system of variables and relations, which I consider to be at the heart of most of mainstream A.I. research.

A stylized world of artificial intelligence

The major ideas of A.I. prophets and researchers can be captured by the use of the following interrelated terms:

Knowledge is considered like the stock variables in economics⁵. That is, it is measurable at each point in time⁶. There has been a long and not very conclusive discussion on the nature of knowledge, on what it is, that actually is measured. In most practical cases the measure simply is assumed to be the number of concepts, facts and procedures an *entity* has at command.

⁴) "My point is that there is very little basic research going on right now. The general principles of most of the expert systems being made today are very close to the specifications published in Alan Newell and Herbert Simons *Human Problem Solving* over ten years ago. The procedures described in their book descend from ideas that appeared in Henry Ernst's robotics program in 1960." M.Minsky in [Winston H./Prendergast K. (eds.), 1984, p.246].

"It might be fifty years, or twenty five, before a few great ideas produce remarkable improvements in intelligence." [M.Minsky, 1984, p.253]

⁵) Knowledge representation and acquisition has been the major theme of A.I. research in the eighties. It also occupies a central part in newer introductory text books (see for example [E.Rich, 1983]). I think this is more than a fashion. The concept "knowledge" indeed is the cornerstone of a theory of intelligence, the one to start with.

⁶) Note that in the macroeconomic models of chapter 8 the stock of knowledge concept enters in precisely the same way as the capital stock.

Closely connected to the concept of knowledge is the concept of *information*. Let me define it for the current purpose simply as the time derivative of knowledge. In other words, information is a flow variable denominating portions of knowledge the entity acquires or loses within a certain time span.

Changing the stock of knowledge, acquiring new information and forgetting old information, is a specific activity of the entity usually called *learning*. Note that this definition of learning in no way implies a "growth" of knowledge comparable to the growth of physical quantities⁷. Note also, that in traditional A.I. there is no correlate to our notion of information production developed in chapter 2. Artificial entities do not change the stock of knowledge of other artificial entities to achieve their goals.

To investigate further what constitutes in A.I. terms information for the entity we have to take a closer look at the process of learning. Being a specific element in the wider range of activities of the entity, learning is always bound to other activities, which are not learning. These other activities include the use of the old stock of knowledge, giving it a certain inertia, as well as interactions with the world exterior to the entity. If we assume, that there exist for each entity distinguishable subsets of activities that are in a closer connection with each other than with the respective rest of activities these subsets can be conceived by the entity as such. They will be given a name connected to the task they are directed to. In the A.I. vocabulary such a task is named problem and the set of activities is labelled "*problem solving*"⁸.

Finally an entity whose problem solving capacity enables learning is considered as *intelligent*⁹. If the entity is a machine this capacity is named artificial intelligence. Figure 7 shows a schematic presentation of the system¹⁰.

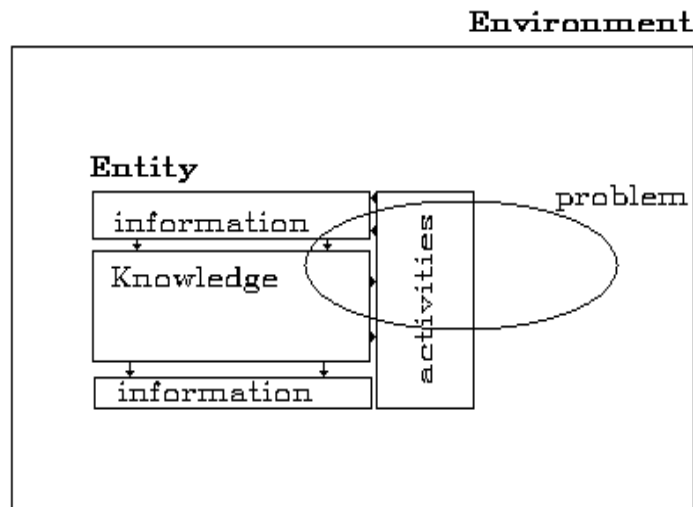
⁷) A growth of knowledge cannot be defined independent of a choice of entities and problems. The only thing we can say about two stocks of knowledge is, that they are different or that they are not. In the same sense our notion of learning is more general and different from the one that goes with the positive connotation of a growth of knowledge, which always refers to specific problems and entities. Recent work in the philosophy of science shares this view: "Whereas logical empiricists concerned themselves with the elaboration of universal models and procedural rules which they believed aptly characterized legitimate scientific practice, post-positivists emphasize the growth of knowledge over time, the dynamics of change within individual disciplines, and the actual practices of scientists." [B.Caldwell, 1982, p.68]

⁸) "Implicit in any theory of learning is a motivational assumption that learning consists in the acquisition of a pattern of behavior appropriate to *goal achievement, need reduction, or the like*." [H.Simon, 1982, p.269].

⁹) Note that in this definition intelligence is linked to learning. An entity performing mechanisms based on a snapshot of a given stock of knowledge, such as many non-learning chess programs, do not qualify as intelligent.

¹⁰) The further division of problem solving is quite common (see for example [E.Charniak/D.McDermott, 1985]).

Figure 7: The stylized world of artificial intelligence



Time and entity

As can easily be seen the concept of an entity interacting with an exterior world is crucial for all parts of the system described above. Of course "interaction" itself is a complicated concept, that is not sufficiently described by assuming that interactions in principle can be grouped in "problems" according to the tasks of the entity. Indeed, the concept of "interaction" always implies the two interwoven concepts of "entity" and "time". Sometimes the usage of the concept "interaction" can hide the implicit assumptions on "entity" and "time" on which it is based. So let me state them explicitly:

An "entity" is characterized as a continuum within an ever changing surrounding, compare chapter 3. The contradiction between its own, constantly existing conscience and the changing exterior is experienced by the entity as "time". That is, the concept "time", like all concepts, is timeless - an attempt to fix the experienced contradiction in a form similar to the entities own existence¹¹. In this sense even if an entity uses what is usually called a "dynamic model", a model in which time spans between variables appear explicitly, one should still consider it as a *timeless structure*,

¹¹) Expounding LACO: concepts are copies of an entities conscience, used by the entity to conserve experienced important interaction with the environment in its memory.

because the *relative* time between variables exorcizes the inherent spell of contradiction¹² from our previously defined notion of time.

Relative time also plays an important role in the form of the speed of learning activities of an entity. Learning, that is the adaption of structures to a changing environment, must be fast enough to allow for a certain control of the entities activities. On the other hand each structure, by definition, has to contain elements of constancy to permit forecasting. If the speed of learning relative to the speed of environmental changes decreases, learning becomes more *urgent*.

Summarizing the argument: intelligent entities, in the above defined sense, might use what some A.I. researchers call *structures*¹³ (and what was called "models" in previous chapters) to support their interactions with the exterior world. Adaption of timeless structures to a changing environment should be fast enough - otherwise learning would not qualify as a task oriented activity.

Let us leave this condensed version of the "Sprachspiel" of the artificial intelligence research at this point and let me ask two closely linked questions:

A) What is to be considered as entity?

B) What is a "problem"?

Evidently if one of the two questions is answered the possible answers to the other one are considerably narrowed. So which one is to be answered first?

Problem oriented research programs

If one starts with question B, and the overwhelming majority of the A.I. research follows this path, one probably will construct a classification system of possible problems. Next one will ask: Is it possible to build machines, that solve problems? Following the bottom-up approach, the methodology usually preferred by engineers and technical intelligence, one then will start with the simplest problems and by and by will try to combine solutions to solve more complex problems¹⁴. But what are the simplest problems?

¹²) Consciousness itself is the prime reason for the contradiction between experienced constancy of the entity and the simultaneous change of *everything else*.

¹³) In the A.I. world these structures sometimes are called "predefined sets of categories". Narrowing down all knowledge to collections of structures corresponds to the project of French Structuralism.

¹⁴) A good book written in this vein is [R.Banerji, 1980].

According to the previous argument the art of learning consists in the capacity to cast a problem into a structure. The most primitive problems therefore should be those already existing in structural form, for example as a strategic game in extensive form. Indeed one could argue that solutions of this type of problems are just a prelude to problem solving.

Having settled the question of what constitutes a problem, one immediately can derive the entity under consideration. If, for example, chess playing is chosen as problem, then the abstract entity "chess player" has a concrete counterpart in the entities of chess playing individuals. Possible types of algorithms for learning and structures for information and knowledge representation could be derived from the characteristics of the entity. In particular one could try to simulate features of human chess players on machines.

To advance from such simple problems to more complex ones has proven to be extremely difficult¹⁵. In fact, it is hard to see, why a solution in the well defined world of chess playing should in general enhance our ability to find solutions for other, more complex strategic games. There is no "general problem solving", but only "particular problem solving".

As the last comparison shows, one must be very careful in stepping from one problem to the next. The prescription to start with simple problems is not a sufficient guide to a successful research program - at least that seems to be the lesson of A.I. research in the seventies.

Entity oriented research programs

Alternatively one could start with an answer to question A, and it is tempting to try an extensional definition of possible entities: plants, animals, human individuals, groups, firms, classes, nations, human society. Evidently the choice of a certain entity again determines problems as well as what is meant by the proposed A.I. vocabulary. Now imagine, that there exist relations between entities. A very special relation is important for our argument: The central idea of A.I. in this orientation would read as the project to *construct* entities, machines, that could be used as *tools* by other entities.

¹⁵) For examples of these difficulties see [Winograd, 1972] (as cited in [Boden M., 1977]) and [H.Dreyfus, 1972].

At first sight the choice of entity seems to be arbitrary. Firms need other tools for their objectives than human individuals would construct for their tasks. As in the problem-oriented approach, we seem to be back at the old problem: the heterogeneity of possible applications seems to hinder any unifying research program. But do we need such a unified view at all? Isn't it enough to construct tool after tool, solve case after case, without too much connection between them¹⁶? In contrast to the problem-oriented approach this indeed is a valid, preliminary research strategy in the entity-oriented approach. In following this strategy, one even could hope, that general principles might somehow emerge out of the bunch of heterogeneous applications.

Nevertheless this strategy is preliminary, because the "vision" of a science, the final goal it tries to achieve, is a most important stimulus and, in allocating research funds, usually determines the direction of future research. In the long run research that does not specify its "vision" will hardly succeed to convince its supporters of its usefulness. The term "artificial intelligence" itself is the best example for the suggestive use of the connotation of words - and it was a tremendous success in allocating research funds. Unfortunately "visions" also can be misspecified and should be revised, which in my view is one of the main problems in A.I.research.

To see this, let me apply a trick: the special topic allows me to feed it back into its own content. Let me consider the whole A.I.business as one piece of information added to the existing knowledge. The genesis of A.I.research then reveals the entity under consideration. Evidently the project "artificial intelligence" has been, and for the greatest part still is a national project. Considered as a "tool", or in modern terminology as a "device", used by the U.S., its genesis can to a greater part be explained according to certain military needs of the nation, or should we rather say of its ruling class. In a friendlier view one could introduce "human society" or the "international scientific community" as relevant entities promoting A.I. research. Although this solution seems to be less convincing as far as the history of A.I. research is concerned, there seems to be some scope for a change of the relevant entity in the future.

Coming back to the question of **misspecification**, I am now in a position to define what this term in my context means: Given a national task, and the interdependence of modern societies has reached a level that practically all major questions (employment, wage, environmental problems, cultural problems, etc.) can only be solved on a national, if not an international basis, A.I. research fell back on bad

¹⁶) For an illustration of this research strategy at the MIT see [Winston P./Prendergast K., 1984, p.3].

old methodology emphasizing the human individual as the only relevant starting point for all social problems. In doing so, this type of research necessarily got stuck in the same old questions in which methodological individualism, applied mainly in the social sciences, agonizes since hundred years. Remember part I of this book, the problems now only have new names. So misspecification simply means a mismatch of method and object to be studied, of tool and material to be worked on. There is no way for a hammer to be a usefull tool if a nation needs some rules to determine its exchange rate. Even a most sophisticated combination of hammers probably would not contribute to the solution of the problem - although an interesting discussion on the possible applications of hammer machines might arise. Economists discussing "applied general equilibrium theory".

So while the entity that initiated A.I. research surely is not an individual human person, and the historical objectives of this research seem to be national tasks too, it still might be possible that in this special case the premises of methodological individualism are the most promising research strategy. Starting with individuals and aggregating appropriately still could solve the problem. Unfortunately the experiences in economic theory to develop macro-behaviour out of micro-motives of individuals are discouraging. Indeed the analytical cut between micro and macro itself seems to be the central obstacle to be overcome. The obsession to deduct one from the other obscures the more important question concerning the evolution of their interdependence. Translated into the world of A.I. this means that I suggest to consider the interdependance of individual "intelligence" with an entity called man, and something I call *social intelligence* with society as entity. The analogy to the final proposal of chapter 3 should be evident. But before I go into a more detailed description of this new notion let me briefly address the startling problem why "wrong" visions can evolve. Of course the possibility of "wrong" visions, based on a "wrong" choice of relevant entity, implicitly rules out the arbitrariness of this choice in entity-oriented research programs.

Is there a homunculus?

Two hundred years ago the choice of the human individual as the relevant entity for theoretical arguments was very appropriate and progressive. In an environment dominated by rigid feudal hierarchies, legitimated by religion, the emphasis on the self-determination of human individuals really appeared to be the most important ideological support for the bourgeois revolution in France. Rationality, as opposed to the dogma of the church, from the very beginning of the age of enlightenment onwards always

referred to the ratio of the single individual, the "common sense", as well as to the ratio of society as a whole, usually named "science". J.W. Goethe took up the themes of the french enlightenment and in the romantic way so typical for Germany in these days condensed them to a tragedy: Faust. "Science", personified in Dr.Faust, inspired by Mephisto the opponent of God, tries to construct a man, a homunculus. Actually the cynic Goethe supposes, that it only needs Wagner, the mediocre pupil of Faust, to do so. It is just a question of the "right mixture", as Wagner says somewhere. In some sense it is not a far cry from Goethe to the current discussion.

As counterpoint to an omnipotent God the concept of omnipotence of man emerged, and from the beginning "man" had a double meaning: it meant the individual man as well as the human species. Indeed in traditional societies this difference did not make much sense, since individual action was determined by a fixed set of rules, see the notion of a "traditional society" in chapter 2. Only in the newly emerging bougeois society individual behaviour started to play an important role. For the first prophets of this new type of society the interplay of individual and system behaviour seemed unproblematic: they simply identified the one with the other - that is the source of humanism in its different versions. Surprisingly enough Newell and Simon in their classic on "human problem solving" basically still stick to this view¹⁷, although two hundred years of development since then showed, that things are not that simple. In fact the new disciplines called social sciences (sociology, political economy, etc.) can be interpreted as attempts to understand this complex relationship between the socio-economic system and its elements.

Starting off with a strong emphasis on the evolution of the system, where the individuals are fitted in harmonically (A.Smith, A.Comte), via the challenge of evolutionary system concepts that insist on an only temporary success of the system (K.Marx), the last quarter of the 19th century sees the individual elements in the center of the stage (K.Menger, L.Walras, S.Jevons, M.Weber). Finally in the first half of this century social sciences appear as dissolved in the agenda of neopositivist (L.Wittgenstein) methodology: the construction of logical exercises based on an atomistic view of society, a view borrowed from the natural sciences in the hope to repeat their succes (G.Debreu, T.Parsons). Evidently such hope more or less ignored the

¹⁷) Their book begins with a diagram, that "attempts to compress in one diagram many of the dimensions along which the total human system can vary." This diagram divides the world in different regions. "Each region provides a starting point for investigation and description; each leaves out most of the human phenomena." [Newell A./Simon H., 1972, pp.2-3]. "Individual man" and "mankind" are still the same thing for them!

differences between natural and social sciences, not to speak about the differences between E.T.1 and E.T.2.

Is artificial intelligence a natural science? In our view it is not, it is a social science, if we adopt the following distinguishing characteristic. Social sciences are concerned with the interaction of individuals in society in a way, that has to take into account the feedback of the science itself on the evolution of society. In physics one can safely assume, that the behaviour of atoms does not change if the scientist knows it, whereas it is likely that for example the behaviour of workers will change if the social(ist) scientist makes clear that they are exploited. Referring back to chapter 1: system behaviour is not independant from scientific progress. Rather is the latter to be considered as part of system behaviour.

So while the emergence of individualist methodology can be explained in its historical context quite neatly, it simply is anachronistic in our contemporary societies. There is no homunculus! Indeed recent research in many fields seems to support my view of a trend to a more wholistic approach in the social sciences.

Does this mean, that all the work done by A.I.researchers, who are more or less attached to the neopositivist line of thought, is futile? This is certainly not the case. I am only arguing for a shift of weights: more support should be given to research in a field that I previously called "social intelligence support". Only in the light of the results of this new area of research, A.I.research can realize and overcome its current impasse.

"Social intelligence support" - a preview

To give an idea of what I mean by "social intelligence support" let me briefly reinterpret the stylized world of A.I. in these terms.

Knowledge is the sum total of societies knowledge stored in libraries, databases, expert brains and the like. If the entity under consideration is the human society, then the concepts it has at hand do exist in various forms. It is not a trivial problem to measure the so defined stock of knowledge.

The acquisition of information, that is added to this stock of knowledge now simply appears as the process of scientific research. Nevertheless, one has to keep in mind, that if one includes the knowledge of skilled workers in the definition of social

knowledge, then one also has to accept the contribution to this stock that comes from them as scientific. The wider definition should not be frightening, the academic profession itself is just part of a larger group of skilled workers. Of course information also can be lost, usually this appears if the physical carriers of this information are destroyed or if their capacity only allows for a limited amount of memory, that makes permanent restructuring of its content necessary as soon as this limit is reached.

Next let me consider learning. With society as entity, learning indeed is a very complicated process. Even if a set of problem solving activities, which are not learning, is given (see above), a double selection problem appears. First, a new piece of information has to be chosen out of the rich supply of possible interpretations of the current problem, second the limited capacity in many cases leads to a selection of increasingly irrelevant information in the existing knowledge base, that now is to be discarded.

The real challenge of course appears if one goes one step further and asks: "What constitutes a problem for society?". Nevertheless this question is indispensable if we accept, that problem solving activities are centered around concrete problems. *This* problem cannot be solved by a simple list of all possible problems. What constitutes a problem for one group, e.g. a high budget deficit, can be the solution to a problem for the other group, e.g. high unemployment, and vice versa. Evidently the postulate I started with, that is, to consider society as an entity, as a whole, is not justified if one goes into the details of determining certain problem spaces in contemporary society. Contradictory forces with their corresponding world views and visions are at work in modern society, that should be no secret. Again this fact makes problem-oriented research dependent on the choice of entity. But in this case this means a political choice. The trend towards larger and more integrated entities breaks its path in the form of battles, real ones and that includes ideological ones, between countervailing groups, each of them claiming to be the nucleus of the new stage.

The final paragraph of my prototype of the world of A.I. defined intelligence as the problem solving capacity needed to enable learning. Now one recognizes, that "social intelligence", the intelligence of the entity society, still is a program for the future, because the constitution of mankind as an entity has not been achieved. The construction of machines therefore is not a paraphilosophical task, but just a modest attempt to support the constitution of the entity society. To construct databases for societies knowledge, that are easily accessible, to support selection processes and

learning, all that implies a choice of problems, that itself is a political decision. Clearly the group, whose agenda are to be supported, should be the one expected to be an early representative of society as a whole¹⁸.

"Social intelligence support" is an **urgent** task in the above defined sense: If society learns to slow relative to an environment that increasingly calls into question its very existence, both from inside and from outside, we have to redirect our research efforts to deliver both: tools and visions for a new society¹⁹.

¹⁸) The standard approach to AI of course has its own breed of a philosophy of science, cognitive science, which leads to different conclusions. For a recent introductory text see [Gardner H., 1985].

¹⁹) A similar thought stood at the beginning of system theory: "The application of the modern method of scientific agriculture, husbandry, etc., would well suffice to sustain a human population far surpassing the present one of our planet. What is lacking, however, is knowledge of the laws of human society, and consequently a sociological technology." [L.v.Bertalanffy, 1968, p.51]

Chapter 5:

Social intelligence support¹

From the very beginnings of research in the young science of cybernetics much work has been spent to conceive and to build man-like machines. As pointed out in the last chapter, this task can lead to misspecifications stemming from the postulates of methodological individualism. Two types of research programs were distinguished: problem oriented research programs and entity oriented research programs. The problem oriented approach has been judged to be limited in the sense, that although successful AI applications for special problems might be developed, no general break-through to overcome basic difficulties in the field can be expected from this side². Entity oriented research on the other hand concentrated on individuals and firms. Methodological individualism even claims that any research in the social sciences must deduce its issues from the behaviour of individual men. Instead of opting for a certain type of entity as the only valuable starting point, reference to the genesis of this debate is made showing how each preferred interdependence between the individuals and society played its respective, historical role. In contemporary societies the "robinsonades of the 17th century" are inadequate, this is roughly spoken the main argument.

The question of the *relevant entities* for theorizing thus is an acute one. Should one consider households, firms, classes, nations, the human species or something else as objects to investigate? This is essential if we want to support an entity in providing tools like machines, robots or cybernetic models. Basically entities use tools in their interaction with their environment and it is evident, that different entities need different tools. So in a setting like Robinson Crusoe - set 1 of tools - island

the tools considered in set 1 would look very different to the tools in a set 2:
Society - set 2 of tools - environment³.

¹) Central ideas were published in [Hanappi G., 1989c].

²) That is, the work done in this research program corresponds to Kuhns' concept of "normal science" [T.Kuhn, 1962], and cannot further the coming "scientific revolution". (Compare also Kuhns' clarification of what he means by the work done in a certain paradigm [T.Kuhn, 1974]).

³) This distinction probably has a similar impact on the concept of entropy as the division in living and non-living:

"It is tempting to believe that the laws of Nature may have developed by a kind of trial and error from randomness: somewhat analogously to Darwinian Evolution. Perhaps physics should look for ratchets

In the following a special type of entity, namely the entity society, will be explored.

In the notion of entity another notion, the *concept of time* has been shown to be inherent. Only because a structure displays some constancy on the background of something changing is it possible to perceive it as an entity in an environment⁴. If an entity is able to perceive itself (and its environment) I call it a social entity. As a consequence relative change is indissoluble mingled with the concept of entity. This topic will be discussed for the entity society under the header "social time". The reason for the explicit treatment of "time" in chapter 4 was to develop the notion of urgency. Here again we can ask the question: which tools are urgent for society? The preliminary answers to this question form the basis for the proposed research project - social intelligence support. But first we have to ask: "Why society?".

The entity society

As stated in chapter 4, society as an entity does not yet exist. It is a desideratum. This is so, because I defined social entities as being able to perceive themselves - of being conscious. The doubling⁵ of the "real", physical processes into the "reality" and a model of these processes⁶ possessed and used by an element of the process, which therefore could be called social entity, has not been achieved by mankind. So the very foundations for cybernetics on this level are missing.

The interesting point of course is, that we can talk about "visions" of future social entities; and the major reason why we can do so is, that we have stored the genesis of existing (and historical) social entities in something like a "social memory"⁷.

capable of creating the order of Natural laws. Perhaps, indeed, animate and inanimate - living and non-living - may be distinguished by the kinds of ratchets which produced them, and continue to protect and maintain them, as islands of improbability in the primordial sea of random chaos." [R.L.Gregory, 1981, p.156].

⁴) The same elements appear in Bas C.van Fraassens formulation: "In one straightforward sense, I do not believe that time, or space, or space-time exists. First there do exist physical entities, events and processes, which stand in various relations to each other, and thus constitute a complex relational structure. In addition there are mathematical structures, which we use to represent ("perceive", G.H.) (aspects of) this physical world. But there is no third entity - no space-time in which the physical events and processes are located,..." [B.C.van Fraassen, 1985, p.200]

Differing from my usage of the word "entity" Fraassen considers theory (his "mathematical structure") as an entity of its own (his "second entity").

⁵) Remember, that in LACO a model is a copy of the essential features of reality.

⁶) Of course this model also is part of "reality", that is the distinction between "reality" and model is something done only within the model.

⁷) The pioneering work exploring this question was probably done by Maurice Halbwachs [M.Halbwachs, 1925].

So any speculation on future developments implies a specific interpretation of history. A choice which in turn in most cases can be traced back to some political predisposition⁸. The apparent variety of possibilities can be classified in two broad groups, both rooted in french enlightenment.

The first view interprets history as a process of gradually increasing personal liberty of individual men and women. Under the experience of the bourgeois revolution all past developments were seen as leading to societies consisting of atoms called "citizens". "Liberté, égalité, fraternité!", these were the characteristics proposed for the macro-environment, for the political apparatus, within which these atoms needed only to have one property to maximize social welfare: rationality⁹. This liberal vision still is the omnipresent ideological force behind most of the political arguments in the western hemisphere. Clustering of individuals in certain groups, as often encountered in traditional societies, is increasingly dissolved, neither gender nor race can withstand the historical trend. The modern nation state and in last consequence a world government equipped with the monopoly to exert power needs only to guarantee that the rules of the game of rational individuals are not violated - the rest is done by some mechanism, which is an essential part of the rules: it is called "free market".

It is easy to imagine how the "information revolution" can further the liberal project. If, for example, we assume, that consumers can be supported to come closer to a situation of full information on prices, one would assume that competition increases and leads to productivity gains, which in turn cheapen commodities and reduces average, necessary labour time. But if there are increasing returns to scale, the same impact would lead to an accelerated tendency towards monopolization, which means higher prices, lower output and ambiguous productivity effects. This is just one example, but there is a wealth of literature treating the diverse effects of the introduction of more information in the market model. Basically markets with less information and fixed rules are more stable than markets with almost perfect information like the stock

⁸) In modern social science this background often is hidden behind some formalism, e.g. mathematical economics. A wonderful counterexample can be found in Norbert Wiener's classic book on cybernetics [N.Wiener, 1985 (1948), pp.1-29].

⁹) Modern treatment of rationality in cognitive science seems to be more careful (though less rigorous) than the economic formulation.

"Most evaluations (of beliefs, G.H.) treated in academic epistemology have been in the category of evidential evaluations (loosely speaking). I have in mind such evaluations of beliefs as justified, warranted, well-grounded, reasonable, rational and the like. It should not be supposed that these are all equivalent; in fact I doubt their equivalence. One point of this section is ... to prepare for needed distinctions." [A.I.Goldman, 1986, p.21].

exchange¹⁰. This could be a serious verdict against new information technology if stability was itself a welfare goal. In a similar way the impact of the new tools on the political decision process itself is very hard to assess¹¹. One general point, that can be made, is, that supplementary information in a market economy will most probably lead to the formation of coalitions (oligopolies, unions, lobbies, regional alliances, etc.) between individuals at least *as long as there is a basis for this clustering in the production sphere*. This tendency clearly contradicts the original vision of the liberal project¹². Moreover it shows, where its basic flaw might be found, namely in the specification of production¹³. This leads to the second type of interpretation of history.

The second approach assumes exactly those features of social development as relevant that are excluded by the first one: It assumes that there have always been asymmetries between individuals, which cannot simply be treated as disturbances that are gradually eliminated by increasing rationality. Asymmetries, in particular in the production sphere, account for the emergence of social groups, of classes, and the struggle between these groups is not something arbitrary, but rather can be considered as the motor of social development. Only the study of the development of the contradictions in society leads to formulations of social laws - of laws of motion in which social entities emerge and vanish dynamically. Moreover the development does not follow a smooth and continuous path. One rather has to accept, that there are "nodes" of historical development¹⁴, where progress is made much faster, and in between the nodes there are lagoons of relative stability. A certain constellation of classes characterizes such periods of relative stability¹⁵. So whenever we talk about social entities, we should bear in mind, that we speak about specific historic episodes

¹⁰) For a survey see [T.Negishi, 1962].

¹¹) In some recent work Iain McLean shows, that some logical deficiencies of democratic elections never will be solved by new technology alone [I.McLean, 1986].

¹²) There is however no reason why more information should be better than less information - at least no reason easily to be found in the free-market-paradigm. It seems to be rather in the spirit of this paradigm, to assume, that there exists an optimum amount of information, where the expected losses due to further labour spent on the production of information are equal to the expected gains deriving from this new information. So what I developed in chapter 2 for players in a strategic game should hold for macro-behaviour too.

¹³) The argument cannot be developed here in full length. For a detailed discussion see [G.Hanappi, 1989a].

¹⁴) The picture chosen shall remind on Hegels "Knotenlinie" (line of nodes) of history.

¹⁵) The term "relative stability" by no means implies that such epoches are periods of peace. Quite the contrary should be analyzed: during these periods of relative stability an "inner dynamic" is evolving that finally leads to the end of the era. For a broader discussion of the methodological issues involved in the concept of "inner dynamic" see [G.Hanappi, 1988].

and not about some "first things" of a secularized *prima philosophia*¹⁶. It is within these finite universes of successive production epoches that the respective superstructural phenomena evolve, the concept of "free market" being no exception. The fundamental problem therefore is to determine entities in the context of their social genesis.

Essentially these are the roots of Marx' class analyses, of Webers view of changing elites or of other sociological theories referring to sudden shifts in the composition of a society with distinct strata. Having determined the social entities it is their role in the inner dynamic of the production epoch which is of interest. Let us consider Marx' view as a typical example: there is always one group whose agenda carry the whole system from one regime of relative stability over the break-point of revolution to the next. This group is called progressive. As history shows, he argues, the progressive group always used an ideological disguise, revolutions took place in the name of past ethical values or seemingly outfashioned doctrines. In fact, he believed, that the proletarian revolution would be the first that could take place without ideological delusions, that has to rely solely on truth to be successful¹⁷. Other important scholars, who worked along the lines of this approach were less optimistic and denied that there is any (progressive) direction in these changing tides in the social structure of society. But whatever point of view is taken, the consequences for the design of information processing tools¹⁸ contrast with the first approach: the whole design process now refers only to a part of society.

In fact the design processes themselves will be stimulated by specific groups in society and will not be some neutral outcome of increasing general rationality. As a consequence the designer has to decide which groups to support. Personal links, expected progressiveness, pay or any other reasons might guide his choice. Or, more realistic, the groups might choose their appropriate information process designers.

As an example consider the government and in particular the executive power in a country. They will try to design an information framework that gives them full control over the citizens. On the other hand groups without strong feedback control on the government will press for an information design that excludes the access of the state to

¹⁶) "It is not the task to discover below the elements of pure phenomenology some first things proper, types of original existence, and in doing so eventually to outbid the phenomenological claims. ... Rather it is the concept of the absolutely first itself that is to be criticized." [T.Adorno, 1970, p.14] (translation: G.H.)

¹⁷) In this perspective Marx still is a protagonist of enlightenment (compare [K.Marx, 1972 (1869)]).

