WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

The Simulation of Social System Evolution With Spiral Loops*

Peter P. Merten

WP-1800-86 July 1986

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139

The Simulation of Social System Evolution With Spiral Loops*

Peter P. Merten

WP-1800-86 July 1986

Paper presented at the MIDIT 1986 Conference on
Structure, Coherence and Chaos in Dynamical Systems
Technical University of Denmark
August 12-16, 1986

*Supported by the German Research Foundation and the Bundesminister für Bildung, Wissenschaft und Kunst

Abstract

Social system evolution is taken to be the result of the interaction of autonomous social systems for the purposes of this paper. An autonomous social system is understood to be a multi-level decision making system which basically uses two types of rules in order to maintain its goals: rule-setting strategies and rule-fulfilling policies.The article gives an introduction to a recently developed methodology which makes it possible to represent rule-setting and rule-fulfilling decision making processes in social systems with their structural and behavioral differences. This new methodology also allows us to simulate evolutionary processes in social systems based on these two forms of decision making. The new methodology combines the servo-mechanistic feedback loop concept of system dynamics with intelligent logical loops, which we call spiral loops. The spiral loop concept, which is based on new developments in evolutionary theory and in the field of artificial intelligence, is used to represent the rule-setting strategic decisions which generate qualitative changes and evolution. The servo-mechanistic feedback loop concept is used to model the rule-fulfilling policy decisions of social systems which can generate quantitative changes in interaction processes. The potential of this new approach is demonstrated with two important social system applications: (1) The "portfolio simulation model" which helps us to explain and to design the evolution of multibusiness firms in duopoly markets, and (2) the "know-how transfer model" which explains the evolution of multinational corporations in less developed countries and which helps to improve the simultaneously ongoing process of know-how transfer.

Introduction

During the last few years we have witnessed the development of two main system simulation approaches to explain and design social system evolution - the system dynamics approach and the approach of the Brussels School (for a more complete overview of existing system approaches see Jantsch 1979, 80). The system dynamics methodology originally developed by Jay Forrester at the Massachusetts Insitute of Technology is based on the assumption that social systems generally are stable and insensitive to parameter variations, and allows us to represent the phenomenon of structural change in two ways. First, with the concept of "shifting loop dominance" which allows structural changes in social systems to be modelled in a continous and quantitative way. Second, structural changes are introduced into system dynamics models by policy making. New policies (new structures) are formulated by the model builder and built into a system dynamics model in order to improve the problematic behavior of a system. The processes of policy generation and policy selection as well as the decisions about the timing of the qualitative change, therefore, are not formulated explicitly in the model. Typically the structural changes generated in this way are marginal changes of the existing model structure, i.e., some kind of recausalization (Forrester 1961, Richardson 1984, Rassmussen/ Mosekilde/ Sterman 1985).

The approach of the Brussels School, originated by Illia Prigogine, and applied to the field of social system evolution by Peter Allen and his coworkers at Brussel University, postulates all systems to be inherently unstable and emphasizes situations in which small parameter shifts change the qualitative behavior of a system. The evolution of social systems is generated in the models of the Brussels School by a subtle mixture of determinism (represented in differential equations), and exogenous stochastic effects (Prigogine/ Stengers 1984, Allen/ Engelen/ Sanglier 1984).

Both approaches developed so far neglect at least one structural element of social systems which plays an important role in social system evolution. They do not consider the difference between rule-setting strategic decisions and rule-fulfilling policy decisions. As we will show in this article, the explicit representation of these two kinds of decision rules in models of interacting social systems allows us to simulate evolutionary processes with their qualitative and quantitative characteristics within a model and without any exogenous stochastic influence. The evolution of social systems is, according to this paradigm, much more dependent on the knowledge bases of social systems, i.e., their ability to memorize and their ability to reflect upon their own behavior, than on exogenous model inputs.

Social System Evolution and the Structures of Human Decision Making

The evolution of social systems is taken to be the result of the interaction of autonomous social systems for the purpose of this paper (Ashby 1962, 268; Röpke 1977, 33; Probst 1981, 206-209). An autonomous social system is understood to be a multi-level decision making system which basically uses two types of decision rules in order to maintain its goals: rule-setting and rule-fulfilling. Rule-setting is defined to be the equivalent to strategy making and rule-fulfilling is defined to be the equivalent to policy making. Social systems are seen as man-made systems as opposed to natural systems (Simon 1981,4-8). Social systems are seen as *goal-oriented.* The people who establish and maintain social organizations want these sytems to stay alive, i.e., to keep their identity and autonomy (Powers 1973, 183). Social systems are considered alive as long as they have the ability to change their internal structures with strategic decisions (see also Beer 1972).