¹⁸) I do not question the importance of design processes for information tools. As point of reference in this respect, with whom I fully agree, see [H.Simon, 1985 (1969), pp.129-160].

their "private" data. As mentioned above, they often resort to constitutional rights of the last century, in a sense disguising in the institutional framework of bygone times to give their demands more prestige¹⁹.

As one might have suspected by now this paper opts for the second approach to historical interpretations, the main reason being that it simply seems to fit empirical observations better than the one of gradually increasing "peoples capitalism"²⁰.

Social time

In his "Critique of Pure Reason" Immanuel Kant gives an illuminating and influential interpretation of the notion of time [I.Kant, 1980 (1781), pp.78-96] (German edition). His entity under consideration still is the human individual and he concludes from the absolute necessity of the notion of time for any experience, that it cannot be something abstracted from the latter. But if time is a concept, that is not learned by experience it must be something existing a priori in the relevant entities, the individuals²¹. It is "a pure form of sensual contemplation" [I.Kant, 1980 (1781), p.79], a "contemplation of oneself, of our inner mode of existence" [I.Kant, 1980 (1781), p.80]. Together with "space", the "pure form of all outer contemplation" [I.Kant, 1980 (1781), p.81] time constitutes the condition for experience. Since both notions exist a priori in the entity (the "subject") they cannot be attributed to empirically given things, this being the reason why this view considers itself as "idealistic".

There is a straight line of thought leading from Kant to the logical apriorism, sometimes called neo-positivism, of our century²². Indeed the a priori given notions of "time" and "space" can be condensed to an a priori existing "logic", existing as a common property of human individuals²³. The analogy to the notion of "rationality", mentioned above, should be evident.

¹⁹) Of course it is not possible to conclude that every disguising group is "progressive" in the sense circumscribed above. Nor can it be assumed that every disguising group knows about its own masquerade. The numerous neo-fundamentalist movements are brilliant examples for different blends of this kind.

²⁰) "Peoples capitalism" is a concept trying to make the first approach more concrete: each individual (égalité) is at the same time and to the same degree worker (fraternité) and capitalist stock holder (liberté). For some time this seemed to be a powerful ideological version of the "American dream".

²¹) "Time is not an empirical notion anyhow abstracted from experience." [I.Kant, 1980 (1781), p.78]

²²) Of course this is not the only line of thought using Kantian "time" and individuals as entities. A much more fruitful example is Piagets genetic epistemology [J.Piaget, 1970] (in particular lecture 4).

²³) Kant himself anticipated this step, when he founded his "pure and general logic" on "principles a priori" [I.Kant, 1980 (1781), p.99].

Why is this detour through the realms of philosophy relevant for my topic? The important point is, that "time" considered as a general "human condition" leads to a very different understanding of the notion of "urgency" as does a derivation of the same notion from "social time". In particular, one will tend to assume that since for different individuals different problems are urgent there simply is no point to develop a general notion of urgency²⁴. From the vantage point of the individual this leads to the notion of "thrownness" into disparate sets of "phenomena". Terry Winograd and Fernando Flores [Winograd/Flores, 1986] heavily exploit Husserl's "phenomenology" to develop some guide-lines for design²⁵. As could be expected "urgency" does not play an important role in these design propositions. As a consequence the hand of the "thrown" designer could grasp for any "phenomenon" to rearrange it: "The most important design is *ontological*. ... In creating new artifacts, equipment, buildings, and organizational structures, it attempts to specify in advance how and where breakdowns will show up in our everyday practices and in the tools we use, opening up new spaces in which we can work and play." [Winograd/Flores, 1986, p.163]. Like the philosophical brands of neo-positivism, phenomenology and (at least partly) existentialism these formulations reveal that a loss of the concept "time" implies a loss of orientation - "anything goes" as Paul Feyerabend puts it²⁶.

Contrary to this result thinking of "time" in the context of well specified production epoches, of periods with a relatively stable constellation of social groups, in short, thinking of "social time", does make sense²⁷. For a particular period and for a well-chosen social entity of this period we can at least in principle measure the force of the contradictions this group is exposed to, that is, we can detect what is urgent for that

²⁴) The only reliable study would be the study of logic. As again anticipated by Kant, science would split into two domains: one treating formal consistency in an ever more rigorous way and one applying postulates to a sea of "things".

²⁵) The notion of "thrownness" they take from Heidegger, who plays a major role in their book. Adorno's critique of Husserl and Heidegger draws an important parallel to neo-positivist positions, supporting the argument presented here [T.Adorno, 1970, pp.31-33].

²⁶) In a cynic remark Adorno characterizes this new "freedom" in his last book: "The awareness of a deficiency, the limits of perception, becomes an advantage that makes it easier to live with this deficiency. Collective narcissism is at work." [T.Adorno, 1980 (1969), p.159] (translation: G.H.)

²⁷) In an interesting passage Niklas Luhmann relates "sense" to "time":

"Even if a time dimension were included in a phenomenology of "sense", for example via the concept of "movement", this still would leave the impression that "time" is something given, something of which one could evaluate if it is the case or not. But in each sensual experience, and therefore also in any kind of descriptive theoretical work that tries to fix the phenomenon, an element of unsteadiness is built into. "Sense" forces itself to change." [N.Luhmann, 1987, p.98] (translation: G.H.)

In our context we do not refer to the autopoietic feature of "sense" connecting it to "change" and "time", as Luhmann does in the cited text. We use "making sense" in the sense of "useful", helpful to reach certain goals.

group. Having done this we can try to direct our efforts to change some of these contradictions. Again the political decision of which group to consider and which position to take towards this group is an unavoidable prerequisite. If there are few groups, classes, in a society, large numbers of people will be concerned by the same contradiction. A fact that gives such theoretical efforts the status of general theoretical work²⁸. At the same time the members of social groups become conscious of their "social time", try to substantiate it, give it a name. Norbert Elias recently studied how various societies experienced and used the notion of "time". His conclusion is, that "time" is a synthetic construct strongly dependent on the stage of development of a society [N.Elias, 1988].

It is tempting to apply the Kantian phrase characterizing time as "contemplation of the inner mode of existence" to the more aggregated entities encountered in society. "Social intelligence support" could try to intervene in this inner dialogue of social groups, helping to bring to the collective mind its own history and perspective. The progressive impact of such modest interventions should not be underestimated, they could in fact themselves be a field of future research activity²⁹. But above all, this is the level of analysis where the old question of problem oriented research programs finally could be posed: What constitutes an *urgent* problem for particular social entities? Or more concrete: Where are contradictions escalating so fast, that accelerated introduction of cybernetic control is necessary.

Social intelligence, learning and knowledge

In chapter 4 I defined intelligence as the capacity to cast a problem into a structure. "Social intelligence" means not only the capacity to do this for "inner" problems of certain social groups, but also the ability to explore problems between groups. The support of this ability by information technology is an urgent task. The carriers of social intelligence are not just the specialized scientists working on socio-economic problems. Virtually everybody concerned by social problems has to be included. The participants in the socio-economic process are not to be treated as "material" to be observed by the scientists, the crowd to be enlightened, rather they are

²⁸) Note that "particular" as used in the concept of "particular production epoches" is to be understood as the mediating moment in Hegels triad of singularity-particularity-general. The particular features are the material "general theoretical work", a term used by Marx, deals with.

²⁹) A promising model to study this is Rumelharts "parallel distributed processing"-model allowing for effects of resonance [McClelland/Rumelhart, 1988b, pp.15-16]. For a general discussion of the PDP-model see especially [McClelland/Rumelhart, 1988a, pp.3-76]

the immediate reflection of the collision between direct personal involvement and an overwhelming mass of officially distributed interpretation schemes. So while the emergence of "social intelligence" surely will never lose this taste of enlightenment, the component of self-enlightenment has to be supported. It is one of the objectives of the "Social Intelligence Support"-project (SIS). Fortunately recent developments in software technology led to some promising technical tools waiting now for their creative application in SIS. They range from easy to handle classical econometric and statistic software packages via expert systems to parallel distributed processing software. They are to be combined with new theoretical insights in such diverse fields like evolutionary economics (non-linear dynamics, see for example [E.Hanusch (ed.), 1988]), political-economy (study of relative stability using synergetics, see [H.Haken, 1977] and compare also [H.Haken, 1984]), voting theory (game theory, see [M.Holler, 1982], [P.Ordeshook, 1986]), expectations formation (pattern recognition, probability theory) and autopoiesis of social systems³⁰ (cybernetics, [F.Benseler et al. (eds.), 1980]). The names in brackets are just crude indicators of formal disciplines trying to cover the "consistency part" of the research area. This distinction in formal and applied aspects - with the first of them being necessary but not sufficient - still follows Kants scheme of analysis and practice. And it was Hegel who emphasized the reciprocal fertilization of the two parts. What all this sums up to is, that the SIS-project must be interdisciplinary to an unprecedented degree.

If this is achieved, social learning will consist not only in the passive reconstruction of prevailing features of social processes as formal structures. It will even enable cybernetic design, that is, well-founded strategies, equipped with feedback mechanisms, for social groups can be formulated and even integrated to allow for simulation of the interplay between groups. In that way even an anticipation of the next "node of history" comes into sight. But note the time order of the just mentioned events. Note furthermore, that such a course of history presupposes informed or at least "informable" participants of the political process. Now under current circumstances information is not only used to transmit messages but there also exists the use of pseudo-information as a tool for the creation of disturbances. This practice of social institutions (firms, government, parties etc.) aims to draw closer limits to the information processing capacity of the addressed, filling them up with noise to prevent the acquisition of competing knowledge³¹. So any transformation to a better informed

³⁰) This point deserves qualification: the border between biological autopoietic systems and autopoiesis in social systems must be drawn clearly. See chapter 1 for my proposal.

³¹) It is easy to see, how the models of chapter 2 could be augmented to cover such "filling up of processing capacity"-strategies.

public implies an information design that takes into account the limited capacity of the recipients. In other words, a barrier against noise is unavoidable to create room for social intelligence. Now the distinction between noise and relevant information clearly is a delicate matter that cannot be solved in a once-and-for-all "definition". Rather it should be a permanently updated result of the SIS-project itself.

What will then "social knowledge" be? As explained in the last chapter, it will just be accumulated "social learning"³². Storing past social experience, including past simulation, more systematically should lead to an even stronger integrated human society. Given the capacity constraint of human brains more emphasis will be put on the mechanisms enabling access to the commonly stored social knowledge. But before these more technical aspects are to be envisaged, there will be some crucial problems concerning questions of brutal, physical power waiting to be solved. Is it really possible to look beyond the next "node of history"?

Conclusion

In the last paragraph of the last chapter the programmatic issue was made, that the SIS-project should deliver both: "tools and visions for a new society". As should be clear by now, visions can be tools for certain groups in society but not vice versa. This is not just playing with words. Especially people working in information technology areas tend to see their technical products as goals in themselves. On the other hand most prominent scholars in the social sciences are very cautious in formulating visions about possible future societies³³. They have good reasons. Considering the theoretical difficulties of building an adequate model of global developments any forecast beyond a level of five years seems to be an extremely doubtful enterprise. Nevertheless this questions must be approached. The SIS-project could be a frame for interdisciplinary action and international cooperation, it could help to identify problems and to concentrate intellectual effort. Going through the outcome of recent work in the field one might get the impression, that it already started to exist.

³²) This is different to the Kantian view: There is no "rest" of social knowledge, no residue, that has to be explained by a priori given concepts. This difference also explains a large part of the scientific revolution from Kant to Hegel.

³³) There are very few Utopia created by academic social scientists. Neither Marx nor Schumpeter thought it to be appropriate to look beyond the solutions of current contradictions, which means a mid-term perspective. Beyond the next "node of history" there lies the unknown.

PART III

Pragmatics - applications

Chapter 6:

Evolving strategies - gaming in economics.¹

In a sense the quintessence of part II is the suggestion to exploit the growing convergence of simulation techniques and richer economic models. In particular A.I. methods could help to model complex, information processing economic agents. Though the *methods* become clearer, only forerunners of economic *applications* do exist. One early attempt to use computer facilities to support economic reasoning was the so-called *gaming approach*. This chapter is devoted to discuss its merits and pitfalls.

In his classic book "Cybernetics", published 1948, Norbert Wiener created the name of a new interdisciplinary science and tried to figure out its perspectives². Coming from electrotechnology the approach taken by Wiener in this book is that typical for practitioners in the field, an engineering point of view, dealing with problems of servo-mechanisms and trying to develop more general methods and concepts. It is not only the outstanding scholarship of the author, which makes for the success and the continuing acuteness of Wieners agenda, it is also caused by the upsurge of computer technology, the central tool of the new science, in the last 40 years. Wieners analytical framework still proves to be extremely useful in discussing applications of new information technology.

"Gaming" undoubtedly is a very specific application of modern computer technology analyzing economic questions in a very particular way: choice- and game-theoretic situations are simulated letting human actors take their decisions within an environment of a socio-economic model implemented on a computer. What is the use of such experiments? The answer to this question from an "engineering point of view" will be a good starting point for giving structure to the objectives of "gaming".

¹) An abbreviated version of this chapter was presented with the title "Perspectives of Gaming" at the workshop on "Macroeconomic Policy Games" at the Institute of Advanced Studies in Vienna [Hanappi, 1989b].

²) Two chapters of the edition of Wieners book [N. Wiener, 1948] used in this chapter have been added 1961.

Black boxes and white boxes

Engineers construct machines. Norbert Wiener considers these machines as automata, automata, whose development and implementation can be structured in different ages in the history of technology³. In our age technical progress focuses on automata for communication and control. The working of these automata can in principle be described as a *feedback system*:

To achieve certain goals with certain instruments the first thing to do is to observe the process to be controlled and to describe it using adequate, measurable variables⁴. Of course this observation already includes an implicit judgement of what is to be considered as relevant. In many cases this first description even determines the specific role different variables are thought to play in the whole feedback system. Process-oriented observation distinguishes between inputs and outputs. Inputs can be further divided into those, which can be controlled and others, that are determined outside the system under consideration without being open for controlled variation. On the other hand a subset of outputs will play a special role, namely those which are to be directed in a desired way by the use of the controlled inputs. These indirectly controlled outputs are called goals⁵. The process between inputs and outputs is only characterized by the observed time series. Input and output series are our only mean to infer what "really" happens in between - the real process is a "black box"⁶.

³) "If the seventeenth and early eighteenth centuries are the age of clocks, and the later eighteenth and the nineteenth centuries constitute the age of steam engines, the present time is the age of communication and control." [N.Wiener, 1948, p.39].

"Thus Leibniz considers a world of automata, which, as is natural in a disciple of Huyghens, he constructs after the model of the clockwork. ... The monad is a Newtonian solar system writ small." [N.Wiener, 1948, p.41].

"In the nineteenth century, the automata .. are studied from a very different aspect. The conservation and the degradation of energy are the ruling principles of the day. ... All the fundamental notions are those associated with energy, and the chief of these is that of potential." [N.Wiener, 1948, p.41-42].

"In short, the newer study of automata .. is a branch of communication engineering, and its cardinal notions are those of message, amount of disturbance .. quantity of information, coding technique and so on." [N.Wiener, 1948, p.42].

⁴) Wiener is rather sceptic about the application of the cybernetic method in the social sciences: ".. a field in which my expectations of cybernetics are definitely tempered by an understanding of the limitations of the data which we may hope to obtain." [N.Wiener, 1948, p.25].

⁵) The close relation to the usual distinction between exogenous and endogenous variables, instruments and goals in economic model-building should be evident. Compare chapter 3, in particular figure 4: model building.

⁶) From this it should be clear that the choice of variables, and, closer to the data, even the construction of time series is a most important part of **theory building**.

Starting from the data, a "white box" is built. By this expression a process is designated, which is completely known because it is constructed by the theoretician. A process that is in as many aspects as possible functionally equivalent to the process that takes place in the "black box". How good the analogy, the functional equivalence, works, can only be judged on the basis of an ex-post simulation: The outputs of the "white box"-process given historical inputs of the "black box"-process has to be compared with the actual historical outputs of the "black box"-process⁷.

It is possible to incorporate the process represented by the white box in *different manners* in processes that take place in reality. A simple mechanical apparatus for automatic regulation of some technical equipment is an example, consulting work for policy-makers using macro-econometric models is another one. White boxes can be part of larger theories, economic theories or theories of the natural sciences, and they can loose contact to the black box that they originally were designed to replace, acquiring a kind of independent reality of their own in other fields of research. Though most of these white boxes are formulated in one way or the other in mathematical language this need not be the case⁸. *Gaming* is a special form of incorporation of economic models, which is the name of white boxes in this context, in real socio-economic processes.

It is therefore tempting to structure the applications of gaming according to its fields of application. One could distinguish

applications as an education tool in universities,
applications for empirical investigation in the validity of theoretically assumed behavioural assumptions
applications in the field of strategic management.

In the first case the process to be controlled (the black box) is the learning process, the goal is to achieve competence in a special field of economics. To reach this goal the interactive evaluation of the performance of the pupil plays the role of a regulator, hidden behind the game-like character of the situation. Without going into the details of a discussion of the psychological reasons, many experiments clearly show,

⁷) Note that the question, if good functional equivalence could be considered as an "explanation" of the "black box" by the "white box" remains open.

⁸) Compare for example the methods of behaviourists in psychology.

that this game-like atmosphere, reminding on leisure-time activities, contributes substantially to the efficiency of the learning process⁹.

The second field of application should help to perform laboratory experiments in the social sciences - where this appears to be possible at all. The process in which gaming is incorporated is in this case the research activity, for example research in the theory of strategic games and oligopoly. A possible goal in this example would be to support the researcher in providing software tools to further realistic modelling of equilibrium concepts in oligopolistic markets. Assume that direct observation of the behaviour of oligopolists in a stable environment is impossible. Now let us assume that a gaming process has been designed, which is a sufficiently close functional equivalent to the original situation and in which test persons replace (and imitate) the oligopolists. The behaviour of these test persons can provide important hints about the relevance of possible equilibrium concepts. Further research will be concentrated in areas designated as interesting problem areas by the results of the laboratory experiments, which means, that the gaming methodology could be understood as directing, at least partly, the focus of future research.

One important clarification has to be made at this point: in each of the two above mentioned fields of application white boxes appear at two different levels. On a low level a model of an economic process is used - the game process itself. On a meta-level the gaming *methodology* is itself a white box trying to grasp important features of the black boxes "education" and "research". Neglecting this distinction can lead to confusion about the cybernetic aspects of gaming.

Contrary to the first two cases for gaming the third one does not aim at teaching and investigating abstract theory, but concentrates on training for decision-makers in well-specified, concrete environments. For obvious reasons gaming applications of this kind usually constitute a part of the training activities of large firms. "Learning by doing", as implicitly touched upon in the first two areas of application, in this field often is in danger to be reduced to single stimulus-response pairs, to "learning doing". If this happens, then the goal of the training program consequently is to produce a certain, well-defined behaviour in real-life decision making. This is done by a simple gratification-punishment feedback of the results of the white box, i.e. by continuously

⁹) The way learning takes place remains unexplained. It is only the empirical comparison of goal achievement with and without gaming that is used to justify the introduction of *edutainment*, the new educational tool. In this sense this application complies with the above mentioned methodological framework.

evaluating the gaming process. In most cases the fact that complex real-life situations, so hard to understand left alone to control are now explained in a handy (low level) white box is sufficient to induce the trainees to use the explanations and reactions they have been made familiar with¹⁰.

To the three types of application there correspond three groups of users of the gaming approach: teachers, scientists and firms.

Another widely used distinction of gaming applications follows the type of economic model (low level white box) used: Applying microeconomic models of firm and consumer behaviour leads to gaming simulations called "business games", whereas a simulation with a macroeconomic model will commonly be referred to as "economic policy simulation". It is this distinction, which usually is preferred by most economists and it indeed played an important role in the development of gaming applications by economists.

Some experiences with micro- and macro-games

In the course of the sixties business games became popular in some American universities. These games usually dealt with oligopoly markets. Students had to take the decisions characteristic for oligopolists (prices, output quantities, investment, etc.) using punched cards as input device for a large mainframe computer, which then produced the aggregate outcome given the individual micro-decisions and some predetermined environmental variables. Printouts of the market results in the sequel were consulted before making the next set of decisions. Although the methods used look archaic nowadays these experiments clearly are gaming¹¹.

It is no matter of chance that gaming originally was developed in the context of the simulation of oligopoly markets. From the very beginning the development of cybernetic models was intrinsically interwoven with that of information theory and that of John von Neumanns game theory¹². The latter has of course been used in economics

¹⁰) Indeed this could be made a big issue of: the more complex the real-life problem, the stickier the simple white-box-answer.

¹¹) Shubik takes the year 1948, the appearance of Chamberlins contribution as the birth of "gaming" [E.H.Chamberlin, 1948].

¹²) "Wiener's *Cybernetics* appeared in 1948, resulting from the then recent developments of computer technology, information theory, and self-regulating machines. It was again one of the coincidences occurring when ideas are in the air that three fundamental contributions appeared at about the same time:

primarily as a description of oligopoly¹³. Microeconomic gaming surely is the older and more common form of gaming. It is applied in all three areas of application that have been distinguished above.

The starting point for the micro-games studied at the institute of economics at the university of technology in Vienna has been a business game developed by Martin Shubik at Yale university¹⁴, which has been used in different versions for teaching and research since the mid-seventies. In general the applications in the field of teaching have been remarkable successful. In particular it proved advantageous to form groups of three or, a little bit riskier, four students to represent a single player. In that way group dynamic processes, a game in the game, will evolve, which enables horizontal communication between students about the content of the (low level) game¹⁵. What concerns the number of oligopolists to compete, experience shows that five is a good choice and that in any case seven should be an upper limit¹⁶. Another important factor for a successful simulation game is a time schedule that allows for communication in few but well-designed breaks. In any case immediately succeeding days should be preferred to once-a-week time schedules. Before the game starts there should be an introductory lecture giving all the necessary information on market structure and all qualitative relationships. Quantitative information on parameters should not exceed some basic ranges for the most important ones. Too much quantitative information easily misleads players to try to compute optimal policies and destroys the game-like character, which in turn is crucial for efficient learning. On the other hand insufficient information lets players ignore the connection to the underlying economic theory, their actions will follow a simple trial-and-error process. Similar arguments can be made for the choice of the market structure. Again a medium size model customized to the needs of the material taught will lead to the best results. The ability, even of very experienced

Wiener's *Cybernetics* (1948), Shannon and Weaver's information theory (1949) and von Neumann and Morgenstern's game theory (1947)." [L.v.Bertalanffy, 1968, p.15].

Bertalanffys idea is to subsume these three theories under the common header "General System Theory".

¹³) In the last chapter of his introduction to oligopoly theory James Friedman writes:

"The reader familiar with game theory will have noticed that the models discussed in earlier chapters are treated as noncooperative games of strategy, and the reader who is totally unfamiliar with noncooperative game theory will have obtained a lengthy introduction to the subject, together with an application of the topic to oligopoly theory." [J.Friedman, 1983, p.207].

¹⁴) A good description of the original version can be found in [M.Shubik/R.E.Levitan, 1980].

¹⁵) "The basic philosophy underlying most applications of computers to education has been wrong. The main thrust of computers in education has been to push facts into students. The approach that works best, however, is to use the computer and auxiliary technology to create a stimulating learning environment .. " [J.Licklider, 1987, p.262].

¹⁶) Interesting enough, professional software design also recommends a similar range for the number of choices in a menu. It evidently has to do with perception capacities. If single decision makers are confronted with more items, they usually "aggregate" into types of items.

players, to handle more than three instruments simultaneously to reach more than one goal at a time usually is overestimated. In any case an upper limit of ten instruments should be perceived¹⁷. What is to be considered as a goal need not necessarily be made explicit in advance: to discover the interdependence of goals might be part of the learning process.

All of these above mentioned guide-lines come from our teaching experiences. They should be considered as crude measures, which we hope will help us to approach a kind of "optimal design" of micro-games for teaching microeconomics¹⁸.

In the second field of application, in research, micro-games have been a little bit less successful. Experiences of people working in that area, including our own, show, that it is extremely difficult to produce an appropriate environment for laboratory experiments. Students acting as oligopolists in most cases are less risk averse than real-life entrepreneurs¹⁹. As a remedy monetary incentives have been introduced, an effort to construct a direct link between the outcome of the game and the utility function of the player. This lead to a slight improvement of the realism of the experiments. But a new problem arises if one wants to cover both areas of gaming, teaching and research, with the same set of simulations, since now the more conservative way of playing is inferior in respect to the efficiency of learning. Risk-seeking behaviour, curiosity about new and dangerous strategies, all that enhances the quick understanding and lies at the heart of the success in the teaching area. Another problem, that cannot be solved by monetary rewards is the appearance of last-period-behaviour. It has been a striking feature of almost every game of fixed, predetermined length, that the behaviour of players changed dramatically in the last period. Coalitions broke up, surprising actions were taken only because it was sure, that the competitors could not hit back. In some cases the last period has been considered as the last possibility to test the reaction of the underlying microeconomic model on extraordinary shocks. It is hard to capture the continuity, the long-run existence of firms in simulation experiments that have to take place in a rather

¹⁷) Since instruments usually are interdependent the number of rather independent instruments should be even smaller, preferably in the range from three to five.

¹⁸) Again it is to be underlined, that the gaming environment is constructed by the teacher (as a meta-level white box) to reach a certain goal. Since this construction is an artifact it has to be designed: "Design .. is concerned with how things ought to be, with devising artifacts to attain goals." [H.Simon, 1969, p.133].

This understood, the question if there really do exist many oligopolies with exactly five competitors is irrelevant.

¹⁹) A common phenomenon is the preference for cut-throat strategies, which in real-life oligopolies only appears in exceptional situations. In simulation experiments making the competitor look foolish often seems to be more important than making high profits.

short period of time (compare the recommendations for the teaching applications). Due to all of these reasons theoretically derived equilibrium constellations, like the competitive equilibrium or the "grand coalition" usually were not empirically observed. Probably the time of the simulation experiment has to be extended considerably to get results, that converge to equilibrium solutions²⁰. And even in this case the simulation environment has to be "stable" in a broad sense, which constitutes not only a problem for the designer of the laboratory experiment, but also calls into question the realism of the experiment.

The third area of application can only be touched upon, a more elaborated treatment would need as a prerequisite an empirical investigation concerning such applications in particular in the United States and Japan. Experiences with a pilot project in this area shows, that one of the main problems in this field is the enormous amount of essential, market specific details, that have to be modelled - a challenge for conceptualization and for software design. In our pilot project from the point of view of the firm forty instrumental variables were suggested as a lower limit to guarantee the appreciation of the game by practioneers. These instruments drive 300 to 400 firm-specific variables per period. Moreover in many cases it cannot be circumvented, that the model-builder must produce models of several interdependent markets. In a sense gaming of this kind approaches another rapidly growing field of information technology: expert systems. In the next sub-chapter, where I will make some remarks about the future of gaming, this issue will briefly be dealt with.

Contrary to the history of micro-games, macro-games only have been developed in recent years in a recognizable amount. In his book from 1982 Martin Shubik just needs two sentences to survey their history:

"There have been few applications of game theory to macroeconomic problems and international trade (Nyblen, 1951; Faxen, 1957; Munier, 1972). These have nevertheless suggested the possible uses of treating aggregated units as players in a game of strategy." [M.Shubik, 1982, p.385].

In the same year our first decision-theoretic macro-game was put to practical test. Since then about forty experiments with a wide diversity of groups have been carried through. Not only academics, students and teachers, but also bankers, journalists, politicians, functionaries of parties and youth organizations played our macro-games.

²⁰) Our games in the average had approximately a length of fifteen periods.

Our objective in these games mainly was to show how complex relationships between macroeconomic aggregates are, how careful arguments for any kind of economic policy should be developed. In a few cases our simulation model even was used for forecasting. As a research device, the second field of application, only the latest versions, which are still in the process of continuous reformulation and extension, are used.

Some of the experiences with micro-games can be observed on a macro level too. The same is true for design, similar recommendations for size and length can be given. Again last-period-effects are very common, no real-life politician would dare rigorous economic policy measures like the ones taken by some of our players in the last period of our games. Again it is almost impossible to eliminate these effects. An interesting difference to the experience with micro-games is the influence of ideological prejudices. While these were more or less irrelevant in micro-games²¹, they definitely play a crucial role in macro-games²². This was not only true for our wider audience, as one would expect, the direct comparison of micro- and macro-games with the same set of (academic) participants showed the same phenomenon. Somebody deeply believing in conservative economic policy almost feels physical pain if he is to raise social transfers in a macro-game. There is a close connection between this aspect and the fact, that participants in a macro-game are much more induced to blame the underlying economic model for their own mistakes than the players of a micro-game are. The latter rather make proposals for the improvement of the game after the game is over to "take vengeance" for bad results. In case of unsatisfactory results, the feedback mechanism with a macroeconomic model can be interpreted as an attack on ones *Weltanschauung* and thereby can cause passionate, emotional reactions.

Applications of macro-games on the level of single private firms for training purposes have (at least in Austria) not come to our knowledge. One reason might be that most Austrian firms are too small to make their interaction with the whole economy a relevant, operational issue. On the other hand there is the fact, that private firms simply

²¹) As an exception to the rule a player in a micro-game once stuck to high-price policies to signal quality of the product although it was explained to him several times, that the influence of product quality on demand is not included in the version of the microeconomic model used. His argument had such a high value to him, that he ignored the gaming environment and blamed the model to be "wrong".

²²) Remember Keynes: "... the ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back." [J.M.Keynes, 1936 (1973), p.383].

just start to know that macro-gaming exists, what it is, why it could be important for them.

In the following sub-chapter some research strategies, which emerged from our gaming experiences, will be outlined.

Research strategies

An evident point of departure for further development in micro-gaming would be the inclusion of economic processes that have been neglected so far. As the third field of application already showed, decision structures to be modelled are much too complex, are characterized by dynamic non-linearities, to be subsumed by one general dogma like "allocation of scarce resources". At best such "in principle"-argumentation can be considered as giving a common name to heterogeneous elements. The new black boxes have to be substituted by a whole variety of white boxes, which do not lose contact to the real-life processes but still are abstract enough to further the understanding of the decision-maker. A good example are questions of the economic theories of innovation and technical progress. In the moment there is a lot of work going on for a new module of our micro-game designed to cover this aspect²³. A modular design is necessary to meet the didactic challenges formulated earlier: the size of the models must stay in some "optimal" range to be understood by students. It might be possible that the module "innovation" has to be temporarily eliminated again if a module "dynamic advertisement" is included to support lectures in the latter topic. In the end a kind of toolbox will emerge enabling to cover all desired microeconomic specialities by simply starting from a prototype and adding the respective module when it is needed.

Another disturbing restriction, especially felt in areas two and three, is that only rather small oligopoly markets, with few participants allow for a clear and careful design. Taking a closer look at this question shows that several, different problems are involved. *First*, the question how "entry" and "exit" to and from markets is to be simulated without having human players waiting for entry and re-entry is to be considered. A possible answer is the construction of programs, so-called robots or "automatic players", which substitute humans. This answer opens up a whole new field of research, since it enables the possibility to have different robot types interact - even

²³) The old version of our micro-game allows for "investment in research and development" via an exogenous, controlled variable. With a time lag these investments lead to damped but permanent shifts of the production function. Imitation, that is direct interdependence between production functions of different firms, should also be possible in this new version.

without interference of human players. For research this means, that population dynamics of different robot types under several market conditions can easily be studied. Highly non-linear systems, which are not treatable in an analytical way, can conveniently be simulated and evaluated. Different automatic players are already tested and a new generation using artificial-intelligence-concepts and pattern recognition is on its way. A systematic treatment of behavioural patterns - evolutionary economics - will have to make extensive use of gaming of this kind as a research tool.

As a consequence of this answer to the first difficulty, "entry" and "exit", a *second* one becomes acute: which information assumptions should be made for these robots. In the case of human players this question was neglected - or rather left to the special information processing and information storing capabilities of the individual, vulgo his ratio²⁴. Now the results of the simulation depend crucially on the amount of data available for robots **and** the capability of robots to store, process and interpret this information. An old idea launched by Herbert Simon many years ago, but forgotten due to the difficulties to include it in a purely analytical framework, now, with the use of modern simulation technique, suddenly comes into play: "bounded rationality"²⁵. Now it is possible to make explicit **what** it is, data or processing capability, that is the constraint, **how** it works to make the rationality of the player "bounded".

As a third advantage the emergence of a special kind of information now is mandatory: the emergence of expectations. In a simulation environment there is no need to restrict expectation formation to an "analytically convenient" minimum. All the rigid assumptions concerning the existence of a true model and its identity with the internal models of all players, the pivotal assumptions of the rational expectations school [J.Muth, 1961, p.316], are superfluous oversimplifications²⁶. To include the production of information that is used by the others has been a major topic of chapter 2. What Salop started to model fifteen years ago, the possibility of the use of "noise in the market" as optimal policy [S.Salop, 1977] can now be formulated as the behaviour of a firm, which at certain cost is able to produce images of reality that are then used by its competitors.

²⁴) In this sense the problem had not been solved, but simply ignored. Since it was not made explicit, the treatment of information by the individual has remained a (newly introduced, low level) black box.

²⁵) Again Simon underlines the engineers point of view:

"The engineering activities usually called 'design' have not been much discussed under the heading of rational decision-making. The reason for this should be clear from the foregoing discussion: classical decision theory has been concerned with choice among *given* alternatives; design is concerned with the discovery and elaboration of alternatives." [H.Simon, 1972, p.172].

²⁶) Of course "adaptive expectations" are a special case too.

A common complaint about micro-games is, that the dynamic decision process of national policy-makers is very relevant for the single firm too. On the other hand the micro-behaviour of firms and households exerts a strong feedback on economic policy and probably better should be modelled in a (strategic) gaming framework than in simple macroeconomic aggregates. In other words, gaming combining micro- and macro-games is called for. Again some preliminary versions exist and wait for further testing. The underlying principle is, to model *all* institutions with essential influence, even at the price of a very spartanic formulations for some of them. In our first pilot project a micro-game with up to nine firms is embedded in a macro-game in which a minister of finance (different taxes and government expenditures), a central bank (money supply, exchange rate, credit policy), private banks (interest rates), unions (wages), trade partners (foreign interest rates, exports, imports) and households (marginal propensity to consume or an explicitly formulated model) interact. A simple extension of micro-games going into the same direction is the closure of some exogenous processes via feedbacks: Rising overall volume of credit will raise interest rates, rising employment will lead to increases of the real wage, decreasing employment might lower effective demand etc. Such a link to a pseudo-macro-model again could be just another module of the micro-game prototype.

In the course of the discussion we finally arrived at extensions of macro-games. Beside the possibility of automatic players opening up new research areas²⁷, new challenges for models of the open economy arise, if exchange rate policy and monetary policy are integrated in the simulation framework. The two-country-case and the small-country-hypothesis would be the two prototypes to be constructed. For the first one there exist two rudimentary reformulations of our standard macro-game, which in its original form could be interpreted as an extreme case of the small-country-hypothesis.

In a macroeconomic context the successive opening up of black boxes lends itself to a special interpretation. Many macroeconomic relationships are behavioural hypothesis making rather strong assumptions on constants, assumptions clearly rooted in social psychology. This fact often has been formulated as a critique calling for a microfoundation of macroeconomic laws²⁸. Macro-games with their fundamentally different players immediately imply different ways to open up these different black

²⁷) In a macroeconomic context it sometimes might even be possible to include the models used in reality (for decision-making) as underlying hypothetical models of players: central banks probably use their own macroeconomic model, as do the ministry of finance and large private banks.

²⁸) Precisely this microfoundation is redundant from Wiener's point of view, if for example a macroeconomic investment function is functionally equivalent to the appropriate micro-model.

boxes. The assumption, that a certain type of player is representative, which even in microeconomic models only can be a *preliminary* assumption²⁹ (the representative firm), is not possible in a macro-game. In any case one is forced to formulate the dynamics of the system as dynamics of asymmetric processes. Even if the variation of assumptions on information is neglected, this produces a substantially larger amount of possible combinations. Some conclusions concerning the emerging dynamic systems can be drawn.

There is no simple classification scheme for the behaviour of large, non-linear³⁰, dynamic systems as it exists for example for linear differential equation systems. Since such systems in general cannot be solved analytically, the whole research method is reversed: Instead of starting with a postulated equilibrium path and then analyzing uniqueness and stability, in this case one usually starts with an observation of system behaviour for some arbitrary, but economically reasonable sets of initial conditions. With a series of simulation runs it then is possible to formulate some probabilistic statements about the system dynamics for a given range of initial conditions³¹. The loss in the power of the statements made (seen from a mathematical point of view) - to speak about "equilibrium paths" is only of limited interest in this framework - is contrasted by the advantage to construct (low level) models, "stylized facts", that are closer to reality, to have *better*³² white boxes. Another interesting case is the "mixed experiment" to confront some human players with robots, allowing for conclusions in both directions³³.

Even in the third area of application, firm-specific systems, the construction of some automatic players, either typical competitors or macroeconomic actors, seems to be quite a promising and attractive alternative to the usual "business games" and to expert systems. Imagine two human players, say managers of two colluding firms, who try to find out the implications of their strategies, given their expectations about the behaviour of other competitors packed in algorithms of robots and given some

²⁹) At best this issue could be the *outcome* of a stability analysis starting with heterogeneous firm types.

³⁰) Most of the systems are non-linear. Non-linearities will appear due to algorithmic formulations like borders or branching (conditioned jumps). Such techniques evidently are easy to interpret economically **because** they are appropriate to model social behaviour - they can be insurmountable complications if one tries to solve analytically.

³¹) Convergence, divergence, cyclical or chaotic behaviour are typical forms. Numerical methods to detect the latter are just developing. To apply new techniques in this field is one of the stimuli for research in gaming.

³²) Even the aesthetic value system of mathematicians, who consider smaller but functionally equivalent models as more *elegant*, would force them to admit, that elegance must be sacrificed if there is no small *and* functionally equivalent model.

³³) If you do not reveal to humans and to robots which players are human, an interesting question is, if humans **and** robots can find out: a special variant of the Turing test.

"institution" modelled as automatic player too. It should be evident, that these implications due to their complexity cannot be derived by ad-hoc-reasoning or introspection. Expert systems cannot be applied either, since it is not possible to store algorithmic characteristics in a way to allow interference machines to work on them³⁴. This clearly is a case for micro-macro-gaming.

Perspectives

At this point of the argument I have to come back to a critique of the "equilibrium method" and to the cybernetic method proposed by Wiener. In his book, cited above, Bertalanffy criticizes the identification of cybernetics and "general systems theory". The first, he says, is just a particular instance of the latter. Only if the development of a system has reached a certain level feedback systems will evolve:

"So a great variety of systems in technology and in living nature follow the feedback scheme, and it is well-known that a new science, called Cybernetics, was introduced by Norbert Wiener to deal with these phenomena. The theory tries to show, that mechanisms of a feedback nature are the base of teleological or purposeful behaviour in man-made machines as well as in living organisms, and in social systems. It should be borne in mind, however, that the feedback scheme is of a rather special nature. It presupposes structural arrangements .. . There are, however, many regulations in the living organism which are of essentially different nature, namely, those where the order is effectuated by a dynamic interplay of processes. It can be shown that the *primary* regulations in organic systems, i.e., those which are most fundamental and primitive in embryonic development as well as in evolution, are of the nature of dynamic interaction. They are based upon the fact that the living organism is an open system, maintaining itself in, or approaching a steady state. Superposed are those regulations which we may call *secondary*, and which are controlled by fixed arrangements, especially of the feedback type." [L.v.Bertalanffy, 1968, p.44].

But isn't it the case that social systems *always* are characterized by "fixed arrangements" making the cybernetic point of view the only relevant one for them, whereas "steady states", equilibrium paths of interacting dynamic processes, if applied to social systems are nothing but inadequate biologisms? Remember the argument in

³⁴) Of course it might be possible to translate the problem into a form treatable by expert systems. But this misses the point, since the most complex problem still *in principle* can be solved by simple verbal argumentation. If time is a free good sophisticated methods are redundant.

chapter 1, it surely is not *par hazard*, that Bertalanffys examples all come from ontogenesis.

As far as I can see even sophisticated extensions of the equilibrium concept³⁵ are only a fading defence and cannot save it from being finally abandoned³⁶. It has to be mentioned, that it definitely was an "engineering aspect", that led to the goal-driven construction of econometric models to give support to Keynesian stabilization policy³⁷.

But even if one neglects all these relationships between concepts and their genesis, Wiener's a little bit unfashionable point of view is an excellent device to evaluate the perspectives of gaming. Gaming as a technique for the goal-driven application of economic theory, by its very use feeds back on this theory³⁸ - that is its perspective.

³⁵) A good example for such an extension of the equilibrium concept for games in extensive form is Rubinsteins "Sequential Equilibrium". Reference to probability judgements off the equilibrium path makes the interpretation of information assumptions more plausible (see [A.Rubinstein, 1982] and [D.M.Kreps/R.Wilson, 1982]).

³⁶) The reversal of the relation between "equilibrium" and "rationality" is demasking. Originally "rationality" was thought to be something immediately evident to everybody (hence "the economic principle"). Doing its job in a great number of human entities it eventually will lead to a state of affairs that is called equilibrium. Modern writers start with a (more complicated) equilibrium concept right away, which then is said to imply a certain behaviour, which should be called "rational". While "equilibrium" once was the consequence of "rational behaviour", nowadays "rationality" is just a name for the behaviour in "equilibrium".

³⁷) To see this, one should read the classical article by Phillips written approximately at the same time as Wiener's book [A.W.Phillips, 1954] or, for example, the new treatment by Nagatani [K.Nagatani, 1981, pp.164-174].

³⁸) In other words, the meta-level white box "gaming", when used, changes the elements with which it works, the low-level white boxes of economic theory.

Chapter 7:

Challenge and limits of experimental economics

Closely related to the gaming approach are recent research efforts carried out under the common header of being *experimental economics*. Clearly the title tries to borrow from the so-called hard sciences. Experiments always have been a significant property of scientific research. Extending the strategies of research via gaming, as dealt with in the last chapter, the method of *scientific experiments* can be followed more explicitly.

Experiments are designed runs of black box processes, where the design tries to isolate the processes from some influences. The observed behaviour then can be attributed to the remaining influences, enabling the formulation of white box processes for the respective parts of the causation structure. Successive use of this *ceteris-paribus*-design with different influences isolated in different experiments might yield a fuller picture of what is happening in the black box. In the simplest case, if outputs depend linear on inputs, influences simply add up.

Neglecting extremely improbable concurrences of quantum jumps classical physics can be seen as deterministic in the following sense: Since experiments with the same design always gave results so similar, that they could not be distinguished from measurement errors, an underlying causation structure was postulated as a *deterministic law*. Applying these laws again gave good predictive power and in the sequel machines exploiting physical laws could be constructed. Only if the range of space and time approaches extreme values, then classical laws fail. But again new laws can be discovered and lead to extreme types of exploitation (e.g. nuclear power). Discovering laws in our physical environment means discovering structure. And it is the possibility to repeat experiments successfully, that is, giving very similar results, which gives these laws the flavour of truth. It seems, that the structure is there to be found out, it can be *discovered*.

It needed the scientific revolution of relativity theory to point out, that all synthetic judgements in the sense of Kant, all *laws* describing, i.e. combining our

physical environment with a formalism are probabilistic. All methodological problems of induction stem from this basic property. *Truth*, in its analytical meaning, would need an infinite number of repeated experiments to be ascribed to a synthetic judgement. Since repetition is always finite, no synthetic law ever will reach the standards of analytical truth.

Evidently the Kantian divide between analytical and synthetical judgements works in both directions: No formalism ever can leave the land of empty consistency without loosing its purity¹. Putting it another way, one could say, that any formal statement on a non-formal development is always tentative with respect to possible *real* trajectories, and at the same time usually² will be decisive like all analytical judgements. There is no time involved, no repetition needed, to improve on analytical truth³.

Despite this profound difference in principle, experimental sciences try to push synthetical judgements towards the eternal truth of analytical judgements by increasing the number of experiments, the number of observations explained. This works pretty well as long as the laws to be investigated are changing slow compared to the sequence of observations. A major obstacle to such observations being the question, if the observation itself disturbs, or even produces, the laws to be investigated. In other words, the properties of the observation process, its speed⁴ and its interference with the object investigated⁵, restrict the set of laws that can be investigated.

The success of the experimental method in physics lead to the claim, that any scientific research has to use this method. For two hundred years economists escaped from making experiments, hinting at the impossibilities to keep parts of the social environment constant to repeat experiments. This deficiency made economics a soft science. Its issues seemed to depend on high degree upon the personal views of the respective researcher, since they never could be put to a repeatable test. They either had

¹) Of course it is possible to consider one language as object-language, the analogue to *physical reality*, and another one as a meta-language describing it. In that case the ambiguous statements in the object-language (compare [K.Gödel, 1986] for a proof of their existence) can be given a well-defined analytical truth value by the use of the meta-language.

²) Paradoxical animosities of logic usually are not used for formalized "world descriptions". As argued above, even they can be resolved by the use of a meta-language.

³) Remember what has been said about time in part II, namely how the *concept* of time is timeless whereas the movement through time of all observed processes signifies experience and consciousness of entities.

⁴) In part II consideration of relative speed lead to the notion of urgency for an entity.

⁵) This refers back to figure 2 in chapter 1.

to refer to common sense or had to be believed due to the prestige of the researcher⁶. Formulate some common sense issues in a rigid mathematical form and it is only a matter of the correct application of the mathematical apparatus to arrive at a complicated, scientifically looking economic theory. Mathematical rigour makes up for the lacking experimental justifications. This describes state of current economic theory.

But how is it possible to carry out experiments in economics? Is there really a remedy that allows social sciences to *discover* the laws of "social mechanics", the term framed by Auguste Comte, by the use of experiments? Or should a research strategy in the social sciences better look for a *design* of laws for social entities, as opted for at the end of chapter 1 - and contrary to the prestigious research strategy of physics. Does this last mentioned research strategy still qualify as experimental economics? The new boom in experimental economics shows that two diverging solutions are developing: one building upon methodological individualism, labelled microtheology in chapter 1; the other one extending the gaming approach as indicated in chapter 6. Let me take a closer look at both.

Microtheological experimental economics

Evidently the difficulty to create experimental conditions for social entities can be circumvented if one assumes, that they simply do not exist. If social entities are just artefacts, easily to be aggregated from the individual physical persons, then these persons are the only relevant black boxes for experimental design. This, of course, is a strong assumption. It postulates, that all relevant social developments can easily be derived from the preferences of single individuals. In assuming such omnipotent individuals, whose will is transformed into prices by institutionalized market mechanisms, one neglects all types of higher-level interference between preferences. In short, cooperation and communication, as touched upon in chapter 2, is considered to be an inessential epiphenomenon.

Vernon Smith, an outstanding proponent of this type of approach, distinguishes three ingredients of a theory: *environment*, *institution* and *behaviour* [V. Smith, 1991]. Contrary to the use of the concept environment in this work, he defines it as consisting

⁶) Karl Popper constructs his whole theory of scientific progress on the basis of conventions agreed upon by the scientific community [K. Popper, 1934].

of given preference structure of agents and given endowment and technology⁷. The special form of the working of the market mechanism, how bids by buyers and offers by sellers are transformed in new allocations, is summarized under the label "institution"⁸.

Finally *behaviour* is the thing to be tested: First, economic theory makes a hypothesis about the behaviour of a market participant for a given market process and fixed endowments, technology and preferences. Experimental economists then try to support or to falsify this hypothesis, in keeping environment and institution constant and testing behaviour of real physical persons. In recent years a vast literature on this type of experiments developed. But even in the narrow field of testing the expected-utility-hypothesis, equilibrium concepts and the like in stylized market experiments the way individuals behaved seemed to be completely different to the assumptions of microtheory⁹. Despite this discouraging results researchers in this type of approach do not seem to be ready to abandon the basics of their research strategy, namely to start with individuals as entities.

In my view, it is just those features of the experimental design, which are held constant, taste and technology, that underwent the most dramatic development in recent economic history. Neglecting their dynamics means to lose essential explanatory power. Of course it is the narrowing down of the economic entity to individual persons which is responsible for the exogenous character of the *environment*. Technological evolution can hardly be explained without a notion of cooperation. A change of tastes, not to talk about preferences for newly emerging commodities, can hardly be described without some kind of communication. But these phenomena do not fit into the world of pure market processes with prices being the only language available.

The choice of entity restricts the class of issues to be supported by experimental methods. It might well be, that series of laboratory experiments might allow for estimation of specific functional forms of individual utility functions. Unfortunately this

⁷) "The environment consists of the collection of all agents' characteristics; that is, tastes and technology, which in traditional economics are represented by utility or preference functions, resource endowments and production or cost functions. In reduced form these characteristics are the individual demand and supply schedules." [V.Smith, 1991, p.785]

⁸) Note, that *institution* only characterizes the market process, no other organisational form seems worth elaborating in this approach. Market processes are assumed to be *natural* and therefore dominating all other cultural achievements of mankind.

⁹) "What would be of ... value is research directed at closing two gaps: the gap between decision theory and decision behaviour, and the gap between evidence concerning how people think about economic questions and evidence concerning how people behave in experimental markets. Closing these gaps is crucial if we are not to get stuck on a research plateau." [V.Smith, 1991, p.795]

is of little help if the dimension of the commodity space changes in a fast and hardly predictable manner, if unevenly distributed technological break-throughs shake up the price structure and the evaluation of personal endowments is an unresolvable puzzle. For almost all relevant economic questions the restrictions of methodological individualism are devastating. It needs larger entities, social entities, to investigate these problems.

SIS-driven experimental economics

Is it possible to use experimental methods for *social* entities in the proper sense, which consist of larger groups of individuals? To answer this question, one has to look for a possibility to find black boxes representing larger social entities. Otherwise the old excuse for not doing experimental work would still be valid: It is not possible to make laboratory experiments with, say, all relevant decision-makers of a union and of all important members of the ministry of finance. Even if one is able to bring them together for a policy game once, there still is no way to repeat trajectories of policy response in designed experiments. If "union" is a black box and "ministry of finance" is another one and "employers corporation" is perhaps a third one, then these black boxes have to be substituted by something more treatable for an experimentalist.

Computer technology provides such substitutes: black boxes of the above mentioned kind can be substituted by programs which try to capture essential functional features of social entities. Returning to Norbert Wiener's social engineering language of chapter 6, I will call such programs "grey boxes". They are not black anymore, since they are already abstractions of the *real* social entity. The scientist has already collected data on these entities, has selected some features as essential and others as neglectable. Above all, certain information processing abilities have been ascribed to be significant for the entity under consideration. In formulating the behaviour of these entities as programs, the scientist has to make a lot of choices, in a sense it is a kind of art to derive a suggestive program from a set of hard data about a social entity. With different reaction-functions and sensitivity borders with respect to different other types of social entities one immediately ends up with highly non-linear behaviour.

Having modelled all social entities relevant to the problems under consideration¹⁰, the scientist has to specify trajectories for all the variables that enter the model exogeneously. Such a set of exogenous trajectories usually is called a scenario. Finally the interaction of the different programs representing social entities is studied by the use of simulation runs with different background scenarios. Again, in all but most trivial cases, it is hard work for the scientist to trace back the effects that finally produced the trajectories of endogenous variables. Everybody who ever worked with highly non-linear dynamic equation systems knows how hopeless it is to find analytical solutions to such systems. Though while these systems of interacting programs in principle could be considered as extremely complicated white boxes, I prefer to call them gray boxes as long as they cannot be solved analytically.

It is those gray boxes, representing social entities, whose behaviour is explored by experiments in designed environments. A test is now a simulation run of interacting gray boxes. The designed environment now is called a scenario. The results of tests can be exploited in two directions. On the one hand they can tell us something on the formal mathematical properties of the whole system, on the other hand they might induce reformulation of certain gray boxes. Above all, social entities themselves can use results of tests to understand certain implications of their own strategies and information processing capacities. And knowing better often means changing behaviour. This is exactly the point where the arguments of chapter 5, the SIS-project, come in. For that reason it seems correct to call this type of experimental economics SIS-driven.

While microtheological experimental economics need computers only as supplementary device in the laboratory, computer support is essential for SIS-driven experiments. Software for the support of this type of research has been developed and will be used to demonstrate the fruitfulness of such approaches in future research papers.

¹⁰) This does not mean, that a problem-oriented research strategy has to been followed (compare chapter 4). Starting with an entity and selecting an urgent problem for that social entity usually will force the scientist to bring other social entities in the picture, which also are involved in this problem.

Chapter 8:

Models for policy design

The following two modelling exercises show how a bridge between traditional macroeconometric modelling and evolutionary approaches could be built. Most of the features of these models look very familiar to those involved in this type of macro-modelling, to call the chosen structure evolutionary in their view might mirror just nuances. And indeed it is the extension of these special features, which will be discussed in more detail below, which could give the new fully evolutionary models of E.T.2, but now understood as a straight forward development of macroeconomics.

Two types of models are introduced. First models for western European countries are developed and discussed. A comparison between Austria and Italy is carried out. Second, models for the transition of eastern European countries are studied. In both cases these models incorporate some new, evolutionary features.

Endogeneous technical progress in a macroeconomic model¹

A comparison between Italy and Austria

The objective of this model is to discuss the effects of an innovation promotion program in two European countries, Italy and Austria. To do so, a highly aggregated macroeconomic model is used, which has been successfully applied for similar policy questions in the FRG (see [Frühstück/Hanappi/Wagner, 1990]). The model will be introduced briefly in the next sub-chapter. Some analytical features of this formulation will also be mentioned. The following sub-chapter reports the results of the estimations of the behavioural functions for the Italian and the Austrian economy. Some preliminary conclusions from the comparison of important parameters are drawn. Then a simulation experiment is carried out: If government increases its expenditure on the advance of technical knowledge, then deviations of major economic variables from their trajectories in a reference scenario are computed. Again, results are interpreted and the case of Italy is compared to Austria. In the final sub-chapter the validity of the findings is discussed and some possible extensions are mentioned.

¹) Models of this type have also been developed for Germany (see [G.Hanappi/M.Wagner, 1991]).

A macroeconomic model with endogenous technical change

The model used to explain endogenous technical change in an economy is given in table 1. The key idea is to treat technical knowledge of an economy as a stock variable (KRD), which enters the aggregate production function [1] analogous to the capital stock². Since the inverted production is used as labour demand function [1.1], a higher level of technical knowledge implies lower labour demand.

Technical knowledge is increased by a specific investment (IRD). Investment function [4] explains investment in R&D with the same arguments as function [3] does for regular investment: In both cases on the one hand expected growth, the accelerator, and on the other hand relative factor prices, interest rate versus wage rate, induce investment. Notice that the first argument, the accelerator, can be interpreted as an indicator of the expected profit rate, if the latter depends on the ratio of capacity utilization to output. The difference between the two investment functions stems from the assumption, that R&D investment is less volatile compared to regular investment. Research and development, once induced, is a long-term project. Equation [4] takes care of this assumption by the use of lagged terms.

Other equations of the model are fairly conventional. Consumption function and equilibrium condition in the goods market need no explanation. Government expenditure plus net exports is captured in variable G, which follows output according to the simple relationship [5].

²) Compare the definition of knowledge in chapter 4.

Table 1: MODEL EQUATIONS

Goods market

Equilibrium condition:

$$[0] \quad Y_t = C_t + IR_t + IRD_t + G_t$$

Behavioral equations and technical relations:

$$[1] \quad \ln Y_t = a_{1,1} \ln (c u_t K_t) + a_{1,2} \ln KRD_t + a_{1,3} \ln L_t$$

$$[2] \quad \ln C_t = a_{2,1} + a_{2,2} \ln Y_t$$

$$[3] \quad \ln IR_t = a_{3,1} + a_{3,2} (\ln Y_t - \ln Y_{t-1}) + a_{3,3} (\ln r_{t-1} - \ln w_{t-1})$$

$$[4] \quad \ln IRD_t = a_{4,1} + a_{4,2} (\ln Y_t - \ln Y_{t-1}) + a_{4,3} (\ln r_{t-1} - \ln w_{t-1}) + a_{4,4} (a_{4,2} (\ln Y_{t-1} - \ln Y_{t-2}) + a_{4,3} (\ln r_{t-2} - \ln w_{t-2}))$$

$$[5] \quad \ln G_t = a_{5,1} + a_{5,2} \ln Y_{t-1}$$

Definitions:

$$[6] \quad K_t = K_{t-1} + IR_t - a_{6,1} K_{t-1}$$

$$[7] \quad KRD_t = KRD_{t-1} + IRD_t - a_{7,1} KRD_{t-1}$$

Labour market

Disequilibrium

$$[8] \quad U_t = L^S_t - L^D_t$$

Behavioral equations and technical relations:

$$[1.1] \quad \ln L^D_t = (\ln Y_t - a_{1,1} \ln (c u_t K_t) - a_{1,2} \ln KRD_t) / a_{1,3}$$

Wages and prices

Behavioral equations

$$[9] \quad \ln P_t = \ln P_{t-1} + a_{9,1} \ln P^M_t + a_{9,2} (\ln w_t - \ln w_{t-1}) + a_{9,3} ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

$$[10] \quad \ln w_t = \ln w_{t-1} + a_{10,1} (\ln L_t - \ln L^S_t) + a_{10,2} (\ln P_{t-1} - \ln P_{t-2}) + a_{10,3} ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

List of variables:

Endogenous:

C	.....	private consumption
G	.....	government expenditure plus net exports
IR	.....	investment (regular)
IRD	.....	investment in research and development
K	.....	capital stock
KRD	.....	capital stock in R&D (technical knowledge)
L	.....	employment
P	.....	GDP deflator
U	.....	unemployed persons
w	.....	wage rate
Y	.....	national income

Exogenous:

CU	.....	capacity utilization
LS	.....	labour supply
PM	.....	import price index
r	.....	interest rate

Capital stock and technical knowledge decrease with their depreciation rates and increase with investment (equations [6] and [7]). As is standard in Keynesian macro-models, the labour market can be in disequilibrium if the exogenously growing labour supply exceeds labour demand (equations [8] and [1.1]).

Nevertheless there are forces to drive the labour market at least partially back to equilibrium. In the wage-price-system the wage equation [10] contains a feedback from labour market disequilibrium to the wage setting process. With higher unemployment wages will be lower and, as a consequence, relative factor prices change and encourage firms to substitute labour for capital, employment increases. Prices increase either due to imported inflation or due to a mark-up over wage increases (equation [9]). Since there is more or less central wage-setting in most industrialized countries mark-up behaviour seems to be applicable for wages too.

In both equations [9] and [10] the influence of changing labour productivity is brought into the picture explicitly. The suggestion is, that part of technical progress has to be distributed to wages ($a_{10,3}$ in equation [10] should be positive), while on the other hand increasing competition in times of fast increasing technology should dampen inflation ($a_{9,3}$ in equation [9] should be negative).

As the analytical treatment of this model in [Frühstück/Hanappi/Wagner, 1990, pp.64-78] shows, the stability of the model can only be determined if specific parameter values are assumed. Keeping in mind, that parameter values express economic behaviour, this implies, that for slowly changing parameter values the model might change from a stable region to an unstable one, and vice versa. For a mid-term simulation approach however, questions of stability seemed to be of less importance.

Simulation models

Estimating the behavioural functions of the model for Italy and for Austria did not lead to great surprises. Basically economic intuition proved to be justified. Table 2 gives the results for Italy, table 3 for Austria³.

For the estimation of the production function, the parameter restriction that $a_{1,1}$ plus $a_{1,3}$ equals one has been assumed. That is, increasing returns appear only via growth in technical knowledge⁴.

The estimation of [4] is based on the restriction that $a_{4,4}$ equals one. This assumption can be justified by the argument that firms take a long term view on investment in R&D; they attach the same weight to recent experiences as they do to current ones⁵.

An interesting result is the negative influence of lagged output growth on investment in R&D. A Schumpeterian interpretation would state, that firms start innovation during the recession. As equation [3] shows regular investment behaves procyclical.

Suggestions about signs of the wage-price-systems' coefficients proved to be correct.

³) Since the emphasis of this simulation exercise is not on the econometric estimation of the model, all measures of significance of the single equation OLS estimations are omitted.

⁴) For recent industry specific estimate of a similar function for the FRG see [Błazejczak/Erber/Horn, 1988].

⁵) On long term orientation of R&D investment see [G.Dosi, 1988].

Table 2: ITALY

Goods market

Estimated equations:

$$[1] \quad \ln Y_t = 0.163 \ln (cu_t K_t) + 0.272 \ln KRD_t + 0.873 \ln L_t$$

$$[2] \quad \ln C_t = -2.257 + 1.131 \ln Y_t$$

$$[3] \quad \ln IR_t = 11.862 + 0.515 (\ln Y_t - \ln Y_{t-1}) - \\ - 0.103 (\ln r_{t-1} - \ln w_{t-1})$$

$$[4] \quad \ln IRD_t = 8.331 - 0.223 (\ln Y_t - \ln Y_{t-1}) - \\ - 0.226 (\ln r_{t-1} - \ln w_{t-1}) - \\ - 1 \cdot (0.223 (\ln Y_{t-1} - \ln Y_{t-2}) + \\ + 0.226 (\ln r_{t-2} - \ln w_{t-2}))$$

$$[5] \quad \ln G_t = -4.9072 + 1.23 \ln Y_{t-1}$$

Assumed:

$$[4] \quad a_{4,4} = 1$$

$$[6] \quad a_{6,1} = 0.025$$

$$[7] \quad a_{7,1} = 0.025$$

Labor market

Assumed:

Nominal wages are downward rigid.