Social systems basically use two kinds of decision rules to reach their goals: *rule-setting strategies* and *rule-fulfilling policies* (Ashby 1952, 79-83; Beer 1959; Miller/ Galanter/ Pribram

1960, 90-93; Pask 1972, 49-63; Powers 1973, 54,78,183; Riedl 1980, 99). The rule-setting decision rules are typically developed and applied centralized at the higher hirarchical levels of social organizations. The rule-fulfilling decision rules are normally specified and applied decentralized at lower hirarchical levels (Miller/ Galanter/ Pribram 1960, 90-91, Röpke 1977, 40). All types of social systems consist of a combination of both types of decision rules (see Riedl 1980, 106; Simon 1981,48-52).

In the process of *strategy making* the "inner" and "outer" environment of the organization as a whole is taken into account (Röpke 1977, 47; Ashby 1952; Powers 1973). The informational complexity which is typical of strategic decisions, combined with the computational limitations of human decision makers, makes it normally impossible to find an optimal strategy for a social system which interacts with other social systems. Strategic decision makers, therefore, do not look for optimal strategies but for acceptable ones (Simon 1981,36-37). In order to achieve acceptable (satisficing) solutions, strategy makers normally use some kind of mental or formal heuristics (Simon 1981,34-36,56; Zahn 1979, Milling 1981). The process of strategy making from this point of view can be labeled as "bounded rational" (Cyert/ March 1963, Simon 1976, 1979).

The success of strategy making typically is dependent on the quality of the *strategic knowledge and data-bases* of social systems. The strategic knowledge-bases, which are available in social systems in the form of written information and/or in the form of mental models in the heads of the strategy makers, can be understood as consisting of rules which are able to identify and define strategic problems, rules that generate and select new strategies to solve these problems and rules that guide the implementation of the new strategies (Bigelow 1978, 206-210; Dyllick 1982, 191-195). Further, strategic knowledge bases of social systems can be improved by organizational learning (Powers 1973, 180).The data-bases used to derive strategic decisions in social systems typically consist of two types of data. A first class of data represents data on the environment of the system. The second type of data are internal data on the social system itself. The data and knowledge bases which exist in all social systems (i.e., their culture) allow these systems to reflect upon their own behavior and thereby make it possible for them to change their system structures themselves (Hayek 1972; Powers 1973; Lenski/ Lenski 1978).

Functionally, the centralized strategic decision rules generate decisions to keep or to change a given system structure (Miller/ Galanter/ Pribram 1960, 90-91). The structure of an organization basically can be changed by adding or deleting system elements with their feedback connections or by changing the causal relations between existing system elements (Powers 1973, 180; Eigen/ Schuster 1979; Jantsch 1979).

Strategic decisions are highly *time dependent* decisions (see Ashby 1952, 120 ; Powers 1973, 52). Time plays an important role in the identification of strategic problems as well as in the implementation of a new strategy (the role of time in the evolution of systems is especially discussed by Prigogine/ Stengers 1984, 15-17, 11-117, 253-255). If a strategic problem is identified too late, the space of potential solutions for problem solving may be very limited or even zero. On the other hand, a change in strategy introduced too early may not cause the intended reaction. The timing of a new strategy, therefore, is one of the essential characteristics of strategy making in social systems.

Rule-fulfilling policies are established or changed with a strategy and generate actions that continuously change the resource system of the social system. As long as the decentralized policies of the social system generate actions which keep the actual system behavior close to desired system behavior (i.e., close to an equilibrium), no further structural changes will be generated by strategy making. If, however, the actions generated by the policies create or are expected to create a behavior of the organization which is strongly conflicting with the desired behavior of the organization, i.e., a given policy set cannot adequately react to a given or expected situation, than the process of strategy making becomes activated one more time (Beer 1972, 253; Maruyama 1963; Powers 1973).

The *hierarchical feedback connection* which exists in social systems between the two types of decision rules described before allows us to see social systems as *hierarchical (multi-level) decision/action systems* (Simon 1962; Mesarowic/ Macko/ Takaharo 1970). A social system is called a strategic planning system if it has subsystems and if its primary task is to purposefully define the rules (policies) for these subsystems (Powers 1973, 54,78). A social system is called a policy planning system if its rules are defined purposefully by a hierarchically higher strategic planning system and if its primary task is to manage with the given policy set the actions which change the hierarchically lower resource systems (Röpke 1977, 40). A resource system is a subsytem of a social sytem which transforms information (strategies and policies) into action and thereby generates the behavior of a social system. The hierarchical interaction between strategies and policies makes it impossible to say if evolutionary processes are predominantly generated by rule-fulfilling decentralized decisions at lower levels of social organizations or if they are generated by centralized strategic decisions at the upper levels (see the discussion of this question by Simon 1981, 52-57; see also Nelson/ Winter 1982).

The hierarchical feedback connection between these two types of decision making is seen as one necessary condition in the process of social system evolution (Ashby 1952, 80; Beer 1959, 145; Pask 1972,49) . The interaction of social systems structured in this way with other social systems, which have the same generic decision structure, is seen as a second condition for social system evolution (Ashby 1962, 268; Röpke 1977, 24-35).