Wages and prices

Estimated equations

$$[9] \quad \ln P_t = \ln P_{t-1} + 0.0129 \ln P_t^M + 0.9116 (\ln w_t - \ln w_{t-1}) - \\ - 0.288 ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

$$[10] \quad \ln w_t = \ln w_{t-1} + 0.2829 (\ln L_t - \ln L_t^S) + \\ + 1.15 (\ln P_{t-1} - \ln P_{t-2}) + \\ + 1.362 ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

The case of Austria nevertheless lead to difficulties, which caused a slight change in the model structure. Labour demand could not be estimated as inverted Cobb-Douglas production function. To arrive at reasonable results a constant capital-output-ratio had to be estimated (equation [1]). This is the reason why instead of the two

independent variables K and Y only one variable, namely Y^* , enters the labour demand function [1.1].

In equation [5] the introduction of a time trend improved the estimation tremendously, suggesting that the growth of this variable in Austria depends less on output growth.

Table 3: AUSTRIA

Goods market

Estimated equations:

$$[1] \quad \ln Y_t^* = 0.2184 \ln K_t$$

$$[1.1] \quad \ln L_t = \ln Y_t^* + 14.77 - 1.37 \ln KRD_t$$

$$[2] \quad \ln C_t = -0.656 + 1.0057 \ln Y_t$$

$$[3] \quad \ln IR_t = 9.889 + 0.741 (\ln Y_t - \ln Y_{t-1}) - \\ - 0.301 (\ln r_{t-1} - \ln w_{t-1})$$

$$[4] \quad \ln IRD_t = 2.726 - 2.304 (\ln Y_t - \ln Y_{t-1}) - \\ - 0.564 (\ln r_{t-1} - \ln w_{t-1}) - \\ - 1 \cdot (2.304 (\ln Y_{t-1} - \ln Y_{t-2}) + \\ + 0.564 (\ln r_{t-2} - \ln w_{t-2}))$$

$$[5] \quad \ln G_t = 9.68 + 0.13 \ln Y_{t-1} + 0.033 \cdot (t-1)$$

Assumed:

$$[4] \quad a_{4,4} = 1$$

$$[6] \quad a_{6,1} = 0.025$$

$$[7] \quad a_{7,1} = 0.05$$

Labor market

Assumed:

Nominal wages are downward rigid.

Wages and prices

Estimated equations

$$[9] \quad \ln P_t = \ln P_{t-1} + 0.02736 \ln P_t^M + 0.6634 (\ln w_t - \ln w_{t-1}) - \\ - 0.019 ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

$$[10] \quad \ln w_t = \ln w_{t-1} + 0.311(\ln L_t - \ln L_t^S) + \\ + 0.79(\ln P_{t-1} - \ln P_{t-2}) + \\ + 1.197 ((\ln Y_{t-1} - \ln L_{t-1}) - (\ln Y_{t-2} - \ln L_{t-2}))$$

Comparing some key parameters gives the following picture. As the output elasticity shows, the Italian stock of technical knowledge contributes more to output than the Austrian does. The fact, that substitution between capital and labour is much more rigid in Austria might have contributed to this.

On the other hand investment behaviour, in particular the accelerator mechanism, seems to react much more sensitive in Austria than in Italy. For relative factor prices the long prevailing stability of distribution between labour and capital could have lead to higher sensitivity.

Equation [9] shows, that Austria could be hit by international inflation slightly more severe than Italy. Austrian firms meet less favourable circumstances than Italian firms do to compensate wage increases by price increases. On the other hand Austrian entrepreneurs are better off in preventing increasing competition from driving down their prices.

Austrian labour unions react with their wage setting process more sensitive to labour market disequilibria than Italian unions do. Austrian workers seem to receive their wage increases rather in relation to increased productivity, whereas Italian workers seem to get higher wages as compensation for inflation.

Evidently suggestions like these are only as good as a highly aggregated model can picture a complex economy. Nevertheless most of them sound quite plausible.

A simulation experiment

Forecasting the two economies for five years by the use of the two simulation models gives an idea of the highly interdependent structure of these models. In this chapter only one policy experiment is carried out, and the results of this experiment in both countries is compared.

Assume that instead of following equation [5], government suddenly adopts an innovation promotion program. More precisely, one percent of GDP are taken away from government expenditure, lowering variable G , and are added to investment in R&D, increasing variable IRD . Moreover this policy shock is permanent, that is, it appears in each year.

Table 4 compares the deviation of the performance of the two economies if they are hit by such a policy shock. Figures given are the differences of the growth rates of the respective variables, measured in percentage points. In other words the growth rate of a certain variable in the reference run (without policy shock) is subtracted from the growth rate of this variable in the policy run.

Table 4: Results of the simulation experiment

Year	1989	1990	1991	1992	1993
ITALY:					
GDP	0	-0,02	0,02	-0,02	-0,01
Unemployment Rate	1,55	1,55	3,2	3,19	3,4
Prices	-0,46	-0,24	-1,18	-0,48	0,02
Wages	-0,52	1,07	-1,32	0	-1,65
AUSTRIA:					
GDP	-0,58	0,53	-0,71	0,6	-0,55
Unemployment Rate	0	2,3	2,18	4,45	4,18
Prices	0	-0,99	1,37	-0,92	-0,05
Wages	0	-1,53	2,14	-1,4	0

As this table shows, the Italian economy is hit by such a policy shock much less severe than the Austrian. Growth of GDP remains almost unaffected, while Austrian

growth rates start to oscillate. This might have been caused by the long stable development of Austria, which somehow taught Austrian agents to react stronger on slight changes.

In both cases employment suffers from labour saving innovation in a very significant way. While Italian consumers will benefit from lower prices, Austrians in general will not. In both countries wage growth will become unstable, higher unemployment surely will drive down wages in the long run.

As this model shows, even small and highly aggregated macroeconomic models can reproduce plausible features of inter-country comparisons. Extensions of this type of models, incorporating international trade, money markets and exchange rate dynamics have been tested for the FRG [Hanappi/Wagner, 1990] and for Austria [Hanappi, 1990]. A model with a more elaborated public sector is in preparation.

Comparing Italy and Austria shows certain advantages of Italy as far as its capacity to translate higher productivity into lower prices is concerned. On the other hand Austrian workers seem to be in a better position if technological unemployment starts to increase. For both countries the disadvantages of a forced technology policy, which is not encompassed by a complementary employment program, probably overweigh its benefits.

Macroeconomic transformation models for Eastern Europe⁶

In the years before the declared turn towards market processes, that is roughly till the second half of the eighties, macroeconomic models of Eastern European countries have not been a favourite subject of interest for economists. From a theoretical point of view a command economy, with its politically determined production and distribution structures, that is, with its lack of economic agents in the proper (western) sense was not very attractive. Applied analysis, on the other hand, was equally frustrating, since the more or less smooth developments of major economic time series could either indicate the bad quality of the officially reported data or could simply be assumed to suppress underlying, economically determined, disequilibria. A good deal of the work, that nevertheless was done in the field, dealt with filtering out excess demand, inflationary

⁶) These models have been presented in a paper [G.Hanappi, 1991b] called "Roads to Capitalism" prepared for the symposium "Europe between East and South" in Urbino, Italy, 24.- 25. October 1991.

pressures and the like⁷. With the announced turn towards market processes all this has changed.

As the transformation of these economies, once initiated, takes place in an accelerating speed, which evidently was not foreseen by its promoters, unexpected new phenomena occur. Models of the stable era before the transformation could, and did in fact, try to investigate some underlying long-term behavioural traits, that could be described in a very traditional economic way (constants of social psychology, propensities towards consumption and investment, etc.), traits that were supposed to be suppressed in CMEA-countries by the political system. The strong influence of the political system made economic forecasting simple.

Unfortunately enough, it is just the period of rapid economic and institutional change, that needs economic consultancy most urgent. To interfere in the transition process and to design and redesign economic mechanisms is something, that cannot wait till data sets are large enough to mirror long-run behavioural characteristics of economic agents. Given this crux, the following models try to demonstrate, how the use of evolutionary transformation scenarios nevertheless could help to illuminate which choices and consequences decision-makers involved in this process might face.

As a first step it is necessary to defend the necessity of a macro-approach against the objections of radical micro-theorists. The latter claim, that any relationships between aggregate variables postulated by a macro-theorist are avoidable ad-hoc assumptions, which should rather be derived from the interactions of micro-units, whose behaviour is characterized by *their* (microeconomic) ad-hoc assumptions. An evident counter-argument is, that micro-units use aggregate variables in their decision-making process and the emerging interdependence between aggregation and information feedback is to be considered as one system. There is no reason, why a description of this system using only macroeconomic variables should not be a valid starting point for what has been called a micro-macro-model in chapter 1.

This idea leads directly to the next sub-chapter, where a small set of important variables is chosen to picture the transformation processes in several countries from 1984 till 1990. No relationships between these variables are postulated at that stage (stage 1), a variety of dynamic systems could produce this outcome. But there are some

⁷) An interesting classification of work done can be found in [Brabant J.v., 1990].

similarities between the transformation in different countries, that could be used to inform the model-builder about the puzzles to solve.

Three different examples of dynamic models to explain the empirically observed data-set are presented. These specific formulations are stage 2 of the model-building process. Moreover the three models also represent three different methodological approaches.

The first one, MODEST-0 (**MODE**ls-of **EaST**ern Europe), uses classical economic concepts, like monopolist behaviour, to explain one of the major problems, the decrease of output during the introduction of market forces. In a situation characterized by excess demand and high savings (at least in the case of the USSR), main-stream economic reasoning would expect a boost in output and prices. MODEST-0 shows, how a simple macro-model, which assumes, that privatized firms are large enough to justify a dominance of monopolistic behaviour, can solve this riddle. The first approach thus consists of a suitable adoption of standard demand-driven macro-models to the conditions of supply-constraint economies.

A second, slightly different approach is to introduce new behavioural equations, which are thought to represent important economic processes during the transformation. My second model, MODEST-1, is an example of this type of approach. Building on the structural model of MODEST-0, some new equations are introduced to grasp specific "behavioural" traits of the transformation: The emerging hard-budget constraint for firms, for example, now explicitly leads to the exit of non-profitable firms. One could think of a central agency as well as off the forces of international markets to enforce this exit. The price for the richer formulations of models of the second approach is, that the closer they try to track reality the harder they are to solve analytically. As mentioned earlier, a possible way out then is the simulation of scenarios - SIS-driven experimental economics. But in the case of rather singular events, like the transformation under consideration, even for simulation scenarios almost insurmountable problems appear as soon as parameter values should be estimated. What is left, usually are suggestions about qualitative issues, like the signs of dynamic multipliers.

To come up with this type of result in many cases a less structured model would be sufficient. This is, what the third model, MODEST-3, tries to demonstrate⁸. Going back to the typical dynamics found in the graphs, a simple 4-dimensional linear

⁸) Model MODEST-2 is an extended version of MODEST-1 and is not discussed in this chapter.

difference equation system is postulated. Propositions for the signs of coefficients as suggested by the graphs are made and economic interpretations for them are put forward. In other words, this approach upsets the usual procedure of economic reasoning: Instead of starting with the assumption of economic rationality of given actors, deriving some consequences and finally using empirical observations to falsify or, more often, to verify the whole story, in this case we start with empirics. More precisely, the first task of the economist is, to choose variables as relevant elements, look at their historical time series, then assume simple dynamics (linearity) and suggest some qualitative features. Only as a last step the coefficients are given an economic interpretation, that is, actors, social entities, are found, motivations and their relative weights are discussed, policy implications are suggested.

Models MODEST-1 and MODEST-3 are used for simulation. MODEST-1 gives an idea of some dynamic multipliers and MODEST-3 is used to forecast the transformation of the USSR. In particular the grouping of countries is used: the future developments of policy parameters in the USSR is believed to follow a path similar to that in Poland and Hungary. The basic forecast derived by these, admittedly crude methods is then confronted with the implications of two alternative policy regimes, radical freedom of pricing (FOP) and radical freedom of employment (FOE).

Despite the limits of such very small models, which immediately become evident, still some conclusions about policy design in the transition period seem to be possible. The final sub-chapter summarizes some of these policy implications and puts them into a broader historical context.

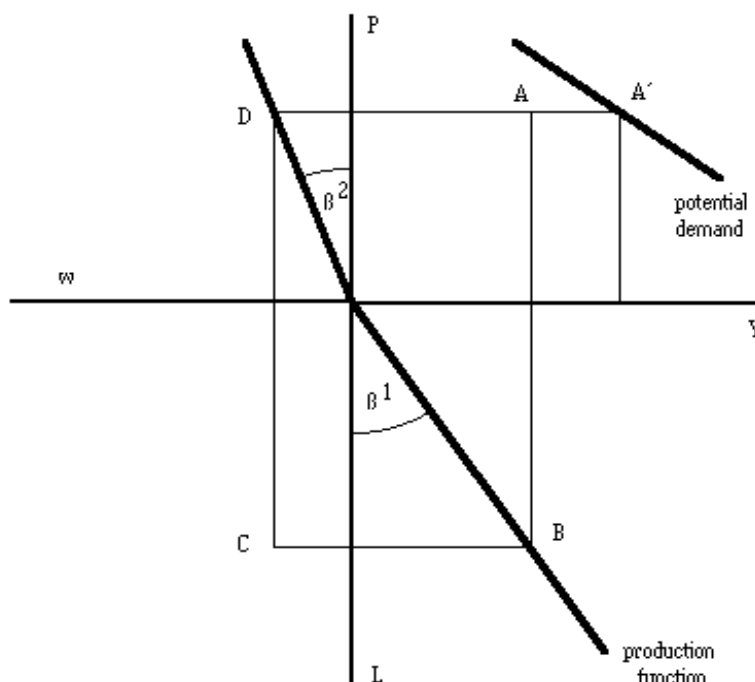
The last five years of transformation - stage 1

Talking about a transformation process implicitly assumes, that there is an old system, from which transformation starts, and a new system, where the transformation is assumed to lead to. Moreover, there has to be a reason, why the old system had to collapse. And there has to be an idea how the new system, after the transformation process, will master old problems.

The following four variables are suggested to give a first impression of the nature of the transition process: Output, price level, employment and wage level. Using all four quadrants of a diagram for these four variables, plus three derived ones, can be represented at once (see figure 8): Ankle β_1 in figure 8 shows labour productivity, ankle

β_2 shows the real wage and finally the ratio between the two rectangular areas from realized point to origin in quadrant 1 and 3 gives a crude measure of profitability⁹. Figure 8 also includes a budget constraint in the first quadrant, which can be used to measure the amount of disequilibrium in the commodity market¹⁰.

Figure 8: Basic relations in a supply-constraint economy



Figures H1 to H7 show such a diagram filled with real data from seven eastern European countries (Bulgaria, CSFR, Hungary, Poland, Romania, USSR, Yugoslavia) for the period 1984 till 1990¹¹. All four variables have been scaled to 100 in the year 1984. If the development in some quadrants is so dominant, that the shapes exhibited in other quadrants appear only as points, then a second, rescaled set of diagrams is added.

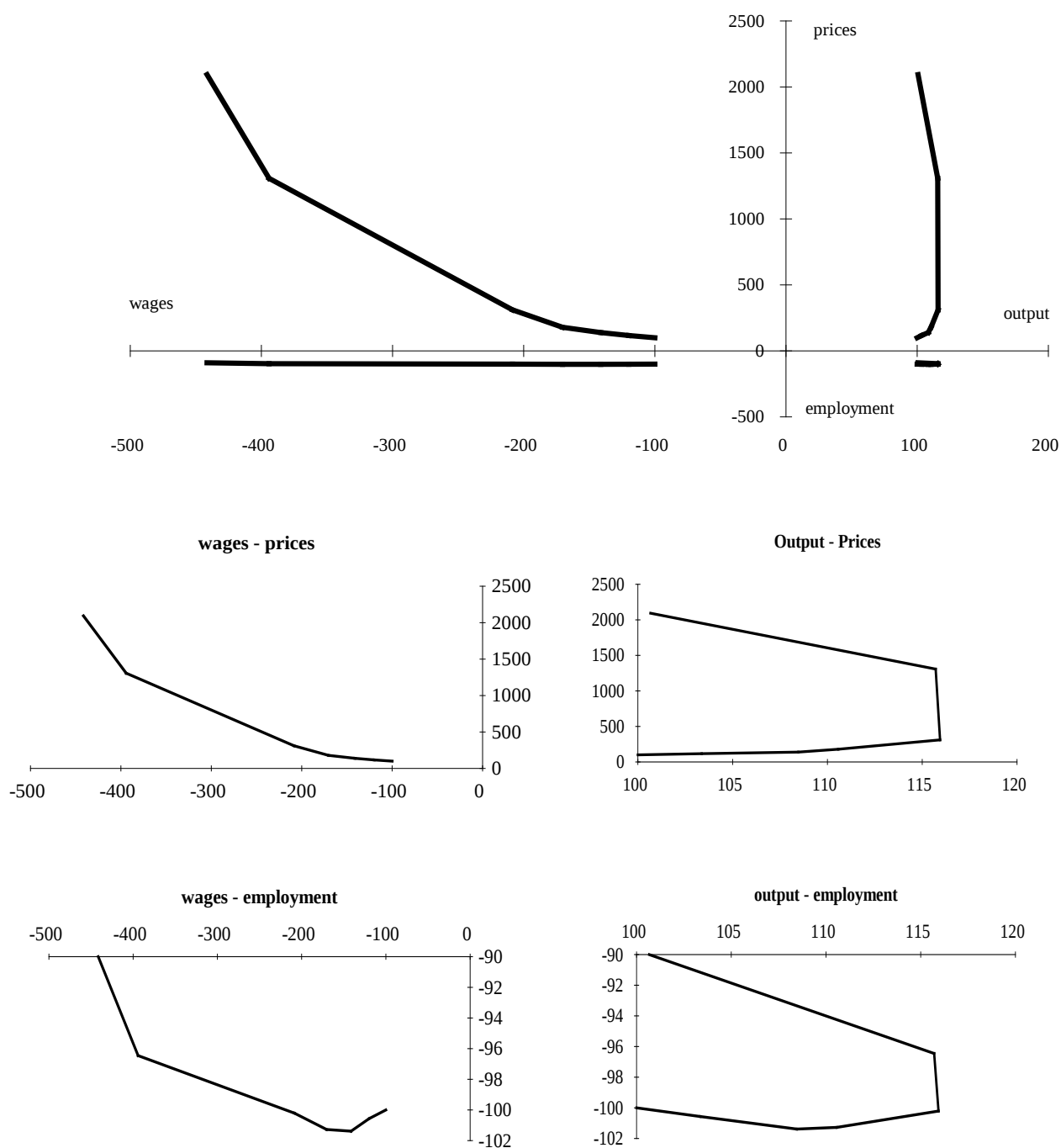
⁹) This will be explained in more detail in the next sub-chapter.

¹⁰) The first model in the next sub-chapter will use this concept.

¹¹) With the exceptions of Romania, where data was only available till 1989, and Hungary, where no wage-index for 1990 could be used. Main data source was the database at the Vienna Institute of International Comparisons. For most recent developments various other publications were used ([Dyba/Svejnar, 1990], [Prasnikar/Pregl, 1990], [Crane K., 1990], [Dhanji F., 1990], [Hausner J., 1991], [IMF et al., 1990] and others). I wish to use the opportunity to thank my colleagues at this institute, in particular Raimund Dietz and Peter Havlik for their support and inspiring discussions.

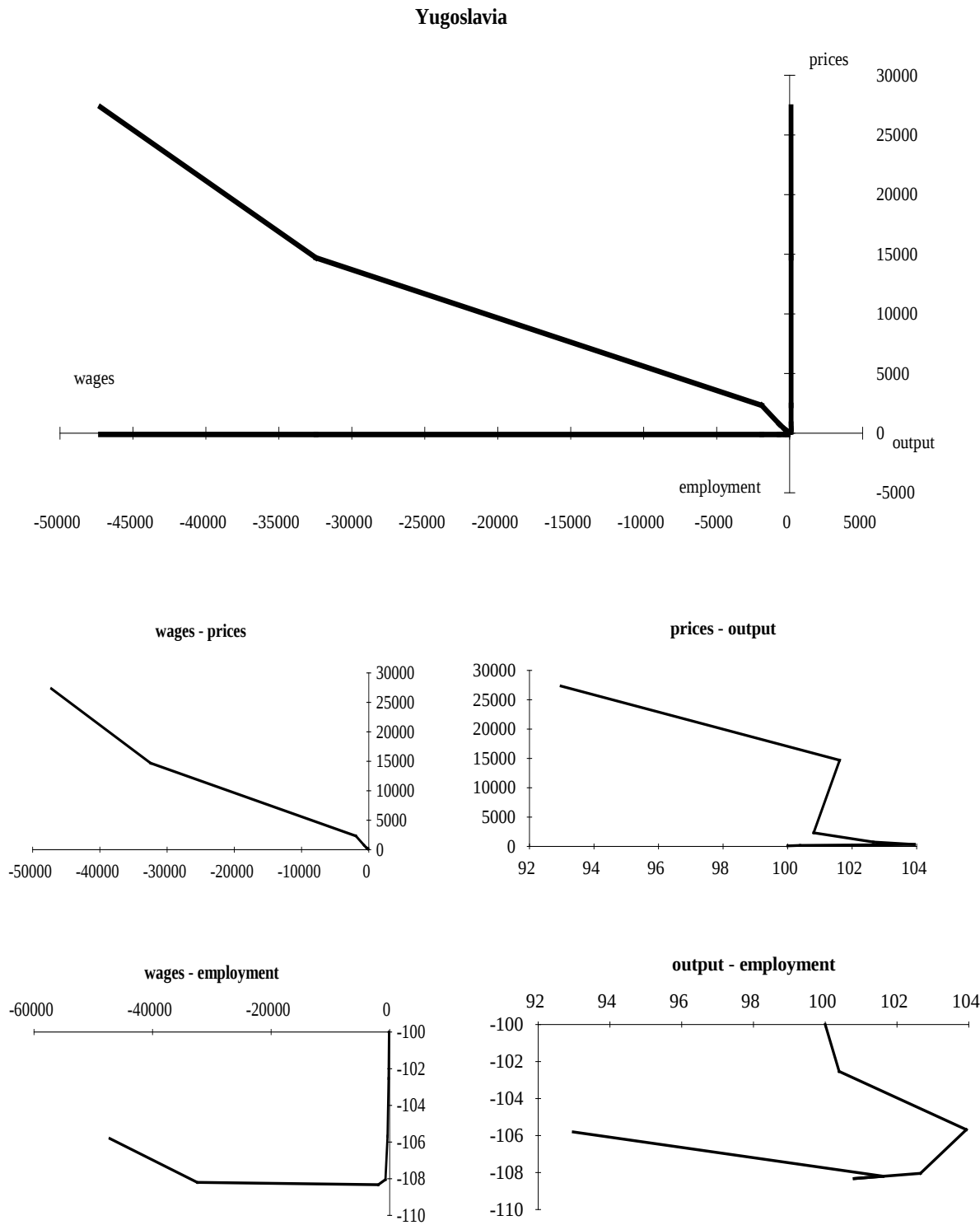
Figure H1

Poland



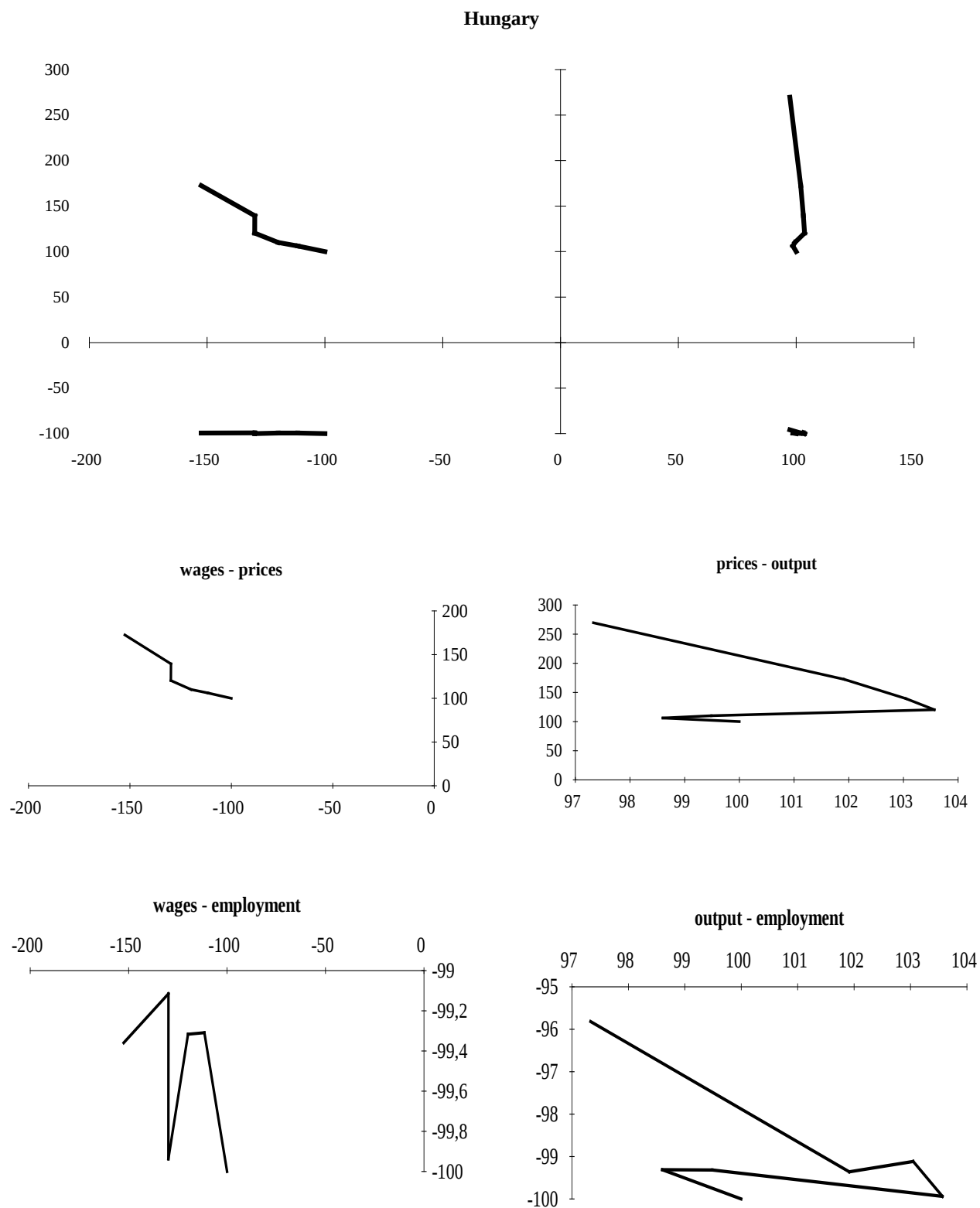
All variables are indices with 1986=100.

Figure H2



All variables are indices with 1986=100.

Figure H3



All variables are indices with 1986=100.

Figure H4

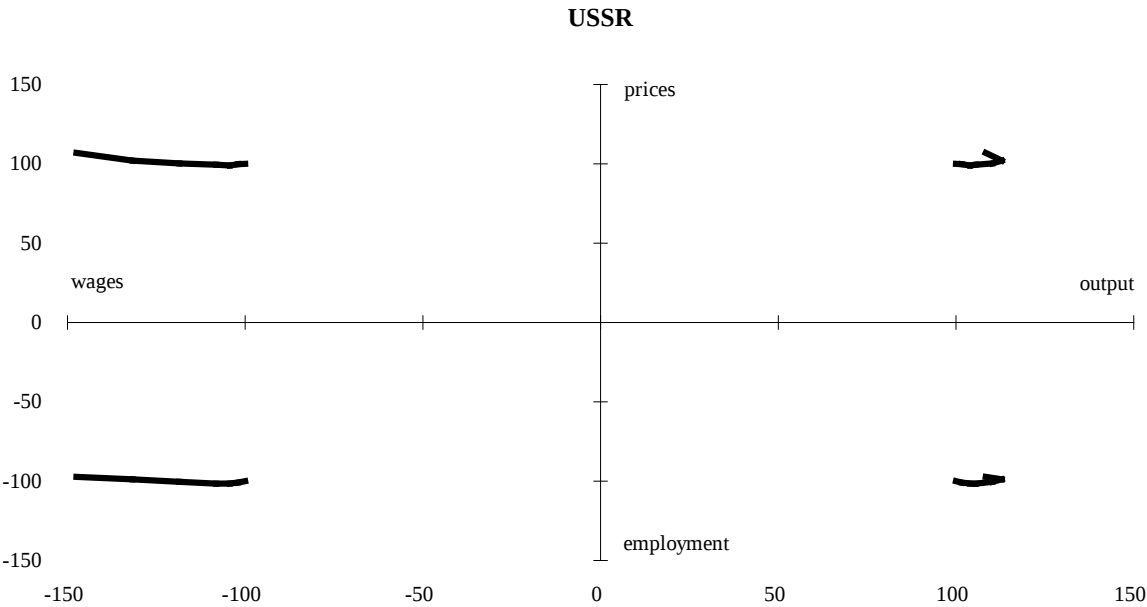
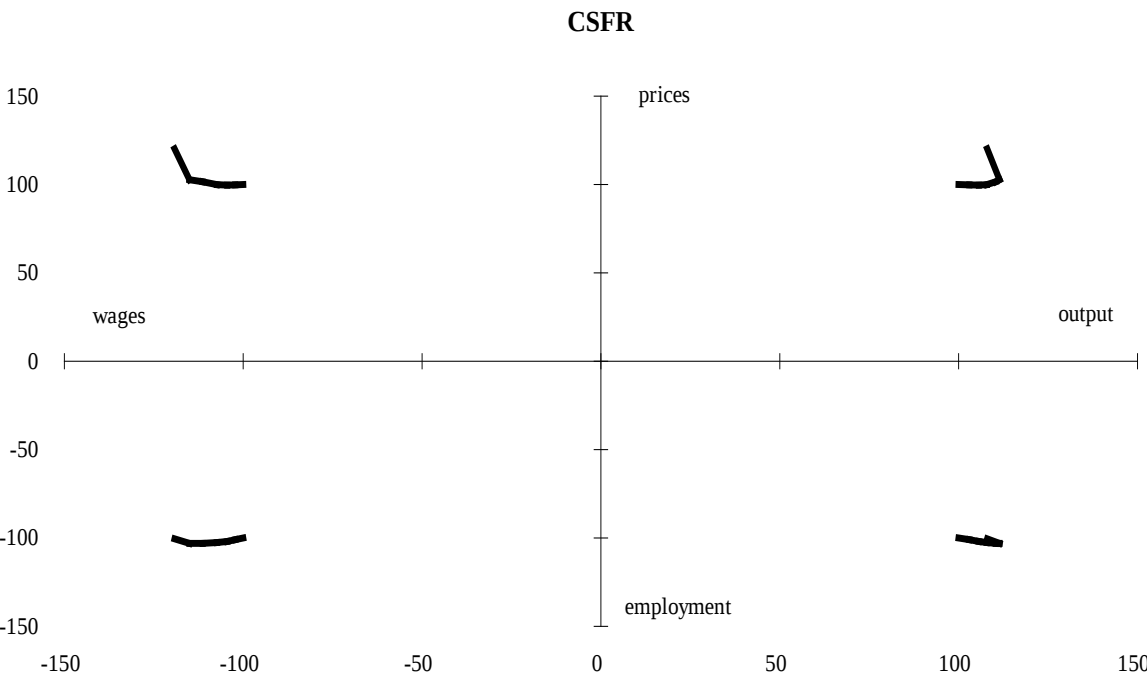


Figure H5



All variables are indices with 1986=100.

Figure H6

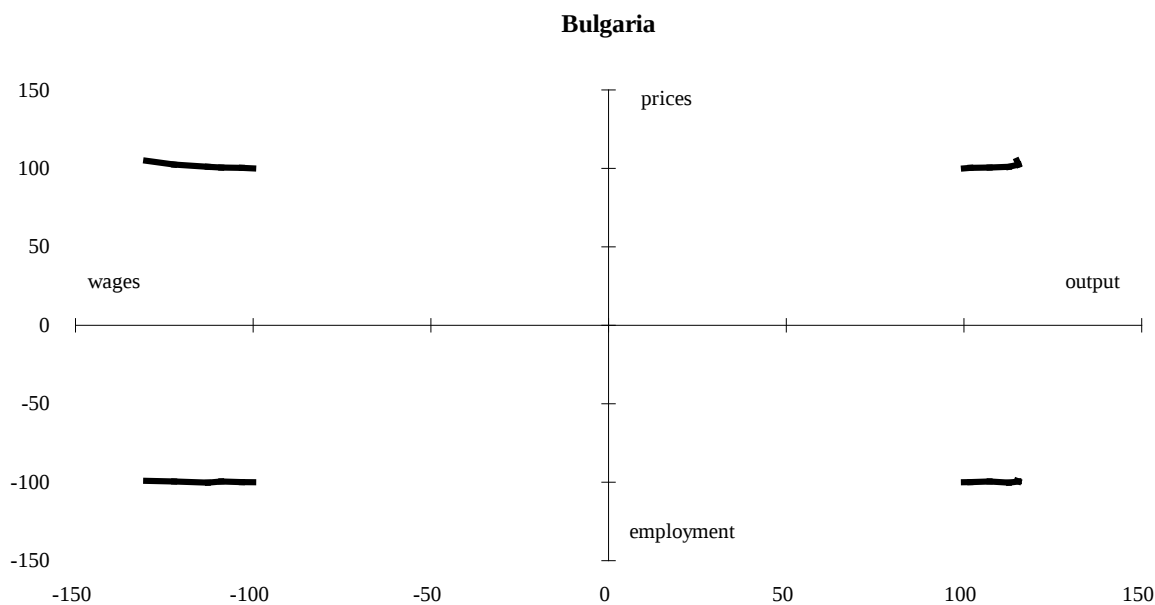
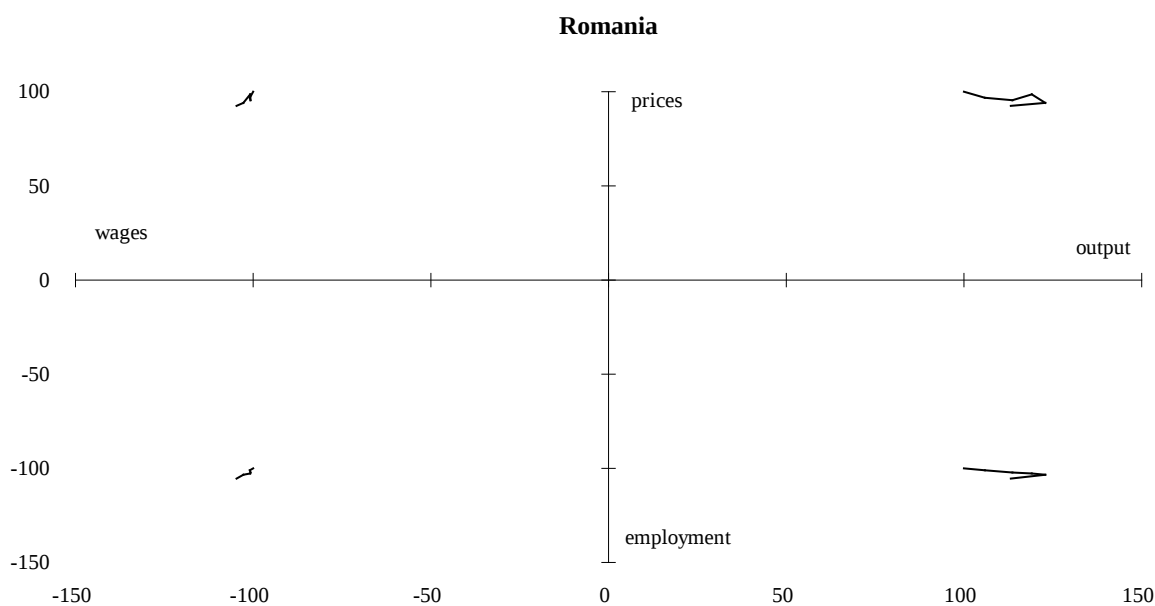


Figure H7



All variables are indices with 1986=100.

As all of these graphs show, there is no empirical support of "free market euphoria". On the contrary, the three "oldest" reformers, Poland, Hungary and Yugoslavia, still seem to face most severe problems¹². With the exceptions of Yugoslavia and Romania a common feature of transition seems to be an upward and to the left bending curve in the second quadrant: less employment followed by output decrease. Price increases tend to accelerate into hyperinflation in the course of transition. The importance to check real wages seems to be recognized only after a time lag (see Poland and CSFR in contrast to the USSR) and depends probably also on the organizational strength and militancy of unions. Even this very crude first impressions suggest a grouping of the countries under investigation. Poland and Hungary seem to be most advanced in the typical transformation process (group 1), followed by the CSFR and the USSR, where the same process just begun (group 2). In Bulgaria preconditions for the same typical process are building up (group 3), whereas Yugoslavia and Romania are non-typical outliers (group 4).

Three models - stage 2: Overview

The central ideas for the major features of the transformation process in eastern European economies first are summarized in a small macroeconomic model called MODEST-0. This model essentially consists of eight equations describing relevant mechanisms of this process. It is possible to present these relations in a common diagram (see figure 8).

The first quadrant shows the relationship between total output and price level. From a macroeconomic viewpoint there is no demand-curve as it is usually assumed for a single market. What in western textbooks is called "aggregate demand curve" is a set of equilibrium points of money, bond and commodity markets for different price-output combinations. Since neither of these markets can be found to exist in eastern Europe in a way comparable to the West, this concept is not applicable. All we can say, and all we need to assume, is, that commodity markets in the command economies of the late eighties were in a supply constraint disequilibrium. That is, customers were willing and able to buy more commodities than there were available, this unsatisfied excess-demand leading to forced savings.

¹²) Important variables not shown in these graphs are budget deficit and foreign debt. In both respects Poland and Hungary are in most severe troubles, Yugoslavia following them as a consequence of civil war - all this confirming my point of view.

As a consequence, owners of commodities would raise prices as soon as they are allowed to, without having the immediate risk of demand constraints. This "freedom of pricing" (FOP) can be seen as a policy instrument indicating how far price regulations are abandoned. (Equation [3] in Table 5 is a possible formalization of this process.)

Concerning future output levels, no clear trend is assumed. With greater FOP the assumption of the immediate emergence of competitive markets would probably lead to a tendency of fast rising output levels with low inflation. The fact, that in all transformations of eastern economies such a behaviour has *not* been observed, leads to the assumption, that at least in the mid-run prices are not determined by competitive market forces, but by a behaviour reminding on monopolistic pricing at low output levels. This last behavioural assumption is even more realistic, if one takes into account the difficulties (and high cost) of an expansion of the physical capital stock under the current circumstances - fast expansions of output levels are unlikely. The change of social entity, from bureaucrats in the a stalinist system doing their administrative job to high-ranking managers of large private firms, might even keep some individual persons in power.

In the second quadrant a simple production function, linking output with labour inputs is used to demonstrate some crucial features of the current dilemma. First it is important to remind, that this relationship concerns physical quantities, output and workers employed. The quotient, output per worker, usually is called productivity. As an ex-post measure of the performance of an economy, productivity is a derived variable summarizing different influences on the production process during the time period under consideration. Analytically one could distinguish factors like "average technology used", "average labour intensity" and "average length of the work day". Each of these factors plays its one decisive role in explaining the current impasse of the transformation process:

The slow adoption of new technologies resulting not only in low quantities of output, but also in bad quality is one of the major reasons for what has been called the "consumers revolution in eastern Europe". It has to be reminded, that the ability of western-style capitalism to promote new techniques via the innovating power of "capital", now used in the non-physical meaning of the word, lies at the core of the

historical mission of this mode of production¹³. The implicit judgement about the reasons of the breakdown of eastern command economies given by my model hints in that direction: innovation (in a technical but also in a social sense¹⁴) has not been taken to a higher level, but has been completely dismissed together with the destruction of early forms of mostly "agrarian capitalism". This is the ultimate reason for the omnipresent catharsis in late stalinism.

The axis for labour inputs is also used to measure labour supply, which is taken as an exogenous variable, mainly driven by population dynamics. In a stylized way, an important feature of command economies can be captured by the assumption, that the growth of labour supply is identical to the growth of labour inputs, i.e. there is no unemployment, at the cost of an adjustment of labour productivity, measured as the angle β^1 in figure 8. Note that, according to the explanation given above, this angle is influenced by three different forces: purely technical advances (denote them as a^T), political circumstances like strikes (denoted as a^{PO}) and labour intensity (called a^I). The latter is assumed to adjust as endogenous variable to equilibrate the labour market in the case of "pure command economies", from now on called SPS ("Stalinist Production Systems"). Equations [1] and [2] in table 5 show a way to formalize this idea.

Again deviations from the "pure command economy" - case can be modelled by the use of a policy variable allowing for a labour demand of firms that might be lower than labour supply. In the model MODEST-0 the emerging unemployment thus depends basically on two processes: First on the (legally constrained) ability of firms to raise labour intensity above the full-employment level to a level optimal for the firm. This is measured as policy variable a^L in equation [2]. Second on the kind of optimization used by the firm. Note that the firm in this simple setting is confronted with a two-fold decision problem concerning prices and outputs. Both decisions should be the outcome of some type of optimizing behaviour¹⁵, which then is constrained by policy variables controlled by the government. For prices this process has already been described (Equation [3]), for outputs it is assumed, that there is no direct influence of government control on output levels. But since outputs and prices are optimized simultaneously, price constraints are taken into account in actual output levels. Given these output

¹³) The overemphasis on issues about optimal allocation of resources in mainstream economics has severely obscured this fundamental insight, whose last great promoter was Schumpeter following in his argument, ironically enough, Karl Marx.

¹⁴) The central social innovation, the emergence of society as social entity, had only been *declared* by the communist party. No quantum jump of highly integrated political feedback loops actually occurred.

¹⁵) Of course optimality does *not* exclude so-called "satisficing behaviour", which always can be interpreted as an optimal outcome for appropriate information cost, transaction cost or the like.

levels, employment decisions again are directly influenced by the exogenously controlled ability to raise labour intensity.

Obviously a crucial point of the argument is how far controls and other exogenous variables are anticipated in the optimizing behaviour of firms. (Equation [5] summarizes a possible type of optimal price-output decisions.)

A more drastic variant of output and employment choice of firms is captured in model MODEST-1: Decreasing average profitability will force a number of firms to "choose" bankruptcy as optimal decision - no output, no employment.

The third quadrant could be used to show the usual labour-demand and labour-supply schedules. Evidently there are no such relations in a SPS as long as employment is guaranteed at wage levels which are centrally determined. All one can see in this quadrant at the beginning of the transformation process is the area of the rectangle with the diagonal from the origin to point C. This area represents the wage sum. Neglecting depreciation this could be taken as a proxy for production cost. Comparing it to the area of the rectangle with diagonal origin to point A in the first quadrant, which is a crude measure for revenues, one can get an idea of a "latent profit rate" of the system. The transformation process can thus be easily identified as the attempt to raise this rate by increasing the rectangle in the first quadrant (revenues) and decreasing the one in the third quadrant (cost), and to make it an actual profit rate by leaving profits at the disposal of firms.

If the SPS starts to be transformed, that is, optimal price-output-employment decisions of firms can to a certain extent be carried through, then these decisions typically have to take into account the amount of forced savings. As the macroeconomic accounting framework immediately shows, forced savings depend to a great extent on wages. (In the formulation of my basic model MODEST-0 equation [7] takes care of this). The higher the wage-rate in a supply constrained economy, the higher will be forced savings. A fact, that does not matter in a SPS since profit rates are only latent¹⁶. As soon as they become actual - and any kind of profit oriented management salaries makes them more "actual" - the wage setting process becomes important.

¹⁶) It is important to notice, that it is low productivity, basically measured by β^1 , lack of innovation and political oppression which caused the "consumer revolution" and not low, "latent profit rates". Only small quantities of consumable output per head can be experienced in an SPS, not profitability. This is so, simply because the entities to react on it, independent firms, do not exist.

The fourth quadrant can be used to present different wage processes. Starting at point D, any point on the beam through D represents the same real wage given by the angle β^2 . A policy of constant nominal wages would result in movements on a vertical line through D.

Now consider the problems faced by a stylized SPS over time. Let us start with a quadrupel of points in the four quadrants, say ABCD in figure 9. Population growth combined with a low rate of technical progress and decreasing labour intensity might eventually lead to point B" in the second quadrant. The different use of the new output can be inserted in the first quadrant leading to point A". A high and inflexible part has to be reserved for government expenditure, including defence expenses, all kinds of cost of bureaucracy and investment¹⁷. Another part consists of net exports, which, for the basic model are taken as exogenous¹⁸. The rest can be considered as available for consumption. As a consequence the amount of consumption per head will be quantitatively limited. This happens independently of any wage-price developments, so that, for example, rising real wages result only in high savings without any feedback to the production side of the economy. If, therefore, such a rise of real wages at more or less constant prices leads to point D" in the fourth quadrant, then the corresponding point C" in the third quadrant might be considered as signalling via the large wage-sum rectangle disastrous latent profitability, but again this remains without any feedback effects in the rest of the system.

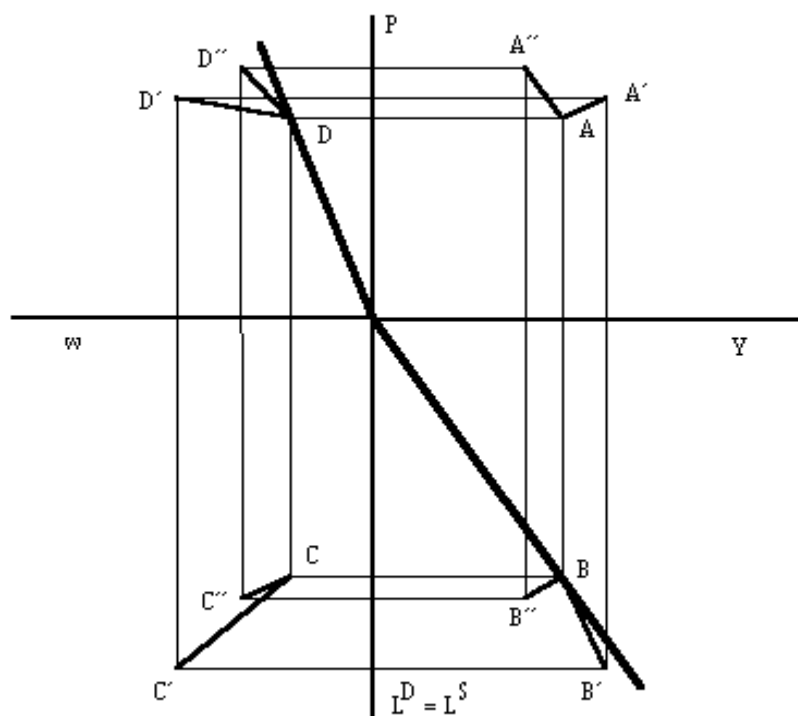
Slight reforms of the SPS towards a market economy immediately will start to reveal low rates of latent profitability and, given the well-known difficulties of capital formation (in the physical sense), as a consequence prices will be expected to rise. In such a situation hoarding of output at all points of the production process, and by all agents able to do so, is a rational strategy. Nobody wants to sell today if he can expect substantially higher prices for *his* product next month. The important point is the emphasis on the word "his", expressing that agents expect rising revenues to contribute to their personal, disposable income even if a general rise of the price level lets relative

¹⁷) In a more detailed treatment each of these expenditure classes would have to be dealt with explicitly to be able to recognize the types of problems associated with them: The scope and the "mechanics" of the influence of lower military expenditure differs between countries; the problem of bureaucratic overheads is a general feature of modern societies with no general solution proposed so far; the "who" and "where" of investment decisions is the crux of the success of capitalism - as well as its periodically appearing major problem. The latter point strongly calls the design of a social entity.

¹⁸) Trade in an SPS traditionally amounts only to a comparatively small share in output, reflecting Stalins notion of autarcy: "socialism in one country". Despite the important part played by internationalization during the transformation process, an explicit formulation can therefore be postponed as an extension of the basic model.

prices unchanged. It is a paradox, that these agents start to act as "latent entrepreneurs" by postponing the point of sale. The emerging crisis of further decreasing consumption possibilities leads to political destabilization, strikes, even lower labour intensity and other self-perpetuating forces causing output to fall substantially. In figure 9 as an outcome of a timidly initiated reform process finally the set of points A'B'C'D' could be the result. Evidently this interpretation of the transformation process differs radically from the usually told success story of "introducing market forces". Moreover, the fact, that this "free market euphoria" obviously is shared by agents, shapes their expectations, is at least partly responsible for the crisis predicted by my interpretation.

Figure 9: Typical developments of supply-constraint economies



Having briefly demonstrated the fundamental assumptions of MODEST-0 and MODEST-1 and having given an economic interpretation of the working of the models over time, I now proceed to some more arbitrary hypothesis, which are necessary to make quantitative judgements about certain types of economic policy.

The first assumption concerns the functional form of the production function. Equation [1] assumes, that there is a proportionality between labour inputs and output, which is modified by the above mentioned three variables: technical progress, political disturbance of production and labour intensity. There is no term for the influence of the capital stock on output. That means, that at least in the mid-term no significant change of existing physical capital stocks, able to constrain or stimulate production, will appear. If new capital goods are introduced, then this will be an intentional initiative of economic policy captured in equation [1] by a rise in the exogenous variable "technical progress". At the outset of the numerical simulation the first two influences are set to unity and the third, labour intensity, includes the constant of proportionality.

In equation [2] the endogenous variable "labour intensity" is used to formalize a change in regime¹⁹: Policy variable a^N can assume any value between 0 and 1 indicating how far the transformation from an SPS, with complete adjustment of labour intensity to labour market equilibrium ($a^N=1$), to a demand determined labour intensity ($a^N=0$) is fostered. Indeed there are a lot of policy measures, ranging from the cost of direct control of workers to the legal possibilities of increase of labour intensities at the firm level, which are summarized in variable a^L . The first term just consists of the inverted production function multiplied by the policy variable a^N . In an SPS output is produced with all available workers L^S , the second term becomes 0. On the other hand, if they could ($a^N=0$), firms would raise labour intensity to a level allowing them to produce expected demand. In this case only the second term would determine labour intensity.

During the transformation process firms start to formulate their own labour demand function, so that in the second term employment L is used instead of L^S in the inverted production function (see discussion of equation [4] below). Note also, that they fully take into account political disturbances and technical advancements when they determine their labour intensity. In a later extension of the social entity "entrepreneurs" this assumption could be loosened to see the effects of less informed firm behaviour.

Clearly, as soon as the restrictions of the SPS start to fade, there are many roads to optimality open for firms. As optimal labour intensity is restricted by a^N , so is optimal price setting by the policy parameter a^{PR} . Again a^{PR} is normalized between 0 and 1. The price equation [3] now follows the simple formulation used at other places

¹⁹) The decline of factor utilization rates investigated by Brada [Brada J., 1989] is just a consequence of the full employment imperative.

of the model: a weighted average of old and new price determination with a transformation policy parameter as weight.

$$[0.1] \quad P_t = a^{PR_t} P_{t-1} + (1-a^{PR_t}) P^*_t$$

An important question is how the virtually possible price level P^* is determined. If government assumes, that all of forced savings could be spent and could drive prices up, then for any given amount of the *flow* of savings²⁰ a budget constraint for consumption would be

$$[0.2] \quad P_t (Y_t + S_t) = P^*_t Y_t .$$

That means, that points on the potential demand curve could either be reached at the old price level and at a higher quantity (compare point A' in figure 8) or at the old output level with prices driven up to a level that reduces forced savings to zero. Note that S is a money amount measured in constant currency units, a real flow variable. Elimination of P^* and a little simplification leads to equation [3]. Observe the special information assumption: the base for government expectations of the highest possible price is the aggregate amount of forced savings and *not* an optimal price computed by firms. In other words, this formulation assumes, that in the current transformation process government does *not* use a model of optimizing firm behaviour²¹. Instead of anticipating maximizing behaviour it simply reacts on easily observable aggregate outcomes of this behaviour²².

To close the model several routes are open. A straight forward approach is to assume some kind of optimizing behaviour of firms in the new regime. That is, given assumptions about information, firms choose prices, output and employment to maximize profits. In this case the type of market has to be specified too. As mentioned above competitive markets lead to low prices and high output, a scenario that runs counter to what is observed in eastern Europe. If one assumes classic monopolistic

²⁰) Since [0.2] is a flow constraint, it is clear, that even if this constraint is met, there still could be a positive stock of forced savings. Prices still could rise with rising output by reducing this stock.

²¹) It is a remarkable feature of social entities in transition periods, that they often use extremely simplified models of other social entities and spend more effort on direct intervention.

²²) If, on the other hand, one would assume, that governments do use the correct model of firm behaviour, and therefore are always able to compute all relevant decision variables of firms, this could only be interpreted as an equilibrium outcome of a long-run learning process as lined out in chapter 2. The use of such an assumption for the cases under consideration seems to be quite unrealistic.

behaviour, collusion of all firms, output will fall and in most cases prices will rise. This case is studied in model MODEST-0.

Another possibility to complete the model is to assume that the major problem is, that in the process of transformation many firms have to be closed. As market processes reveal low profitability this leads to exit of firms and lower output. A simple formulation of this process is presented as model MODEST-1. The greater flexibility of this model allows for a fall as well as for a rise of output, employment and prices.

Optimizing firms: MODEST-0

Maximizing behaviour enters the scene only as firms start to deviate from government controlled prices, output and employment. Equation [4] reduces the number of decision variables for firms to two, stating that, given an optimal price-output choice, employment has to follow the path traced by the inverted production function. The crucial point of course is, how to compute optimal output Y^* . Equation [5] summarizes some very specific assumptions on profit maximization.

As a stylized fact the hypothesis, that perfectly competitive markets will be the dominant market forms in eastern European states is rather counterfactual. Low prices and high output as the result of competition between many small and very active entrepreneurs - this is a story which is hard to justify as future scenario in countries, where entrepreneurial activity never could develop, where large amounts of investment will be necessary to replace unproductive capital goods, and where only few, big foreign investors and their local representatives seem to have the possibility to overcome the current crisis. On the other hand oligopolistic behaviour, with its game theoretic underpinning, is extremely hard to model and its solutions are very sensitive to slight changes in assumptions. MODEST-0 circumvents this difficulty, proposing that colluding oligopolists, behaving like a monopolist and sharing monopolistic profits according to rules specified in a separate bargaining model, could be a simple but more realistic underlying metaphor. Since the developments of the *relative* profits of these oligopolists is not an essential variable for the aggregate behaviour of the economy the bargaining model can in a first formulation be omitted. So we are left with the usual joint-maximization solution leading to high prices and low output.

Equations [0.3] and [0.4] describe the usual textbook model of monopolistic behaviour. Equation [0.3] is a simple linear demand equation, [0.4] describes profit

maximization with wage cost as only relevant cost element. Employment is proportional to output according to production function [1] to be explained later (see the following table).

$$[0.3] \quad Y = \mu_1 - \mu_2 P$$

$$[0.4] \quad \max \pi = P Y - w L = P Y - (w Y)/(a^T a^{PO} a^I)$$

Solving system [0.3]-[0.4] yields the optimal price-output combination²³

$$[0.5] \quad P^{OPT} = \mu_1/(2\mu_2) + w/(2 a^T a^{PO} a^I)$$

$$[0.6] \quad Y^{OPT} = (\mu_1/2) - (\mu_2 w)/(2 a^T a^{PO} a^I)$$

The problem, how firms in a disequilibrium position can approximate the parameters of the demand function μ_1 and μ_2 , again is solved by the use of aggregate forced savings. Using the budget constraint [0.2] as potential demand curve gives solutions for μ_1 and μ_2 :

$$[0.7] \quad \mu_1 = 2Y + S$$

$$[0.8] \quad \mu_2 = Y/P$$

Substituting [0.7] and [0.8] in [0.5] and [0.6] and assuming that last years parameter estimations are used for current optimization, then shows which price-output combination firms will try to reach.

$$[0.9] \quad P^{OPT} = P_{t-1} + (P_{t-1} S_{t-1})/(2Y_{t-1}) + w_t/(2 a^T_t a^{PO}_t a^I_t)$$

$$[0.10] \quad Y^{OPT} = Y_{t-1} + (S_{t-1}/2) - (w_t Y_{t-1})/(2 P_t a^T_t a^{PO}_t a^I_t)$$

As these equations show there will always be an increase in prices, but if real wages are high enough while productivity and forced savings are sufficiently small, then there might occur a fall in output.

²³) In this static modul of MODEST-0 the time index of the variables has been omitted.

It has to be remembered however, that these optimal values for price and output cannot simply be set by firms, since there is a restriction on price increases fixed by government (equation [3]). Therefore the question arises how far firms are aware of government policy. Since this problem is just the counterpart to that of how far government anticipates firm behaviour, it *either* has to be solved by assumptions which severely limit the ability to anticipate for both sides, *or* it has to be treated in a game theoretic framework, as outlined in chapter 2. Since in a situation like the one in eastern Europe it cannot be assumed, that the players of the game know the models used by their counterparts it seems to be more realistic to suggest a certain level of ignorance of the game theoretic character of the situation²⁴. As for government it was assumed, that firm optimization is neglected, it now is postulated that firms do not take into account possible price restrictions of government when fixing their output²⁵. If p^{OPT}_t is greater than P_t desired by government, then P_t will be set according to equation [3], government reduces inflation. If p^{OPT}_t is smaller than the value suggested by equation [3], then firms raise prices less than possible, equation [0.9] replaces equation [3].

For the latter case simple manipulations show that it only occurs if condition [0.11] is met. It can be seen, that only for a cautious price liberalization with a^{PR} being greater 0.5, inequality [0.11] can be true at all. But even with fixed prices, $a^{PR} = 1$, still condition [0.12] must hold. The share of the wage sum in output in the current period must be smaller than the share of forced savings in output of the previous period. Taking the interpretation to its limits one could argue, that this is only possible if imports (probably at a substantially lower exchange rate) increase dramatically (compare the identity in equation [7]). Since all this is very unlikely, I assume in the following, that firms always aim for prices higher than the ones given by the binding price formula [3] of the government.

$$[0.11] \quad (w_t \cdot Y_{t-1}) / (a^T_t \cdot a^{PO}_t \cdot a^I_t \cdot P_{t-1} \cdot S_{t-1}) < 1 - a^{PR}_t$$

$$[0.12] \quad ((w_t / P_t) L_t) / Y_t < S_{t-1} / Y_{t-1}$$

²⁴) To use some kind of rational expectations at best could be interpreted as the long-run outcome of a learning process, where the players knowledge of other players models and the model really played all converge to the same structure. The opposite is true in eastern European countries: the situation arises for the first time without any historical parallel to learn from and players do not know the characteristics of their adversaries.

²⁵) In the course of transition the social entity summarized as "firms" will develop models of government behaviour. It is assumed, that these more complicated consideration appear only after the time range covered by MODEST.

For their output decision firms simply use equation [0.10] reproduced in dynamic form as equation [5]. As explained above they do not try to manipulate governments price decisions with appropriate choices of output levels, they even don't maximize current profits in expanding output levels to reach potential demand. They simply fix output at the long-run optimal level²⁶. A possible justification for this assumption might be found in high adjustment cost for output changes: for expansion new capital goods must in most cases be bought for hard currency where revenues occur only in rapidly devaluating national currency; for contraction missing markets for selling old capital goods and difficulties in reducing employment will cause cost.

Equation [4] states, that employment is adjusted to the optimal output level as far as government admits changes in employment via a^L ($0 < a^L < 1$). Again firms know the current parameters of the production function.

Wage setting is considered a centrally regulated process. This is evident in a SPS, where there are no feedbacks from latent profitability to the rest of the system and where income might be absorbed as forced savings. To postulate, that wages will be determined centrally and exogenously during the whole transformation process is somewhat more daring²⁷. Equation [6] states, that the real wage is a policy parameter of the government²⁸. Although rising unemployment is realized as the major problem of the transformation, policy makers are assumed not to be willing to leave such an important policy instrument to the mechanics of the market process.

²⁶) Any process like [3] will in the long-run lead to monopolistic behaviour.

²⁷) This indeed could be thought of as the nucleus of a new social entity representing employees.

²⁸) Of course it is the nominal wage which is actually set. The notation in [6] is chosen only for convenient manipulation. It is formally equivalent to consider nominal wages as exogenous and real wages as endogenous.

Table 5: Model MODEST-0

$$\begin{aligned}
 [1] \quad Y_t &= a^T_t a^{PO}_t a^I_t L_t \\
 [2] \quad a^I_t &= a^N_t(Y_t/a^T_t a^{PO}_t L^S_t) + (1-a^N_t)((Y_t+S_t)/a^T_t a^{PO}_t L_t) \\
 [3] \quad P_t &= P_{t-1}(1 + (1-a^{PR}_t)(S_{t-1}/Y_{t-1})) \\
 [4] \quad L_t &= L^S_t - (1-a^L_t)(Y^*_t/(a^T_t a^{PO}_t a^I_t)) \\
 [5] \quad Y^*_t &= Y_{t-1} + (S_{t-1}/2) - (w_t Y_{t-1})/(2 a^T_t a^{PO}_t a^I_t P_{t-1}) \\
 [6] \quad w^R_t &= w_t/P_t \\
 [7] \quad Y_t &= L_t w^R_t - S_t + G_t + NX_t
 \end{aligned}$$

Endogenous: $Y_t, a^I_t, L_t, P_t, S_t, Y^*_t, w_t$.

Policy Variables: $a^T, a^{PO}, a^{PR}, a^N, a^L, G$.

List of variables:

Y total output (real)
 a^T technical progress
 a^{PO} political disturbance of production
 a^I labour intensity
 a^N freedom of raising labour intensity (FOL)
 L employment
 a^L freedom of employment (FOE)
 L^S labour supply
 S forced savings (real)
 P price level
 a^{PR} freedom of pricing (FOP)
 Y^* expected output
 w^R real wage
 w nominal wage
 G government expenditure
 NX net exports (exports minus imports, real)

Finally identity [7] shows, that output is sold to households, government and as net export. Since supply is insufficient households are constrained, their forced savings have to be subtracted from the right hand side. In this simple model government outlays are a residual collecting all types of expenditure. As is the case for net exports it calls for further disaggregation and formulation as a behavioural equation of its own. Nevertheless it is one of the advantages of MODEST to allow for a modular approach, tackling only one set of problems at a time and proceed sequentially to more augmented versions.

Combining [1] and [2], solving for Y_t^*/Y_t , doing the same for a combination of [1] and [4], equating and solving for L_t yields:

$$[4'] \quad L_t = L S_t / k_t \quad \text{with} \quad k_t = (2 - a^L_t - a^N_t) / (1 - a^L_t - a^N_t)$$

From [4'] it is easy to see that unemployment will develop in the course of transformation as policy measure k will grow.

Using [4] again, inserting for L_t and substituting in [5] gives the possibility to solve [5] explicitly for S_{t-1} , if we first consider that [3] can be used to get the following expression for w_t/P_{t-1}

$$[3'] \quad w_t/P_{t-1} = (w^R_t P_t) / P_{t-1} = w^R_t (1 + (1 - a^{PR}_t)(S_{t-1}/Y_{t-1}))$$

Substituting this solution for S_{t-1} in equation [7] after some manipulations gives the non-linear difference equation [7']

$$[7'] \quad A Y_t^2 + Y_t Y_{t-1} + B Y_t - C Y_{t-1} = D$$

$$\begin{aligned} \text{with} \quad A &= 2(k_t - 1)/(a^L_t - 1) < 0 \\ B &= (L S_{t-1} w^R_{t-1})/k_{t-1} + G_{t-1} + N X_{t-1} > 0 \\ C &= (a^{PR}_t w^R_t L S_t)/k_t > 0 \\ D &= (B w^R_t L S_t (1 - a^{PR}_t))/k_t \end{aligned}$$

A more detailed discussion of the properties of this model can be found in [G.Hanappi, 1991d].

The story told by the model is a pessimistic one, and as such it mimics actual developments quite good: Decreasing output leads to lower employment. Keeping employment high via low labour intensity cannot help against further deterioration of output per head.

Profitability: MODEST-1

Instead of assuming some kind of optimizing behaviour of firms MODEST-1 focuses on the profitability of existing firms. That is, the observable decrease in

aggregate output is not attributed to profit-maximizing output decisions of firms, but to the closing down of firms due to deteriorating profitability.

Since profitability did not play a crucial role in the old regime, the transformation consists of two parallel processes: First profitability itself might change during the transformation and second its importance for the existence of a firm is increasing from the "latent" state in a SPS to an actual state with "hard budget constraints".

For the first process a possible index of profitability is the quotient of revenues and wage cost. Equation [8] defines this index. The second process, describing how far the transformation has been made and thus how important profitability is for the existence of firms, is captured in equation [9]. The "transformation index" δ summarizes the two major components FOE and FOP²⁹. As this index runs from zero (no transformation) to one (completely transformed) it can be used immediately to dampen the influence of changes in profitability on output: Equation [10] simply says that, for example, a decrease in profitability by 10 percent will lead to a 10 percent decrease in output if the transformation has succeeded ($\delta=1$). In other words, the 10 percent of firms with lowest profitability had to be closed and since they produced 10 percent of output, aggregate output also is reduced by the same percentage. Evidently some rather strong assumptions about the distribution of profitability over firms and of output over firms are implicitly assumed to keep the formulation simple. If the transformation still is on its way ($\delta<1$) a larger part of firms can survive if profitability decreases.

Technically equations [8] - [10] replace equations [4] and [5] in MODEST-0, with the rest of the model left basically unchanged, to give model MODEST-1. One exception is equation [2] where expected demand, necessary to adjust labour intensity, now is assumed³⁰ to be $Y+S$ instead of optimal output Y^* . Again government expectations, as given in [0.2], can be inserted to give the price equation [3].

²⁹) Clearly the choice of the functional form of [9] is somewhat arbitrary. The multiplicative form suggests that only a transformation in all respects really reveals profitability. If other important transformation instruments (like FOE and FOP) are considered, the index calculation can be generalized easily in an obvious way.

³⁰) That is, if not checked by FOE, firms will raise labour intensity to cover total demand, no forced savings appear.

Instead of optimal firm behaviour, the dynamics of unprofitable production and its consequences are considered as the driving force behind the "transformation slack". Table 6 shows the equations of MODEST-1.

Table 6: MODEST-1

$$\begin{aligned}
[1] \quad Y_t &= a^T_t a^{PO}_t a^I_t L^D_t \\
[2] \quad a^I_t &= a^L_t(Y_t/a^T_t a^{PO}_t L^S_t) + (1-a^L_t)((Y_t+S_t)/a^T_t a^{PO}_t L^D_t) \\
[3] \quad P_t &= P_{t-1} (1 + (1-a^{PR}_t)(S_{t-1}/Y_{t-1})) \\
[8] \quad \pi_t &= (Y_t P_t)/(L^D_t w_t) \\
[9] \quad \delta_t &= (1 - a^{PR}_t)(1 - a^L_t) \\
[10] \quad Y_t/Y_{t-1} &= (\delta_t (\pi_t/\pi_{t-1}) + (1 - \delta_t)) \\
[7] \quad w^R_t &= w_t/P_t \\
[8] \quad S_t &= L^D_t w^R_t - Y_t + G_t + NX_t
\end{aligned}$$

Endogenous: $Y_t, a^I_t, L^D_t, P_t, S_t, \pi_t, \delta_t, w_t$.

Policy Variables: $a^T, a^{PO}, a^{PR}, a^L, G$.

List of variables:

Y total output (real)
 a^T technical progress
 a^{PO} political disturbance of production
 a^I labour intensity
 L^D labour demand
 a^L freedom of employment (FOE)
 L^S labour supply
 S forced savings
 P price level
 a^{PR} freedom of pricing (FOP)
 π profitability index
 δ transformation index
 w^R real wage
 w nominal wage
 G government expenditure
 NX net exports (exports minus imports, real)

Solving MODEST-1 is difficult. A first transformation gives the following four equations:

$$[1'] \quad (1 - a^L_t) S_t = a^L_t (1 - (L^D_t/L^S_t)) Y_t$$

$$[3] \quad P_t = P_{t-1} (1 + (1 - a^{PR}_t)(S_{t-1}/Y_{t-1}))$$

$$[8'] \quad Y_t/Y_{t-1} - 1 = \delta_t((Y_t/Y_{t-1})(w^R_{t-1}/w^R_t)(L^D_{t-1}/L^D_t) - 1)$$

$$[7'] \quad S_t = L^D_t w^R_t - Y_t + G_t + NX_t$$

Equation [1'] can be derived from [1] and [2]. The new equation is equation [8'], which is derived from the new structural equations [8], [9] and [10]. It shows, that the development of output depends on the trajectories of the policy instruments FOP, FOE and wage policy. (Note that δ_t is an index calculated from a^L and a^{PR} as for example in equation [9]. The latter is not included in the last system, to show, that it holds for any kind of index calculation, or can even be considered a policy instrument of its own: 'How soft are firm budgets constraint.')

A set of economic policy measures, a scenario, is translated by the model into a consistent forecast for the endogenous variables, this is what has been called a simulation experiment in chapter 7. Unfortunately the solution of MODEST-1 is a non-linear difference equation of the following form:

$$[11] \quad \beta_1 Y_t^2 + \beta_2 Y_t^2 Y_{t-1} + \beta_3 Y_t Y_{t-1} + \beta_4 Y_t Y_{t-1}^2 + \beta_5 Y_t + \\ + \beta_6 Y_{t-1}^2 + \beta_7 Y_{t-1} = 0$$

with

$$\beta_1 = (1 + A^L_t)^2 + \delta_t(A^L_t/L^S_t w^R_t)(G_{t-1} + NX_{t-1})$$

$$\beta_2 = (1 + A^L_t)(A^L_{t-1}/L^S_{t-1} w^R_{t-1}) - \delta_t(A^L_t/L^S_t w^R_t)(1 + A^L_{t-1})$$

$$\beta_3 = -(G_t + NX_t)(A^L_{t-1}/L^S_{t-1} w^R_{t-1}) - \delta_t(1 + A^L_{t-1}) - (1 - \delta_t)(1 + A^L_t)$$

$$\beta_4 = -(1 - \delta_t)(1 + A^L_t)(A^L_{t-1}/L^S_{t-1} w^R_{t-1})$$

$$\beta_5 = \delta_t(G_{t-1} + NX_{t-1}) - (G_t + NX_t)$$

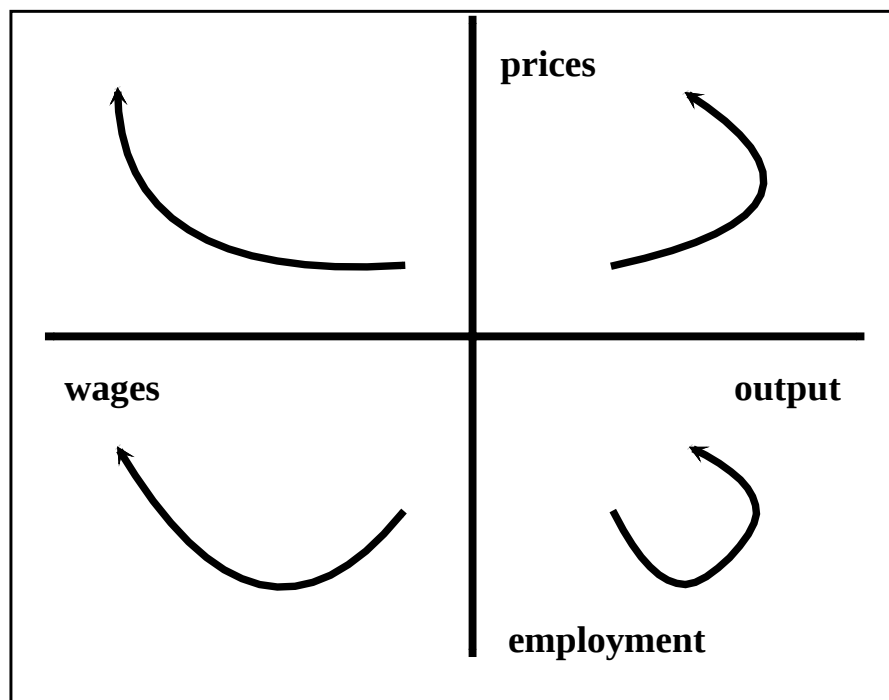
$$\beta_6 = (1 - \delta_t)(G_t + NX_t)(A^L_{t-1}/L^S_{t-1} w^R_{t-1})$$

$$\beta_7 = (1 - \delta_t)(G_t + NX_t)$$

and $A^L_t = a^L_t / (1 - a^L_t).$

This clearly not is an expression to be handled and interpreted easily. Stability and oscillatory behaviour depend on the exogenous settings of policy parameters³¹.

Figure 10: Typical transformation path



The next pages present an example of plausible parameter configurations to simulate the transformation of the USSR.

The third modelling approach starts off with the assumption, that there exists a typical transformation pattern in the diagrams H1 to H7. Furthermore it makes the strong proposition, that this pattern can be approximated by the use of a linear difference equation system. This proposition appears a little bit less restrictive if one accepts, that with yearly data, it probably only has to cover 5 to 10 instances. Figure 10 shows this typical pattern.

³¹) It is tempting to analyze for which type of supplementary relation between policy instruments this type of equation is driven to chaotic dynamics. This task will be the topic of a research paper I currently work on.

Vicious cycles: MODEST-3

Table 7 shows the difference equation system MODEST-3. Looking at figure 10 immediately makes clear, that the dynamics in the most important second quadrant in a linear system only could be approximated as part of a converging, negative oscillation. This indicates, that, if the influence of the rest of the system, of the monetary variables price and wage, is relatively minor, the three parameter conditions should be met: ($a_{12} > 0$), ($a_{21} < 0$) and ($a_{11} + a_{22} < 0$). Similar conditions for probable oscillations in other quadrants could be put forward, but, though most of them are met in the empirical simulation of the next sub-chapter, the historical data-set lets them look less convincing.

Table 7: MODEST-3

$$\begin{aligned}
 [13] \quad Y_t - Y_{t-1} &= a^{10}_t + a^{11}_t Y_{t-1} + a^{12}_t L_{t-1} + a^{13}_t P_{t-1} + a^{14}_t W_{t-1} \\
 [14] \quad L_t - L_{t-1} &= a^{20}_t + a^{21}_t Y_{t-1} + a^{22}_t L_{t-1} + a^{23}_t P_{t-1} + a^{24}_t W_{t-1} \\
 [15] \quad P_t - P_{t-1} &= a^{30}_t + a^{31}_t Y_{t-1} + a^{32}_t L_{t-1} + a^{33}_t P_{t-1} + a^{34}_t W_{t-1} \\
 [16] \quad W_t - W_{t-1} &= a^{40}_t + a^{41}_t Y_{t-1} + a^{42}_t L_{t-1} + a^{43}_t P_{t-1} + a^{44}_t W_{t-1}
 \end{aligned}$$

Endogenous: Y_t, L_t, P_t, W_t .

Policy Variables: all parameters a^{ij} with $j \neq 0$.

List of variables:

Y	.....	total output (real)
L	.....	labour demand
P	.....	price level
W	.....	nominal wage
a^{10}	.....	unexplained influences on output
a^{11}	...	bankruptcy rate
a^{12}	...	labour intensity, output push
a^{13}	...	output hoarding due to inflationary expectations
a^{14}	...	wage cost induced output change
a^{20}	.....	unexplained influences on employment
a^{21}	.....	change of labour hoarding per output unit
a^{22}	...	independent change in labour hoarding
a^{24}	...	fire-hire rate
a^{30}	.....	unexplained influences on inflation
a^{31}	...	share of price setting firms in total output
a^{34}	...	profitability restoration via prices
a^{40}	.....	unexplained influences on wage inflation
a^{42}	...	union power
a^{43}	...	profitability restoration via wages
a^{44}	...	central wage setting in state-owned firms

To reduce the complexity of interaction of this fully interdependent system the four least convincing links were purged: Parameters a_{23} , a_{32} , a_{33} and a_{41} were set to zero, suggesting, that the *direct* influence of the respective variable on the time derivative concerned is of neglectable order. For all other parameters a brief economic interpretation resulting in a proposition for its sign can be given.

The bankruptcy rate indicates how much of unprofitable production is scrapped, or, interpreted in another way, how hard budget constraints are recognized and executed. During transformation this rate should be positive.

At any employment level labour intensity at the workplace will be increased, a^{12} being positive.

As mentioned earlier, expectations of accelerating inflation rates might lead to hoarding of durable commodities, waiting for higher prices. Output hoarding in this case will be positive.

The wage rate, as the main cost element, will have a negative influence on output. Keeping in mind, that a substantial part of firms produces unprofitable, production cost is an especially important cause. Other causes already have been summarized in the bankruptcy rate.

Unexplained causes of output growth should rise during the transformation. They include the emerging innovative powers of capital, not covered explicitly in MODEST-3, the very reason of the whole exercise.

Labour hoarding, forced by the imperative of full employment, will be reduced. This can be done either proportional to output, a second way to increase labour intensity, or proportional to existing employment ("15% of employees have to be laid off"). Both coefficients a^{21} and a^{22} , though partly substitutes, should be negative.

With more market oriented firms during transition, the wage level will also start to play an important part in employment decisions. What the negative coefficient a^{24} says is, that at the current wage level existing employment cannot be sustained.

Positive unexplained influences on employment basically are politically motivated or structural causes of labour market rigidities. They should decrease gradually in the course of transformation.

The coefficient a^{31} is a measure for the share of price setting firms in total firms. That is the way freedom of price setting (FOP) is increased in this model. As long as there exists excess demand, that is during the whole transformation, this coefficient must be positive.

The same is true for a^{34} . But contrary to the former this parameter is not concerned with the number of firms, which are allowed to set prices, but with the degree to which each of these is authorized to improve its profit rate.

High and sudden inflationary shocks can occur due to reasons not explained in MODEST-3³². All these will appear as sudden and persistent jumps in a^{30} .

The argument for a positive sign of a^{42} , union power, is well known in business-cycle theory: The higher employment, the stronger the unions, the higher wage inflation. Though positive, this parameter will probably decrease during transition. During the transformation period the role of an organized labour movement will become marginal.

Increasing the profit rate always works with simultaneous pushes for higher prices and lower wages. Competition and demand constraints check the first push in western, demand driven economies; government controls did so in the east. A variety of checks against endlessly falling real wages exists in western economies, ranging from workers subsistence needs to the power of strong labour organizations. Parameter a^{43} measures how far similar checks will appear in eastern countries. Since this is a new development for this type of economy, the parameter will stay negative during the transformation process.

Finally parameter a^{44} shows the influence of central wage setting in state owned firms. There is no clear-cut economic reasoning on the sign of this parameter. It could be negative, if government views profitability as the major necessity to attract foreign capital - and if it is strong enough to survive such a policy. But it could as well be positive if the preferences of economic policy makers are closely linked to those of the

³²) The best example is Poland, where the obsession to have a fully convertible Zloty over night lead to hyperinflation.

managers of the state owned firms, given some of these firms can survive. All this hints in the direction, that in the beginning of the transformation radical reformers will choose a negative parameter while after some times a more established group will collude with the leaders of the remaining state owned enterprises. Coefficient a^{44} will go up again³³.

The last two models now will be put to work in a small simulation exercise.

Forecasting the transformation of the USSR

Some general remarks on simulations with both models are appropriate. First of all, both are very sensitive to small changes in parameters. The attempt to use the little data available to get an idea of possible parameter values made clear that most of them underwent wild changes. This confirms the common perception of a very impulsive economic policy, characterized rather by sudden initiatives than by a consistent program, in the first years of reform.

Second, this high sensitivity leads to permanent correction of unexpected overshooting or side effects by the use of other policy variables. This feature of the models might well mimic what in general happens in reality, but it is hard to judge *which* policy instrument will be used next. 'Riding the tiger' is a skill of somehow arbitrary moves, which nevertheless keep the process in the track. In such a context any idea of a unique, or even optimal sequence of policy measures is futile. Simulation is just a support, an illustration, for informed story-telling.

Third, it is rather difficult to construct a one-to-one relationship between model parameters and concrete policy measures. Most actual policies will affect a whole set of parameters, just as a change of a single parameter can probably only be effectuated by combined policies. All this adds up to a warning of overinterpretation, to the leitmotif given to this type of models: just MODEST attempts.

³³) The stability of the system basically hinges on this parameter, since the economic reasoning just given has assured a negative sign of the trace of the coefficient matrix. Only if a high positive value of this last parameter outweighs the negative sum of the others, the system will explode. For economic arguments this question, of course, is of minor importance: The whole transformation will take no more than one or two oscillations.

Table 8: Simulation of MODEST-1 for the USSR

year	Y bn Rubel (base 80)	S	L ^D mn	P Index 100=1980	w ^R	L ^S mn	profitrate Index 100=1980	productivity Index 100=1980
1989	884	188	128	102.0	4.5	131	98.1	112.7
1990	867	363	127	112.2	5.4	131	80.8	111.4
1991	776	531	131	121.6	5.7	131	66.4	96.7
1992	752	574	132	146.5	5.8	132	62.8	93.0
1993	800	398	110	191.3	5.8	133	80.1	118.7
1994	843	282	97	238.9	5.8	134	95.8	141.8
1995	843	263	103	310.9	5.5	135	95.1	133.6
year	G bn Rubel (base 80)	NX	Parameters: a ^L		a ^{PR}	δ		
1989	505	-3		0.90	2.32	-0.08		
1990	550	-4		0.93	2.17	0.11		
1991	570	-10		0.95	0.80	0.14		
1992	580	-20		0.95	0.70	0.18		
1993	580	-20		0.94	0.60	0.23		
1994	590	-30		0.92	0.50	0.29		
1995	590	-50		0.90	0.10	0.50		

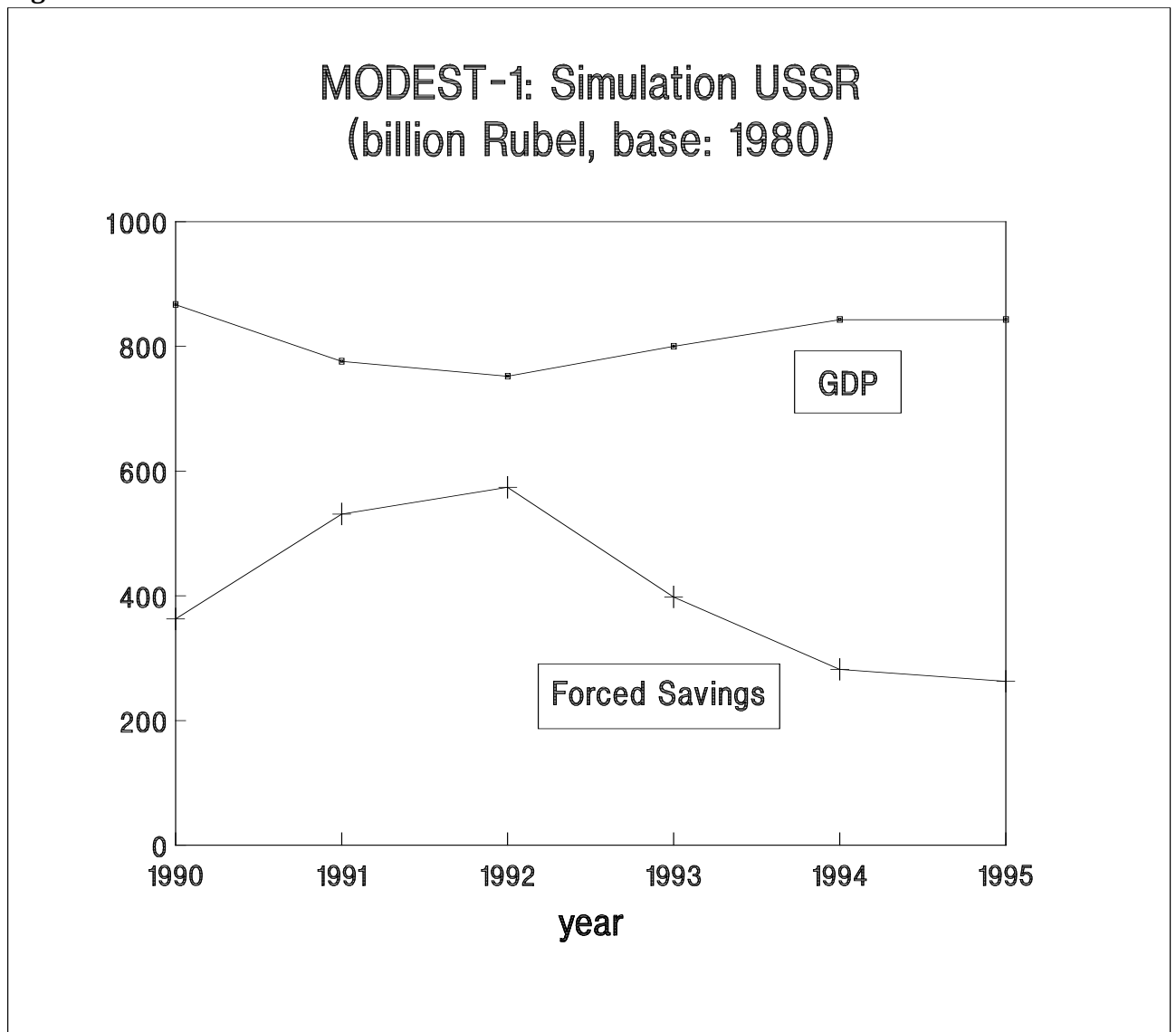
The real wage rate was adjusted to satisfy equation [8].

Figures for 1989 and 1990 are observed data with parameters calculated to satisfy the model.

Table 8 gives the data of a model run of MODEST-1, diagrams F1 to F3 give a graphical presentation. As this run suggests, it is easier to start with FOP, causing inflation and curbing wages, thus improving profitability³⁴, and postponing FOE for the second part of transformation. The background for such a recommendation is, that the dynamic output elasticity of a^L in the early nineties is around -10. Lowering a^L (more FOE) by 1% will cause a decrease of output of 10%, a blow, that will take a very long time to recover from. Price increases, on the other hand, will work out mainly in the monetary part of the system (with an elasticity around 1), but nevertheless will improve profitability. If this happens in an early stage, there is also a large stock of forced savings, which might act as a buffer if real wage losses hit consumers.

³⁴) A 50% cut of defence expenditure in the first stage could increase output for 0.5 percentage points.

Figure F1



As the diagrams show, freedom of employment might set in from 1993 onwards and will lead to high unemployment rates. This will bring down forced savings, the commodity market moves towards equilibrium. In 1995 the first severe output crisis could be overcome, but growth still is weak. The real danger at this point in time comes from the political pressures that arise due to high unemployment. In this simulation, in 1995, half of the transformation has been achieved ($\delta = 0.5$), government expenditure and real wages have been stabilized, but the balance of payments turned into a severe deficit. Profitability and productivity improved substantially, but still will be too low to attract western investors. This is the story told by this simulation.

Figure F2

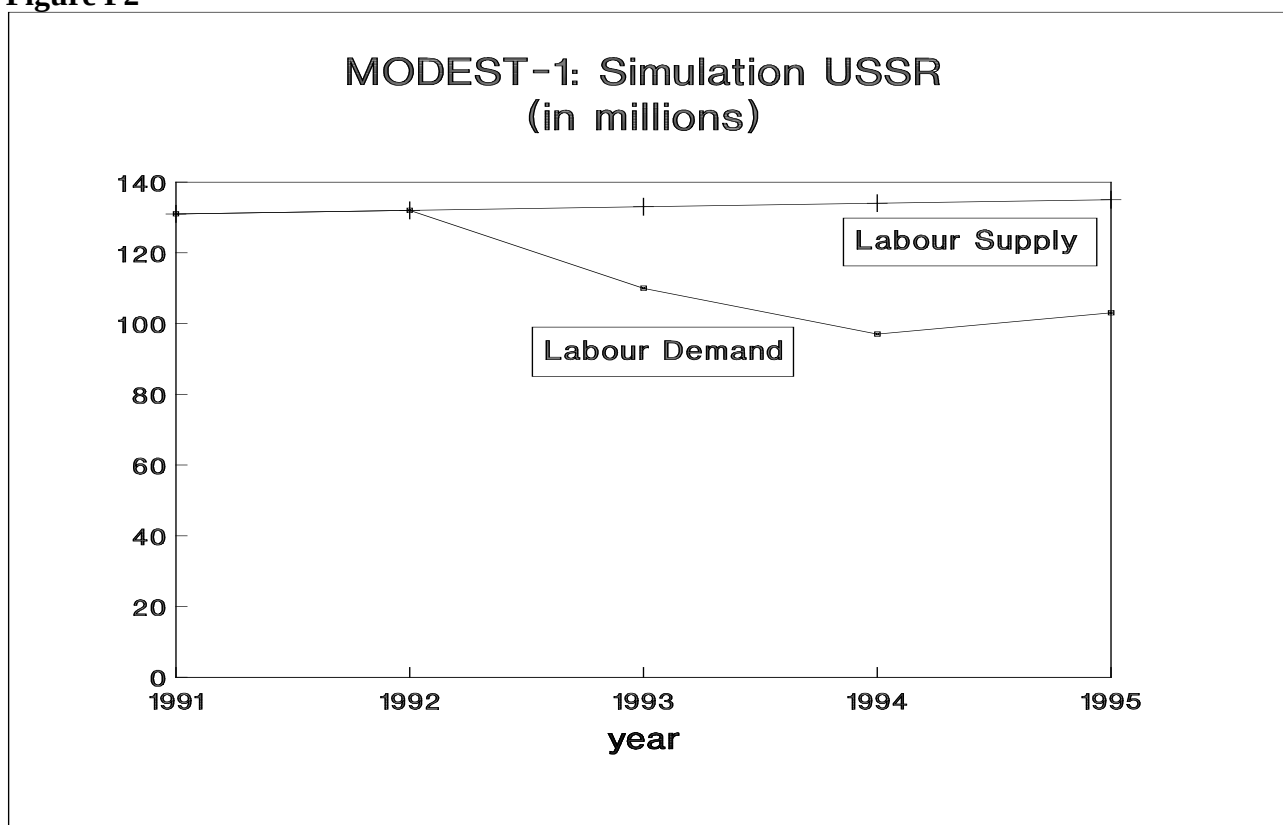
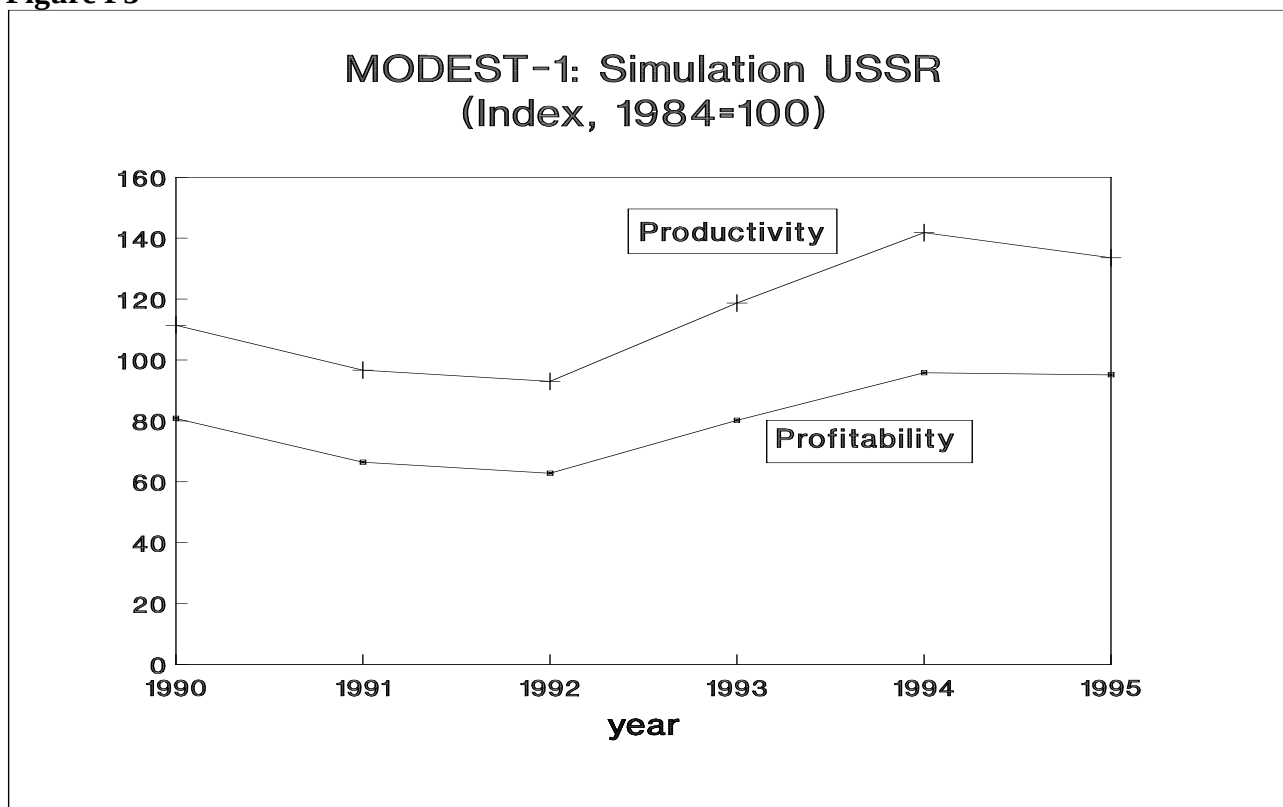


Figure F3



It is not easy to calibrate a non-linear model like this, since effects of single parameter changes do not add up. This property also limits the interpretation of sample runs, they have to remain extremely cautious.

The linear model MODEST-3 is used to try something more ambitious, namely to compare different transformation policies. A basic scenario is compared to a more radical FOP-policy and to an extreme FOE-policy. Tables 9 to 11 and diagrams F4 to F9 summarize the results.

Table 9: Simulation of MODEST-3 for the USSR - BASIC SCENARIO						
year	Y	L ^D	P Index: 100=1980	w ^N	profitrate	productivity
1984	100.0	100.0	100.0	100.0	100.0	100.0
1985	101.6	100.9	99.8	102.0	98.6	100.7
1986	103.9	101.5	99.0	104.3	97.3	102.4
1987	105.6	101.5	99.5	108.1	95.7	104.0
1988	110.2	100.3	100.3	118.5	93.0	109.9
1989	112.9	98.8	102.0	131.7	88.6	114.3
1990	108.4	97.3	106.9	147.5	80.8	111.4
1991	100.7	91.0	226.4	155.9	160.7	110.6
1992	92.1	79.8	554.0	245.8	260.0	115.3
1993	97.0	83.1	849.8	366.6	270.7	116.8
1994	104.0	94.0	1314.8	495.1	293.9	110.7
1995	106.0	95.7	1912.0	675.4	313.5	110.8
1996	110.1	101.0	2302.7	681.7	368.2	109.0
1997	113.4	103.5	2698.6	713.0	414.7	109.6
1998	114.8	104.0	3111.8	917.4	374.4	110.4
1999	114.4	107.5	3627.9	942.9	409.4	106.4
2000	118.3	111.1	4156.6	840.4	526.6	106.5

To make a proposition about the long-run dynamics, simulation now goes till the year 2000. As can be seen, output will take almost a decade to recover from the shocks of the early nineties. The same is true for employment. Inflation will reach very high levels, but still will be lower than the hyperinflation experienced by Poland. Nominal wages will rise, but less than prices leading to a considerable improvement in profitability. In diagrams F8 and F9 profitability and productivity of Poland are also included. They show, that even this rise of profitability in the USSR might not be sufficient to attract foreign investors, as current difficulties of the polish economy indicate.

To construct this basic scenario a great deal of strong assumptions had to be made. As a general rule the cases of Poland and Hungary were taken as examples of a

more advanced transformation, that could show how the twelve exogenous policy parameters will develop in the USSR. For the CSFR the transition seems to be in a similar stage as in the USSR. At first glance the basic scenario seems to be too pessimistic, but, given the model structure and the starting values, it is a rather moderate variant³⁵.

Table 10: Simulation of MODEST-3 for the USSR - F.O.P. SCENARIO						
year	Y	L ^D	P Index: 100=1980	w ^N	profitrate	productivity
1984	100.0	100.0	100.0	100.0	100.0	100.0
1985	101.6	100.9	99.8	102.0	98.6	100.7
1986	103.9	101.5	99.0	104.3	97.3	102.4
1987	105.6	101.5	99.5	108.1	95.7	104.0
1988	110.2	100.3	100.3	118.5	93.0	109.9
1989	112.9	98.8	102.0	131.7	88.6	114.3
1990	108.4	97.3	106.9	147.5	80.8	111.4
1991	100.7	91.0	226.4	155.9	160.7	110.6
1992	92.1	79.8	555.0	245.8	260.4	115.3
1993	95.0	83.1	861.8	365.6	269.6	114.4
1994	97.8	97.6	1403.8	475.0	296.1	100.2
1995	100.1	102.0	1927.8	546.2	346.6	98.2
1996	104.4	108.5	2250.9	558.2	388.1	96.2
1997	102.5	111.9	2582.2	597.0	396.4	91.6
1998	105.2	115.4	2932.0	659.5	405.0	91.1
1999	111.6	119.9	3314.4	720.2	428.2	93.1
2000	114.8	123.8	3730.3	792.4	436.5	92.7

³⁵) In fact recent expert judgements hint in a similar direction, forecasting an output decrease of about 20% for 1991.

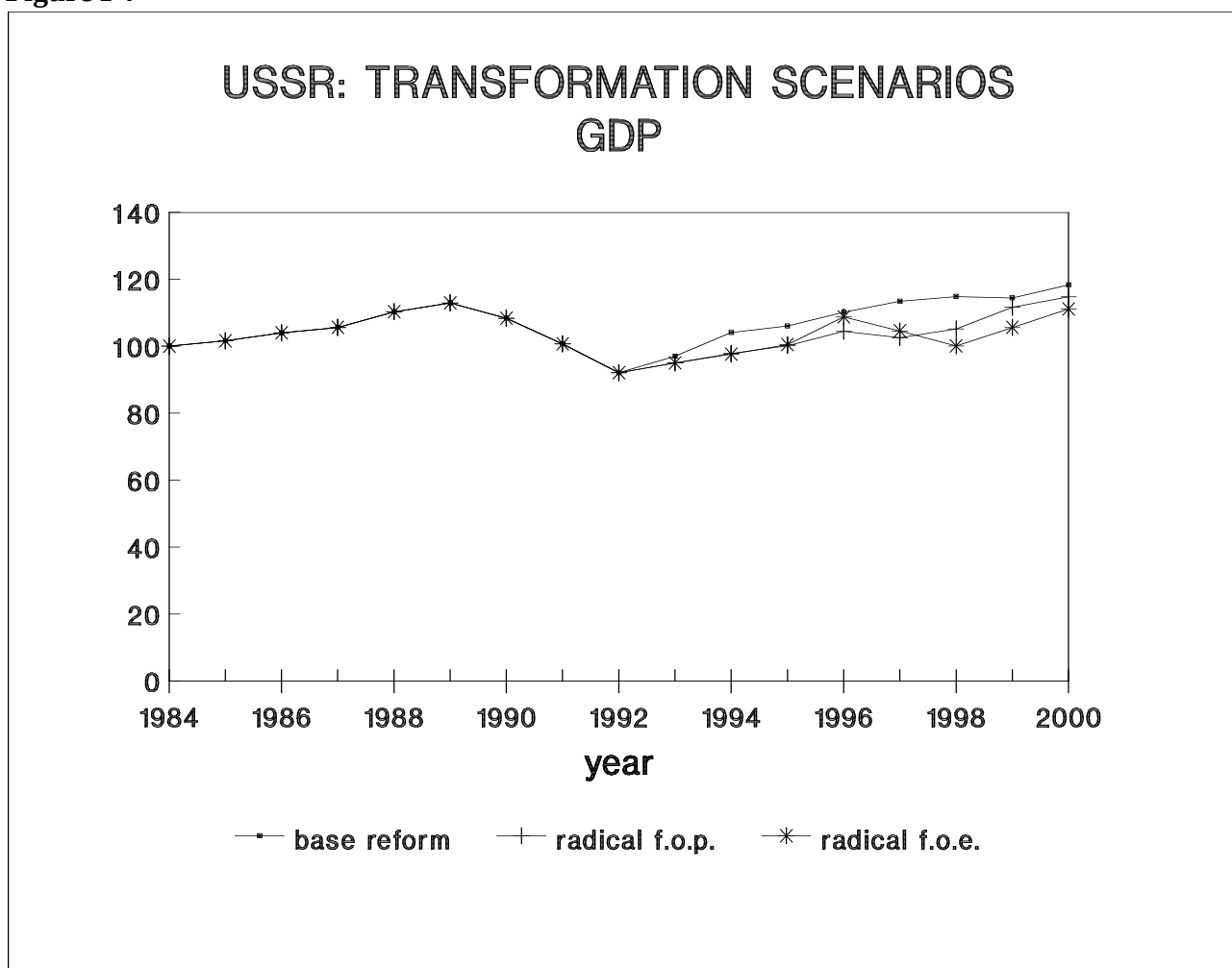
Table 11: Simulation of MODEST-3 for the USSR - F.O.E. SCENARIO

year	Y	L ^D	P Index: 100=1980	w ^N	profitrate	productivity
1984	100.0	100.0	100.0	100.0	100.0	100.0
1985	101.6	100.9	99.8	102.0	98.6	100.7
1986	103.9	101.5	99.0	104.3	97.3	102.4
1987	105.6	101.5	99.5	108.1	95.7	104.0
1988	110.2	100.3	100.3	118.5	93.0	109.9
1989	112.9	98.8	102.0	131.7	88.6	114.3
1990	108.4	97.3	106.9	147.5	80.8	111.4
1991	100.7	91.0	226.4	155.9	160.7	110.6
1992	92.1	79.7	554.0	245.8	260.3	115.5
1993	95.0	82.2	849.8	366.5	268.1	115.6
1994	97.6	91.6	1313.7	494.9	282.7	106.5
1995	100.4	92.6	1907.4	676.1	306.0	108.4
1996	108.8	95.9	2295.7	681.8	381.8	113.4
1997	104.6	95.0	2691.0	713.3	415.4	110.1
1998	100.1	96.0	3099.9	916.8	352.5	104.2
1999	105.6	101.0	3608.3	942.1	400.5	104.6
2000	111.1	105.4	4132.1	842.0	517.1	105.4

Concerning output both alternative scenarios perform worse than the basic scenario, pushing just a particular reform, in that respect at least, seems to be less successful than the introduction of a balanced package.

There also seems to be a tendency towards more accentuated business cycles, especially in the FOE-scenario. Extreme, one-sided reform pushes seem to provoke extreme feedbacks leading to stronger cycles.

Figure F4



Radical freedom of employment evidently leads to higher unemployment rates, but seems to converge to the basic scenario in the long-run. On the other hand, strong price flexibility in an early stage seems to foster employment permanently. But in any case unemployment will stay high. With more FOP inflation in the first years will be stronger, but could be lower than in the basic scenario later on. There is also a smoothening influence of FOP on wages. In the other two scenarios nominal wages are higher, but follow the cyclical pattern more closely.

Given these results, this MODEST-3 simulation seems to favour either a balanced policy mix, the basic scenario, if output recovery is the major objective, or a radical FOP strategy, if employment and the smooth development of monetary variables are the most important targets. A radical FOE-strategy in any case seems to be inferior to these two alternatives.

Figure F5

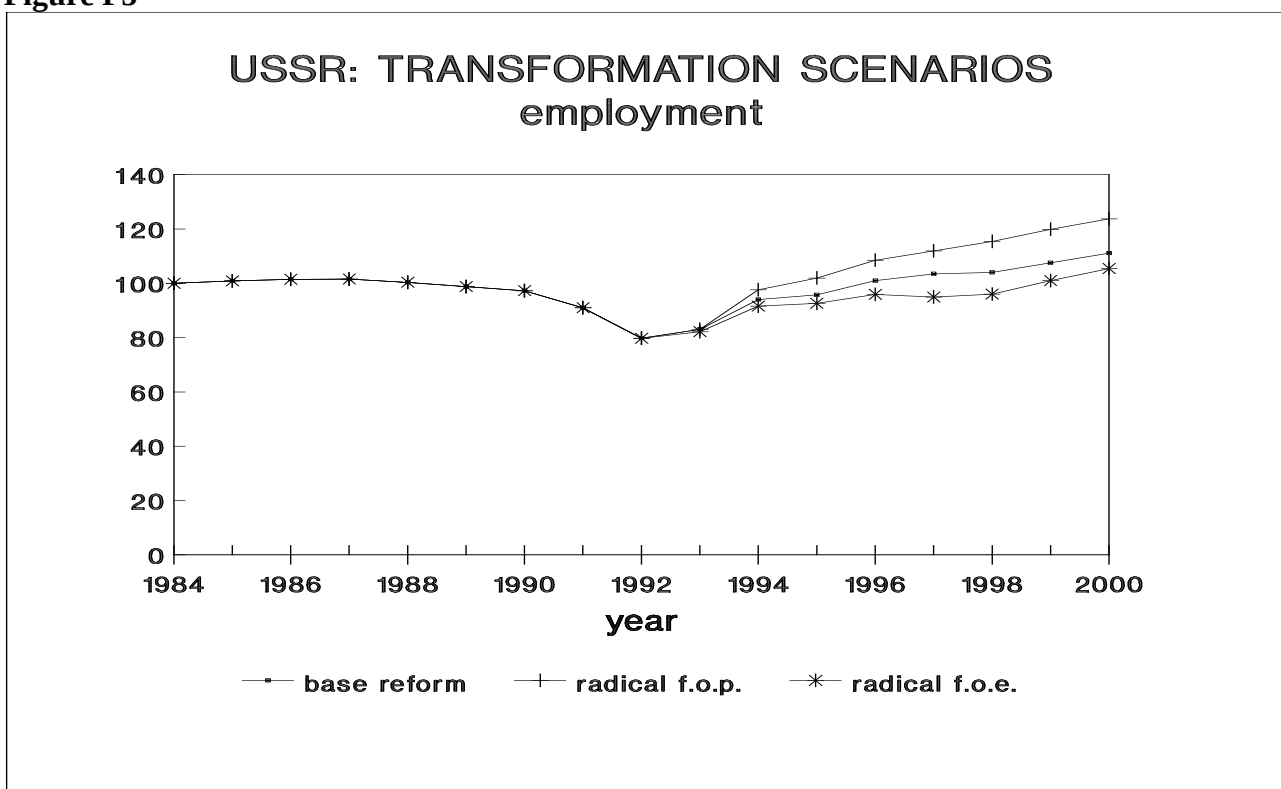


Figure F6

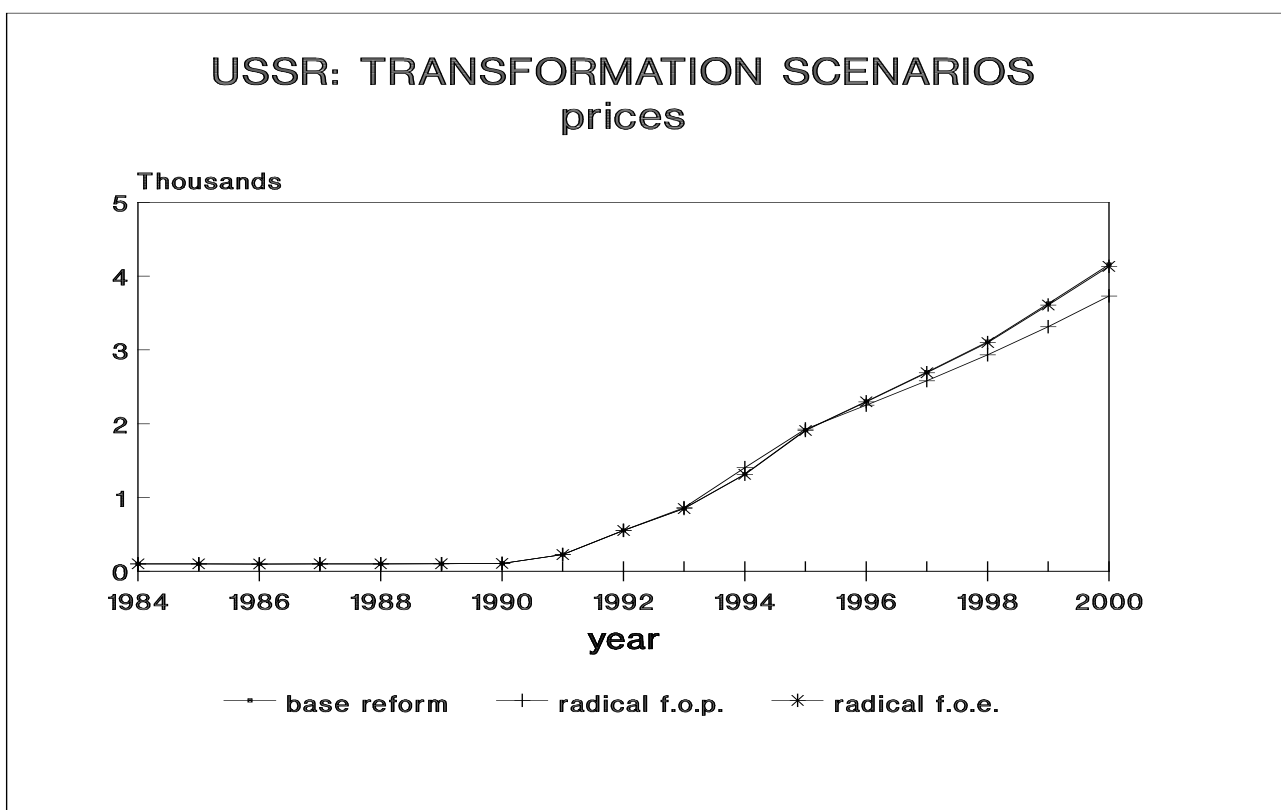


Figure F7

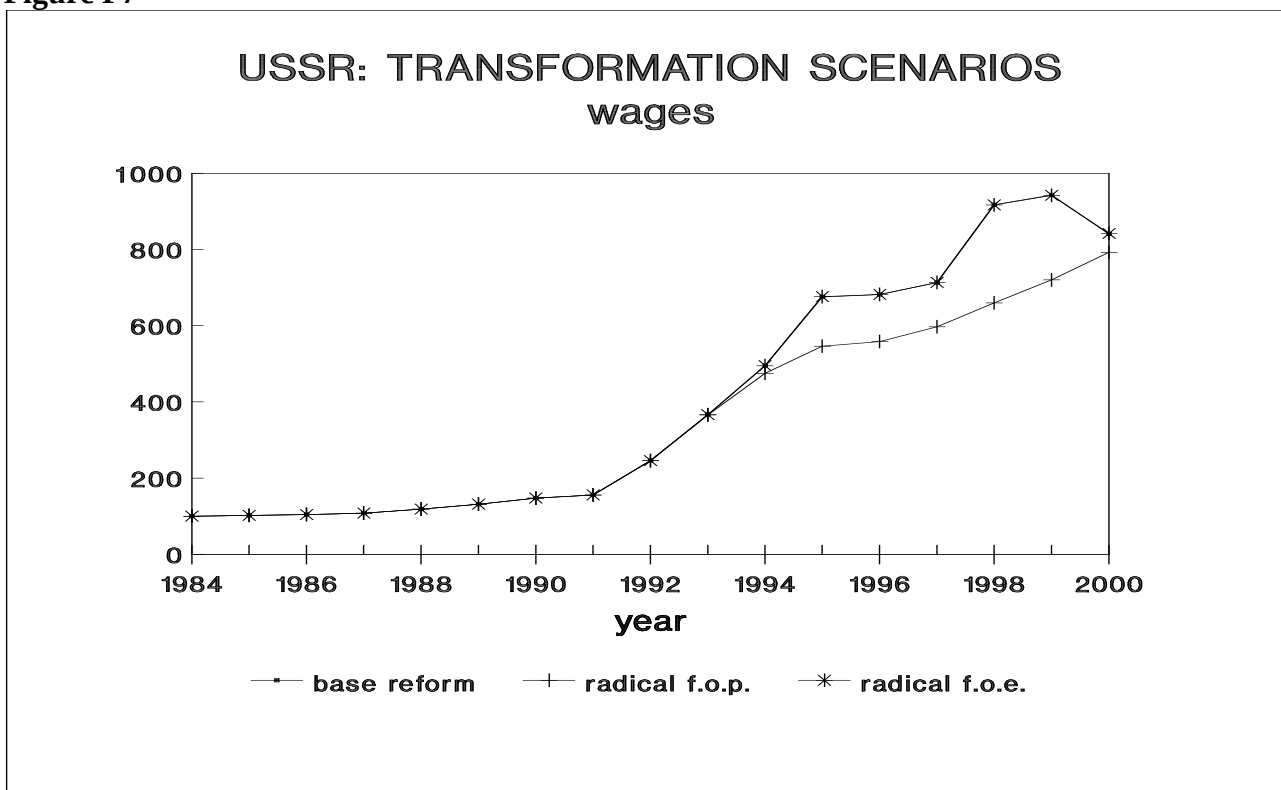


Figure F8

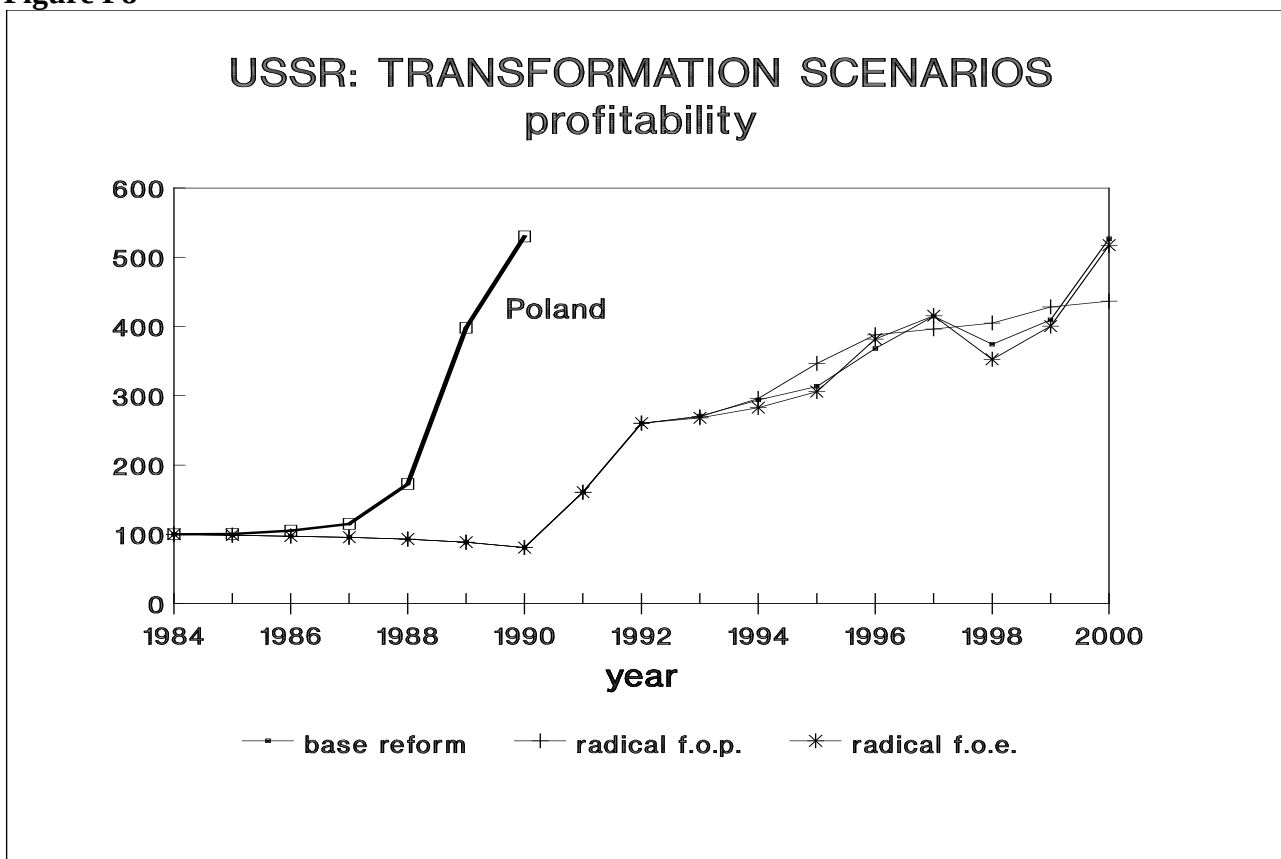
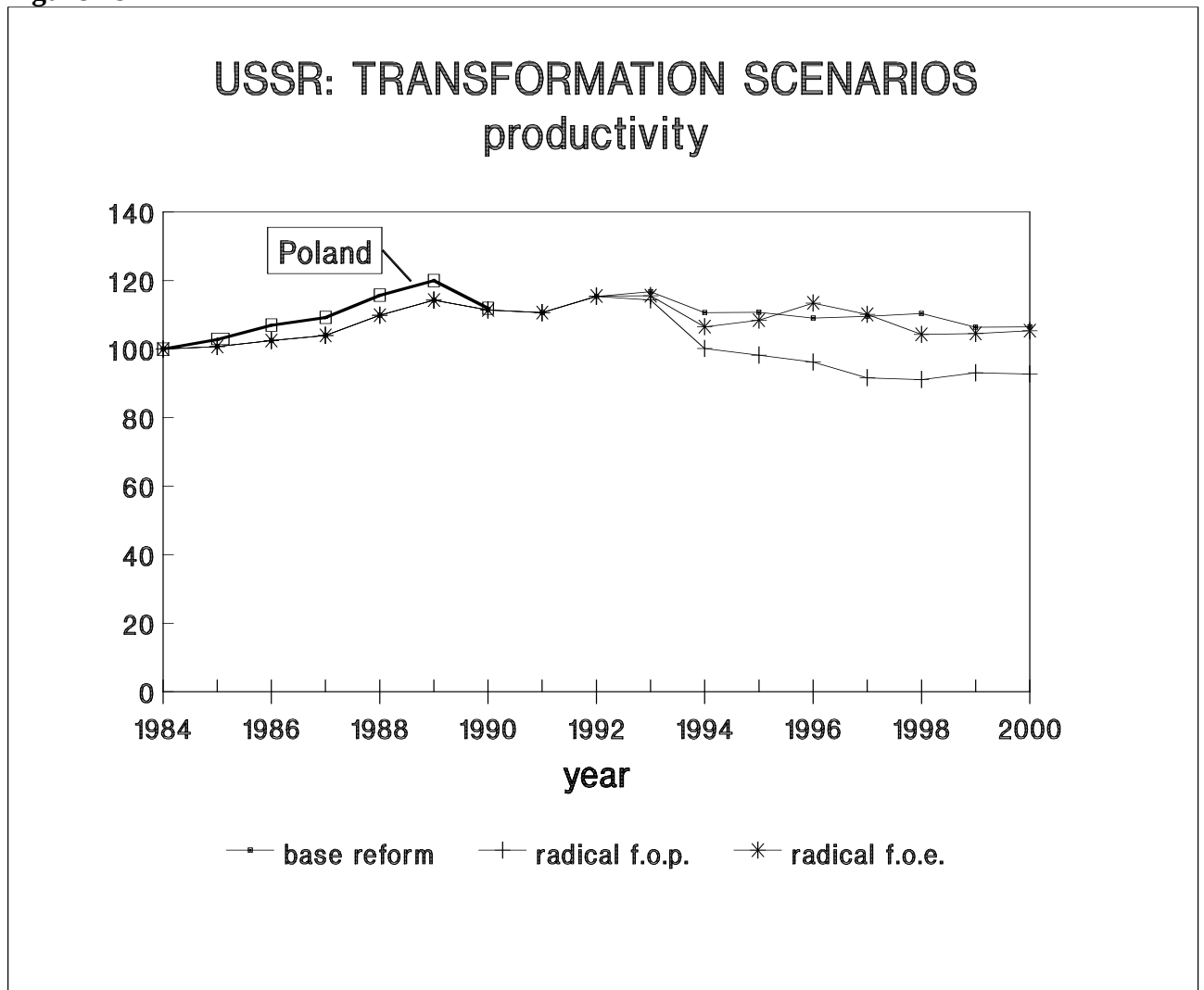


Figure F9



As the case of Poland, a country much closer to European markets than the USSR, shows, even a profitability index five times as high as 1984 is not sufficient to get more productive foreign capital in the country. The productivity index stays low. This is bad news for a country like the former USSR, where a comparable state of affairs at best could be reached in the year 2000, at least this is what MODEST-3 suggests. It is not surprising, that under these circumstances the more advanced republics of the former USSR tried to get on a separate, on a faster lane. What is surprising is, that soviet economists like Shatalin and Yavlinsky present a plan, that, according to them, will be able to accomplish the transformation "within 500 days". This tremendous difference in time frames is just an expression of an underlying difference in vision: What is it, that has to be accomplished by this transformation?

Economics versus politics

For mainstream economic theory the most important feature of western market economies is their capacity to allocate scarce resources via flexible prices. As a consequence most theory-building focused on extensions and refinements of this idea. If the legal framework necessary for competitive price formation really is the only precondition for all the blessings of industrialized economies, then reform of eastern Europe boils down to a set of legislative measures. How fast the enacting of laws can be, is mostly a question of political will of governments. It can be very fast as soon as "men of determination" get into power. This is the general theoretic background, where all shortly realizable transformation plans origin³⁶.

The models presented follow another stream of economic thought. As Joseph Schumpeter demonstrated so convincingly, capitalism cannot be understood as a sequence of market equilibria³⁷. The necessary complement to the equilibrating market forces are the disequilibrating activities of innovators. Market equilibria are only transitory states between recession and depression in the downswing and between recovery and boom in the upswing. The most significant accomplishment of capitalism takes place during recovery and boom phase of the business cycle: the emergence of new products, new production processes and new types of organization. According to Schumpeter, it needs a theory of its own to describe this economic processes, he calls it theory of development. This development actually dominates all other tendencies, its major driving force is the search for temporary extra-profits.

Two points of Schumpeters view are particularly relevant for my transformation models. First, it enables a formulation, which allows for disequilibrium and persistent cycles. The basic idea of MODEST, a commodity market moving closer to equilibrium and a labour market moving away from equilibrium, can thus be encompassed. More precisely, the equilibrium-disequilibrium process of transformation gives into another cyclical process of capitalism proper, the business cycle process of Schumpeterean development theory. To trigger off this process of sequential waves of innovation an important condition must be met: The expected profit rate must be high enough and the

³⁶) It is significant, though regrettable from my point of view, that converted eastern economists, who never experienced the divergence between theory and practice in the west, frequently subscribe to this program. Politicians, in their eagerness to appear 'radical', usually follow their simplistic reasoning. A good example is the Czech minister of finance Václav Klaus [Klaus V., 1990].

³⁷) The major sources for this view are [Schumpeter J., 1939, 1942].

political situation must be stable enough to keep its expected variance sufficiently small³⁸. This leads to the second important point.

Schumpeter gives a theory of the total socio-economic process. Political developments, social structures and historical experiences play a part as important as the impacts coming from the working of decision-logics in a large set of markets³⁹. These ingredients cause the open, evolutionary character of social systems. In the context of transformation models this means, that it might well happen, that, due to socio-economic circumstances, sufficient (triggering) profitability levels cannot be reached at all. Eastern European countries might well be damned to become 'third world market economies'⁴⁰. An immediate consequence of this idea is, that transformation will need substantially more time - if it is successful at all. Note, that in a mainstream economic model transformation cannot fail at all, as long as economic agents act rational. In other words, a failing transformation is a crime against logic. A viewpoint not very helpful for reformers.

If transformation is successful, market discipline will take over and innovative growth cycles will develop. Despite the fact, that a generally accepted growth cycle model does not exist⁴¹, I would suggest a model of this type as possible new regime. Of course such models would have to distinguish between 'third world market economies' characterized by high average unemployment, high average inflation and devaluation rates and fast increasing debt, and OECD-type countries with their well-known features. In the moment it seems to be rather unlikely, that eastern European countries will join the club of highly industrialized welfare states⁴². If this is, what is understood as 'transformation', then it is very likely to fail.

³⁸) Against the views common to most of his contemporaries Schumpeter never ceased to defend profits as the central motivation for entrepreneurial activity. If they are just another name for wages, just an equivalent for marginal productivity in equilibrium, then capitalism is just 'Hamlet without the prince'.

³⁹) Even the aggregation over markets is a difficult problem, which usually strikes back as restrictive assumptions on production functions, utility functions and expectation formation.

⁴⁰) The interdependent character of all countries in the world system is often ignored in discussions of the convergence of institutional frameworks towards optimality, which usually is taken as the capitalist, free market setting (see [Roland G., 1990]). Institutional evolution of one country always is conditioned by the development of many other countries. Convergence of national institutional settings in a diverging (North-South) world economy is a non-issue.

⁴¹) Richard Goodwin's most recent works are probably closest to such a model (compare [Goodwin R., 1990] and [Goodwin R./Punzo L., 1987]).

⁴²) Even the economy of the former GDR, despite its privileged position, seems not to be able to catch up with the rest of Germany.

This rather gloomy perspective leads us back to the question, why the transformation had been started at all. Is it really true, that a severe economic crisis forced Gorbachev in the mid-eighties to start his perestroika? Figure H8 shows the major macroeconomic indicators in the period *before* the transformation, from 1973 to 1984. No dramatic development can be detected⁴³! But probably this was the very reason for the outburst of discontent of consumers, this lack of improvement and innovation in the soviet economy⁴⁴.

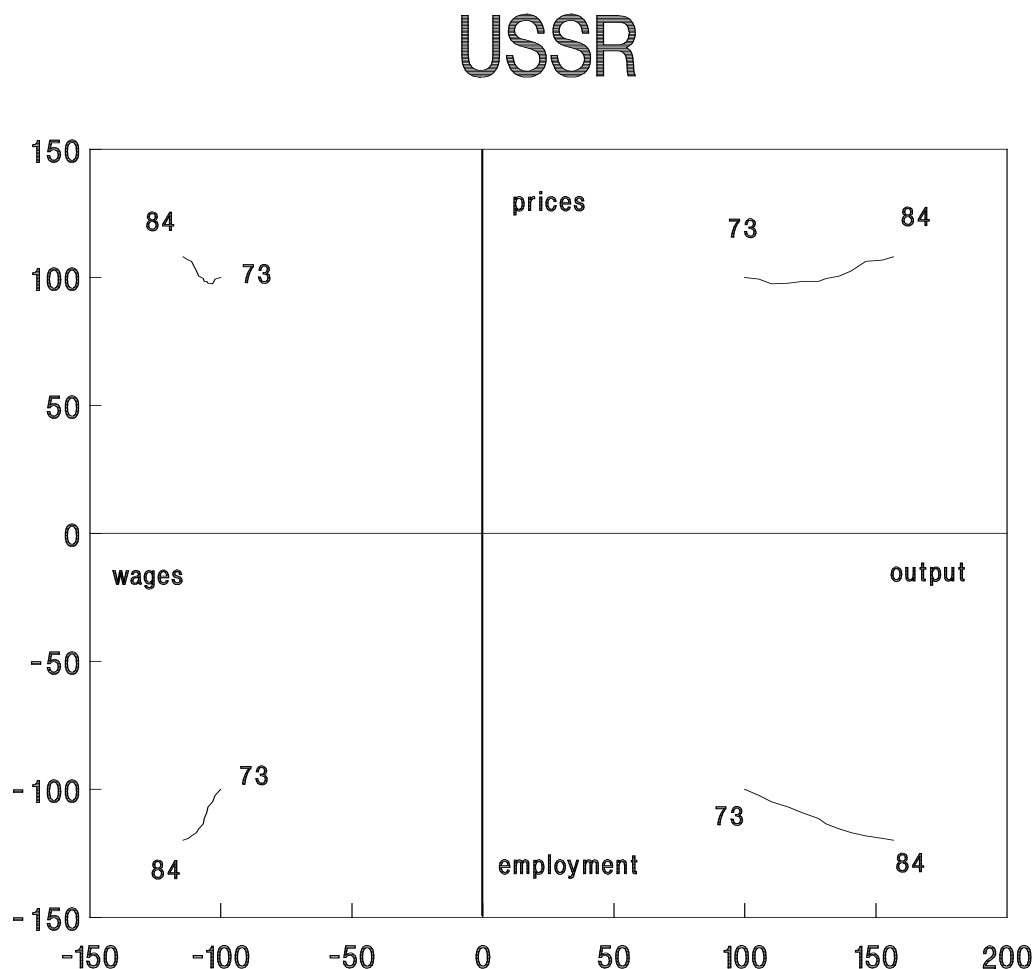
Nevertheless, I think, that purely economic arguments cannot explain perestroika. Noticeable economic improvements could have postponed its start, but their missing cannot be responsible for its take off. Of course, for economists, who always wanted to demonstrate, that 'socialism is infeasible and inhuman', that 'market relations are a natural way of economic organization'⁴⁵, it is tempting to claim, that due to economic reasons the USSR could not survive. In my view, this claim can only be accepted if politics is considered as 'concentrated economics', as Lenin put it. In other words, in my opinion, political processes have to be considered to understand, why perestroika was initiated.

⁴³) Changing external conditions, like falling terms of trade and weakening exports, might have had some depressing impact (see [Dlouhy V., 1990]), which remains invisible in figure H8.

⁴⁴) The lagging behind of infrastructure deserves particular notion: "Infrastructure remained very backward and developed slowly, communications and housing being especially underdeveloped in relation to the general standard of living achieved in Eastern Europe." [Hare P., 1989, p.691]. Hare conforms with my general conclusion that, ".. the only factor which could enable the region to return to more rapid growth is .. the rate of technological progress." [Hare P., 1989, p.696]

⁴⁵) Some economists immediately claim, that markets will produce a just income distribution: "Political access usually plays a lesser role in a market economy (than in a CPE, G.H.). The resulting distribution of income in a perfectly functioning market economy may be judged as equitable, in one sense, since income is equal to the value the factors of production contribute to the production of the final product." [Kempe D., 1991, p.5]. The ideological purport of mainstream economics is evident.

Figure H8



After the death of Breshnev a political stalemate between old stalinist leaders and reformers lead to a deterioration of coercive pressure on satellite countries and on groups within the USSR - a weakness in leadership. Dangers for a stalinist production system, a command economy, can only come from a crisis of coercive power. A SPS is feasible as long as commands are obeyed to and physical survival of participants is guaranteed - no economics in the proper sense is involved.

To overcome this political crisis the reformers around Gorbachev, the winning team, first thought it possible to restructure the economic decision system without touching the political apparatus. In the course of transformation it became evident, that this is an illusion: In a command economy economic decisions *are* political decisions. It

is the same people, the nomenklatura, who are in charge of economic *and* of political decisions. As a consequence of "economic reforms" political power of the leading group deteriorated even faster. Soon the whole process became irreversible, came out of control. With a steady decrease of central power the CMEA broke up, the USSR itself started to dissolve into a loose conglomerate, the CIS. If the end of stalinist production systems in these countries means the start of something else, then there are several roads open.

In an influential book Friedrich Hayek once warned of the political consequences of a socialist economy, that it leads society towards a 'road to serfdom' [Hayek F., 1944]. Echoing Hayek the Hungarian economist Janos Kornai proclaims a turn of eastern European countries. They start to go back on this same road, with a 'free society' and a 'free economy' waiting for them, as he writes [J.Kornai, 1990]. I do have several objections to this idea of a simple reversal.

First of all, there are many roads to a future system. Which one to take is a question of economic policy design. To put it in the words of my transformation models: If there is a constellation of commodity market equilibrium and corresponding (moderate) unemployment, that a specific country tries to approach, then the welfare loss on the path to this goal might be minimized by an appropriate choice of control parameters. Instead of a radical general statement about liberalization and deregulation, "the faster the better", I would argue for case specific analysis and informed, gradual intervention.

Second, reformers in the East, in general, still neglect the complexity of modern capitalism. They prefer rather simplistic visions of a 'free economy', disregarding the burdens that market processes can incur on the economically weaker participants, not to speak of the difficulties of innovation support. With no clear vision of their future place in the world economy, it is hard to steer the transformation. Waiting for a sudden boom in national entrepreneurial activity seems to be unrealistic, to say the least⁴⁶.

Finally, it is necessary to distinguish between economic and political reform. As many examples in the third world vividly show, the two processes of political

⁴⁶) The apparent lack of textbook behaviour causes some reformers to resort to 'ideological education' of the population: "The time that is in fact needed to change the norms of behaviour of economic actors is fundamentally much longer than the political requirements of any reform would justify. This also means that an ideological offensive in the cause of the reform is an important element in bridging the gap between objectives and reality." [Csaba L., 1989, p.23]. This reminds on the "formation of the new man" in the USSR of the early twenties.

democratization and liberalization of markets are not always linked. If free markets are sometimes compatible with extremely authoritarian regimes, why should not a more elaborated and cautious path towards economic liberalization be compatible with radical political democratization?

As some simulation experiments suggest, fast freedom of pricing⁴⁷ combined with a moderate employment policy in the first stage could well be accompanied by a radical political reform towards democracy. Moderate unemployment will contribute to stabilize the political system till, in a second stage, harder budget constraints are implemented to speed up structural change. There clearly is no guarantee for the success of such a policy, but at least it minimizes the political risk of immediate mass unemployment. A risk, which probably is the greatest danger for political democratization.

Conclusion

In both types of macroeconomic modelling attempts social entities implicitly enter at many places. In *western type models*, entrepreneurs are aggregated to form a social entity with specific social functions. The model presented distinguishes between four essential decisions of this social entity: they determine employment, investment, innovation⁴⁸ and prices. Instead of describing the decision process as an algorithm which includes models of the world and models of other entities models, as the research program of E.T.2 would suggest, this small model summarizes this algorithm in four dynamic equations. It is clear, that such a shortcut is only possible if rather strong implicit assumptions about the original algorithm are made. From this point of view the evolutionary approach is just the opening up of oversimplified macroeconomic relations.

Workers are the second social entity, which is treated in a similar way. It absorbs goods to reproduce its work-power, the amount of consumption being linked to income. And it sets wages according to developments of prices, labour markets and productivity.

⁴⁷) Note that administered prices need a certain level of central power of the administrative bodies. If this power is eroding quickly, and only strong nationalist leaders could turn this trend around, then the question of speed of FOP solves itself quickly too. In this likely case, Wageners' suggestion "So, for the near future, if economic conditions do not improve drastically, the adoption of food rationing tickets has much higher probability than the introduction of free market prices." [Wagener H-J., 1989, p.380] will be wrong.

⁴⁸)The non-standard feature of the model is to include innovation as an essential property of capitalist economies.

Again a whole algorithm of decision-making is summarized in two equations. In particular the second activity, wage-setting, shows how the emerging ability of social entities to react on diverse general economic indicators leads to a higher integration of the model. The history of economic modelling mirrors the evolution of workers as a social entity. It has been a long way from Malthus' simple 'iron law of wages' to the highly complicated behaviour described in contemporary models. The genesis of social entities - with a time lag - is reflected in the equations of the respective models. As explained in chapter 1, this is a basic property of E.T.2.

The third social entity starring in my western type model is the state. Though it has a relatively minor role to play in the set-up of the model - it just cares for its own reproduction via government expenditure - this entity is used for policy experiments: different innovation policies are compared. This gives a hint concerning the pragmatics of conventional macro-models. Most models are designed for policy recommendations for government. They are constructed to support the discussion between representatives of different economic policy programs - if they are not just mere formal exercises within the ivory tower of academics. There is no reason why an evolutionary approach in the social sciences should restrict its support to one special social agent. Since the observer, as part of the system, must be financed by the social agents of the system, possible uses of the new language of evolutionary theory are predictable. 'Evolutionary' already labels widely diverging groups of models reflecting the antagonistic intensions of the above mentioned social agents.

Let me turn to the transformation models for *eastern economies* now. First of all, it is clear, that central state power in a stalinist production system plays an overwhelming role. The whole transformation process can be seen as a gradual substitution of state agenda by other social agents agenda. This is, what happens with employment and prices. Both decision-processes will more and more be taken by firms. Evidently the bargaining process between state agencies and the newly emerging social agent 'capitalist' is a very complicated procedure - and to summarize it in two equations is a very heroic assumption. Much room is left for further evolutionary modelling. The situation becomes even more complicated, since firms increasingly can choose labour intensity *and* employment. Instead of taking this choice as exogeneously given, like in MODEST-1, the algorithm of the social entity should say more about it.

With respect to the wage-setting process central government is assumed to have full control during the transformation period. The social entity to take over this

function, the 'total of workers', does not seem to be in a position to become strong and unified enough within the next decade. The only passive role of this agent is to accumulate forced savings.

Finally an interesting new social agent appears in MODEST-1: the international business community forcing the close-down of unprofitable firms. Again, one has to imagine a bargaining process between government representatives, banks and directors of enterprises. The results of these consultations are concentrated in the two-equation processes of revealing profitability developments and executing hard-budget-constraints. As soon as profitability increases, the same equations could be thought to represent the algorithm of firm entry - a process ascribed solely to the social entity 'entrepreneurs'.

As can be seen, the choice of social entities at work sets the scope for the range of issues to be deduced from the model. Transforming societies evidently force the model-builder to formulate more daring hypothesis about the interaction of vanishing and newly emerging entities. Macroeconomic policy models with an evolutionary bias can be considered as first steps towards more elaborated sets of interacting gray boxes. To discuss them as nucleous of social entities' algorithms might even shed some light on the meaning of the original models.

Part IV

Syntax of Evolutionism

Chapter 9:

The Schumpeter legacy¹

There are moments in the development of a science when the views of different schools diverge so radically, that attempts to bridge the gaps fade. As discussed in chapter 7, natural sciences had the privilege to be in a position to use well-designed laboratory experiments as ultimate judges for major parts of their theoretical issues. Questions decided by the results of these experiments basically were accepted by all schools, though opposing researchers often tried to follow up with new experimental designs to support their case. A language of experiments developed, characterized by a kind of exchange of experimental designs and results between schools, a language rooted in the fundamental acceptance of the experimental *method*. Compared to this unifying force in natural sciences, the contribution of a special form of presentation, of mathematical notation, to the general acceptance of new findings seems to be of minor importance. Even if physicists become euphoric about the strengths of their formal language, citing cases where results were predicted by formal derivation *before* they were verified by experiments, even then they accept the decisive role played by the experimental method.

As mentioned before, social sciences are in a less favourable position. On the one hand, experiments based on micro-units, on the behaviour of physical individuals, seem to be misleading if this behaviour expresses personal macro-models, which in turn usually incorporate centrally distributed systematic distortions. In my view, there is no way out from this impasse.

On the other hand, simulation experiments with interacting social entities hinge on the *force of abstraction* of the respective researcher. There is no immediate and generally accepted criterion for the quality of abstractions², they always have a touch of randomness and personal inclinations of the researcher. Therefore it is much harder to establish a common groundwork for an language based on simulation experiments with social entities.

¹) Ideas put forward in this chapter were published in [Hanappi G., 1991a, 1992b].

²) In chapter 7 abstractions of social entities used in simulation experiments were called *gray boxes*.

Take for example the social entity "entrepreneur". Schumpetereans consider this entity as major disequilibrating force. It exerts its social impact in striving for extraprofits. It centers its activities in search for *new combinations*, new technologies, new types of work organisation and the like. This search follows a trial and error process, a considerable part of the population of this type of social entity regularly fails and survivors retain and propagate new characteristics.

The same social entity is modelled by mainstream economics as a fully informed, rational decision-maker in equilibrium³. Any deviations from optimal choices have cancelled out, the full information assumption guarantees, that nothing new can emerge. Since distribution follows marginal productivity of individuals, any profit could as well be considered as wage, in equilibrium entrepreneurs are indifferent of being employer or employee. As a consequence the only remaining feature for entrepreneurial entities is, that on average their personal time preference for saving is higher. Extraprofits cannot occur at all.

It clearly is not very likely, that schools of thought using the same word with such diverging semantics in mind, can communicate at all. Simulation experiments, due to their very nature lend themselves rather to disequilibrium approaches and cannot play the unifying role of experiments in physics. Experimental economics is not an undisputed common field of testing theories of different schools, as chapter 7 shows, it is itself a battleground.

The syntax of scientific progress

Philosophers of science never cease to remind researchers in different fields, that science can only be considered as such if it follows a special method, the *scientific* method. Practicians in the diverse areas of research never cared to much about these warnings. They had the feeling, that whatever was spelled out as rule by a methodologist has only been derived from the actually applied practices, which he himself, the practician, not only knew best but even had *invented*. Any syntax for scientific procedures could only be a restriction for what he considered to be appropriate. Nevertheless numerous rule-sets for scientific procedures exist. Major items in most

³) For the sake of demonstrating my point, the version of mainstream economics presented here of course is a tough one. There do exist less rigid ones.

lists of prescriptions for scientific work are abstracted from the practices of the natural sciences, in particular from physics.

Since the scientific rule-set generalized from physicists practices cannot be applied by social scientists, see chapters 1 and 7, the question arises, how such a syntax of scientific procedures in the social sciences would look like. The example of the different semantic background of relevant social entities in different schools of economics highlights the difficulties with this question: different types of schools use and promote different research methods. The own assumptions are considered as *self-explaining*, whereas the assumptions of competing theories are denounced as being *ad-hoc*. Even the resort to successful application in economic policy is not generally accepted, as long as some schools consider any active economic policy as a disturbance of "natural" long-term states of the socio-economic system. Instead of comparing different research methodologies, I shall concentrate in the following on some properties of a syntax of the evolutionary approach in the social sciences⁴.

Evolutionary theory 2 emphasizes the endogenous role of the scientist, that is, the use of scientific research is not something accidental to be decided separately from science proper. Socio-economic modelling is an intervention in the process modelled, it is always goal-driven. As a consequence the first decision is the selection of the relevant policy question to be modelled. The clear cut between theory and application is systematically bridged by the trade-off between urgency of practical solutions and necessary extension of theory. Let me summarize this property of E.T.2 as *policy-driven*.

A second property seems to be the *emphasis on social entities*. The agents in the relevant socio-economic problems are *groups* of persons, to use a neutral term, and there is no methodological need to start with single individuals. This has far-reaching consequences. First, social entities need a common language, need model-building capacity, for internal integration. Their behaviour is based on the use of dominant⁵, *internal models*. These internal dynamics of social entities allow for an explanation of their birth and their death⁶. Since social entities emerge and vanish, their relevance has

⁴) The following characteristics return to topics in chapter 1.

⁵) There might indeed be a battle between competing internal models.

⁶) For methodological individualism birth and death are biological phenomena outside the scope of social sciences. For this paradigm history is only the history of the environment, of the background for eternal human properties.

to be *specified in historical time*⁷. Why a group is to be condensed in a social entity has to be argued by a suggestive interpretation of *empirically observed interactions*. Only if the group acted as *functional unity* in the observed period, it qualifies to be modelled as gray box. All this fits together well with the property to be policy-driven.

The central role of social entities also implies, that their information processing capacity corresponds to their respective life-spans. As it does not make sense to consider extremely short-living social entities⁸ it a minimum size of internal modelling is obligatory. But the same is also true for the long-term: Social entities always use *models which are short-cuts* compared to the real world interaction⁹. The only exceptions from this rule are models of other entities over-simplified models. The latter might be completely precise. This is the third property of evolutionary model-building, the particular character¹⁰ of gray boxes.

Rules on how to construct simulation experiments have briefly been discussed in chapter 6. I do not think, that such rules are of any importance for a characteristic of the evolutionary method, the above listed three properties are all that could serve as a syntactic guide-line for E.T.2.

Schumpeter - the Schumpeterean

It is surprising how Joseph Schumpeter indeed anticipated methods and current work in evolutionary theory. Schumpeter's tiring style of writing, his preference for oppositional bon-mots, not to say for contradictory positions¹¹, all that hides a bit his deep concern with urgent policy questions of his time. The theory he started to develop was meant to give an explanation of the whole socio-economic development, without sharp distinction between economics proper, politics and sociological trends¹². Only few

⁷) For microtheology a comparable necessity to specify the historical time period for preference functions of individuals does not exist.

⁸) One would rather try to model converging behaviour of this type as collusion between independent entities.

⁹) It is just these over-simplified character of models, which leads to jumps to completely other types of models. These jumps in turn make the whole simulation highly non-linear.

¹⁰) Of course this particularity implies also, that contemporary social entities look very different from each other. Any idea of building "representative economic agents" is bound to fail.

¹¹) See [G.Hanappi, 1991a] for a brief introduction.

¹²) This is not a contradiction to his view on possible separability between what one would like to see and what one thinks of as most probable outcome.

economists followed and interfered with the socio-economic developments as strong as he did.

In each of his works he struggles with what he calls 'observation of facts' to determine the relevant social entities. As many social scientists of his time he did not use any mathematical tools, his writings rather resemble repetitive meditations on special topics. Bringing masses of facts and anecdotes together, he brews the amassed information in long sentences, and leaves the reader with a feeling of a vague but convincing argument. To put essential features in small computer programs would have been, and still is, an interesting complement to his books.

Even traces of what I called consequences of the social-entity oriented-approach can be found in Schumpeter. Limited information processing capacity is implicit in his cycle theories, entrepreneurs periodically overestimate the boom, have only a crude idea in which economic era they are and the like. His social entities, for example his innovative entrepreneurs, emerge and vanish in historical time. Instead of the formal abilities of the most famous contemporary economists, he was a major economic historian. Using his particular set of observed economic behaviour, he tried to produce suggestive, but simple gray boxes for forecasting.

The simplicity of the models postulated as internal models is not as is usual based on the necessity of easy handling of the mathematics involved. It is built on the observation of facts.

The revival of Schumpeters theory is closely bound to the inapplicability of most ge-models. After 50 years of digestion, main-stream economic theory seems to be willing to take parts of Schumpeterean issues back into its main body. The coincidence with the boom in economic computer simulations will further this process. But given the basic divergence between radical Schumpetereans, Schumpeter himself would probably not be a member of this club, and mainstream economists, a full integration is very unlikely. In the end, usefulness of a theory for important groups in society will be the test, which will select the new mainstream - with losers fading away rather quickly.

Chapter 10:

From simulated reality to really 'living' simulations

Simulation is one of key concepts of this book. It simply means to put models to work. Since models are just mutated copies of those parts of reality, thought to be essential for the model-building entity, simulating is testing interaction of these essentials. The most important property of a simulation run is, that it produces interaction results *before* these interactions take place in reality. In other words, time is compressed during simulation to enable forecasting of future events¹. In a sense simulation does what any informed conversation about future events does - but it does it in a rigid and consistent way.

Compressing historical experience and alternative, possible futures in a rather brief simulation run is an activity, which lies at the heart of the existence of social entities. Internal communication is part of the cooperation that constitutes the entity². If smaller social entities, say production units, are part of a larger social entity, say a sector of the economy, then the inner communication of the larger entity is at the same time outward communication of the smaller entities³. So what is described as internal model-building for the larger entity is outward communication from the viewpoint of a smaller unity. In fact this distinction describes the historical emergence of larger entities: If outward communication between small entities becomes important enough to support the initiative to install a specialized agency for common tasks of smaller units, then this agency quickly assumes the role of a common consciousness, that is, of a larger entity. We had this trend towards larger social entities before (chapter 6).

Given the finiteness of information processing capacities⁴, a restriction for the usefulness of inner models appears. If events occur faster than simulation runs can produce results, then, given this information processing technology, simulation is

¹) In chapter 4 the notion of 'urgency' was developed from this property.

²) Even for physical individuals their inner dialogue, their consciousness, is the link between their other activities.

³) If, for example, outward communication between firms is reduced to the assumption that all firms know about a state of perfect competition, then the inner communication of this sector of the economy leads to the welfare maximizing properties of price-taking behaviour.

⁴) In chapter 2 this was modelled as information processing cost.

useless⁵. Viewing simulations as language for communication, new simulation technologies, that is faster and more informed language, opens up new territories of treatable problem spaces. 'Language development' is a crucial part of the development of large social entities. Simulation experiments as part of an evolutionary theory for the social sciences (E.T.2) definitely are such an added piece of language.

When John Maynard Keynes proposed the installation of international agencies for policy accord between nations in the forties⁶, it was exactly the *speed* of the financial crisis initiating the great depression that motivated him. Institutionalised platforms for communication between national agencies enable a fast ad hoc simulation of possible interaction scenarios, a simulation that, since its results are known by all participants, would influence their behaviour and eventually could prevent vicious circles. The step towards a larger social entity clearly is paved with new communication forms⁷. In this respect the SIS-project put forward in chapter 5 is just a proposal to support contemporary evolutions.

Let me take a closer look at the genesis of new social entities. It seems, that surprising catastrophes are preconditions for the awake of consciousness of a larger social entity. Crisis breeds social innovation, as Schumpeter saw it. If socio-economic crisis comes in waves, the small social entities hit, but not destroyed, by the first wave start to enlarge their internal models to understand the shock. At the same time they try to communicate with other entities to form coalitions for improved survival-probabilities. This communication usually implies new forms of cooperation and self-commitment.

At the macro-level one could think of large macro-economic models used as language for national policy scenarios. If elaborate enough, these models include the behaviour of other nations policies'. Simulation of a certain scenario for a national socio-economic system is a statement in the on-going bargaining process. Evaluating and comparing statements then might enable central international agencies to design exchange rate systems, encompass stable growth processes and the like. This is, what I

⁵) Certain types of weather forecasts are typical examples. Though all physical laws necessary are known, the high complexity of interaction leads to simulation runs which take longer than the actually occurring weather developments.

⁶) The IMF and the Worldbank are well-known examples.

⁷) Keynes, like Schumpeter and Marx can be considered as one of the great economists, who considered themselves as active participants in a particular socio-economic system - capitalism. Compare [R.Goodwin, 1986] for a vision of a M(arx)-K(eynes)-S(chumpeter) system.

would call 'simulated reality' through the eyes of smaller social entities - a first step towards the larger social entity.

Exchange of national simulations, as done for example by OECD in a project called LINK, leads to an improved view on the overall development. Global results then enter national decision-rules in increasingly important ways. But still, as long as simulation is carried out by the small entity, step 1 is not left. Only if the central agency takes over and considers national developments as 'gray boxes' in its internal dynamics, only then step 2 is reached. Only then an institutionalized action and reaction system based on an internal image of the larger social entity can emerge. The important point is, that the loss of autonomy of the smaller social entities is compensated by the greater overall stability of the large social entity.

Since the internal model of its inner structure is a core element of the 'life' of a large social entity, one could label such simulation models as really 'living' simulations. They simply are the consciousness of larger entities mediating between the needs of its parts. As such, they need direct and effective control by these parts, the possibility to enter and to change central consciousness, to guarantee smooth and stable functioning. Only in appropriate closed feedback loops, shuffling information from the central simulation to its parts and transporting interaction results of 'gray boxes' back to feed and control the center, only in that case social entities will adapt to and accomodate in a given environment.

It is a little bit surprising, that the need for simulation support can be demonstrated not only at the macro-level, but at all aggregation levels of social entities. This stems from the fact, that experimental simulation is an enrichment of language in the sense explained above. New types of problems can be dealt with - and this is true for all aggregation levels. If regional policy decisions can be 'discussed' by the social groups involved with the support of a simulation model with rich 'gray boxes' representing them, this yields a new quality to results: the region starts to develop a consciousness of its parts - parts start to be interacting elements of a larger unity⁸.

⁸) Similar examples for firms are evident, but not trivial. If the controlling center, the entrepreneur, cannot be checked by its supporting forces, the workers, but only by external market forces, then more complex dynamics for the emergence of larger social units are needed. Marx' notion of 'social class' is an attempt to show how new social entities necessarily change production relations. 'Production units' are not *super-social* given facts.

From the briefly discussed examples, it should be clear, that a lot of work for simulation experts waits to be done. Evidently this work is not only *interdisciplinary*, it is *transdisciplinary*⁹, simulation has to be extremely creative to construct appropriate 'gray boxes' and revealing scenarios. It is not only the most probable development, the forecast, which is of interest, and which, by the way, is the focus in step 1 of simulation support. It is much more the opening up of new possible choices, unknown to the controlling smaller entities before the extension of their communication language, which is of central importance. Social innovation of course has to be carried by the social entities concerned, but their imagination can be engendered by creative simulation scenarios - either to prevent hidden horrors or to discover glorious solutions which were overlooked at first glance. In a word, the consciousness of larger social entities has to retain a certain level of 'deviation' from most probable paths, of creative experimentation, to stay flexible enough for survival¹⁰ and development. Work on concrete problems will show how far this new version of *enlightenment* could lead.

⁹) The term is borrowed from the word '*transnationals*' for big firms operating, as if the different countries were one global environment.

¹⁰) One model in chapter 2 gave a more precise notion of useful 'deviation'.

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