The *interaction* of autonomous social systems is a process of materialized or abstract information exchange (Pask 1972, 35-55; Röpke 1977). The interaction of autonomous social systems takes place between their resource systems (material interaction) or their planning systems (abstract interaction) or a combination of both. The interaction of the resource systems is determined directly by the actions of the interacting systems which are generated by their policies. Material interactions can change the behavior of the resource systems of the interacting systems. The information about behavioral changes influences the local decisions of the relevant policy planning systems and globally can change the strategies of the organization. The reactions of the policy planning system to change is faster than the reaction of the strategic planning system (Probst 1981, 249-250). The abstract interaction of the planning systems of social systems, which can also be labeled simply as communication, can directly change their strategies and policies and indirectly it can change their resource systems..

So far, we looked at social systems as if they were independent from natural systems. In reality, however, social and natural systems are nearly always closely connected. If we want to understand the evolution of social systems it is neccessary to relate human purpose and natural laws. As Simon shows, feedback connections between social and natural systems exist on many levels (Simon 1981, 4-6; Dyllick 1982, 191-193). The evolution of social sytems and the evolution of natural systems, therefore, is interconnected. The evolution of social systems is, from this point of view, to be seen as the result of the interaction of an autonomous social system with other autonomous social systems within an evolving natural environment.

This interactive feedback structure of social systems can generate two types of behavior modes: structure preserving behavior modes ("morphostasis") and evolutionary behavior modes ("morphogenesis")(Maruyama 1963, 304-305; Jantsch 1979, 67; Eigen/ Winkler 1985, 87-121).

The behavior of a social system is *structure preserving* if it is generated by a given strategy, i.e., a given policy set, and a given number of integrations which represent its resource system (Maruyama 1963).Typically, morphostatic behavior modes are growth, decay, adaptation, stabilization and oscillations of all kinds (Forrester 1971). Morphostatic behavior modes can be described as changes in the quantitative dimensions of a given set of system variables. Structure preserving behavior modes do not change the quality of a system, i.e., its structure (Maruyama 1963; Jantsch 1979,190).

Evolutionary behavior modes of social systems are generated by changes in the strategy and policy sets of interacting social systems which are normally accompanied by changes in the number of integrations of their resource systems. Morphostasis changes the quality of a social system by adding or deleting system elements with their feedback connections or by changing the feedback connections between existing system elements (Powers 1973, 180). Different types of evolutionary behavior modes of social systems can be seperated. *Autopoiesis* is an evolutionary behavior where a system produces or reproduces itself (Maturana/ Varela 1980, 4-9). *Dissipative self-organization* is an evolutionary behavior mode generated by situations of severe disequilibrium in social systems (Prigogine/ Stengers 1984, 12-15). The driving forces of dissipative self-organization are basically imperfections in the interaction of a system with its subsystems and/ or with its environment, "wrong" expectations about actions of interacting systems and conflicts between interacting autonomous systems (Eccles/ Zeiher 1980). *Co-evolution* is an evolutionary behavior mode where the interaction of two social systems causes structural changes in both (Jantsch 1979,130). *Evolution by learning* is a morphogenetic behavior mode which allows social systems to improve their knowledge bases and thereby to reorganize themselves (Powers 1973,180; Riedl 1980, 106).

Spiral Loop Methodology

In order to simulate evolutionary behavior modes of social systems we combine the traditional *system dynamics approach* (see Forrester 1961; Richardson/ Pugh 1981) with intelligent logical loops, which we call *spiral loops* (Merten 1985, 401-408, Merten 1986a). The servo-mechanistic causal feedback loops of system dynamics, with their level-rate and policy substructures, are used to represent the decentralized rule-fulfilling decision rules (policy making) and the resource systems of the lower levels of a social system at a given stage of system evolution. Spiral loops represent the logically structured, and time-dependent information-processing mechanisms of strategic decisions at the top management level of social organizations that are responsible for structural change and evolution. Figure 1 shows how the structure of social systems can be represented with the combined approach (see also the similar concepts of Miller/ Galanter/ Pribram 1960, Tschdijian 1976, Patil 1981, Richmond 1981; Muir 1986; Denker/ Achenbach/ Keller 1986 and the control theoretic concepts of Powers 1973 and Reynolds 1974)(1).

Spiral loops portray, in contrast to servo-mechanistic causal feedback loops, feedback processes which exist between the structure and the behavior of a system ("evolutive feedback") as shown in figure 2 (see also Jantsch 1979, 77-81)(2).

Spiral loops govern systems in a centralized way and have the ability to change the structure of systems qualitatively when there are severe discrepancies between the actual or expected behavior and the desired behavior of a social system. A severe discrepancy between the desired and the actual behavior of a system normally exists when important system variables go out of bounds, i.e., when a given policy set cannot adequately react to a situation. In the long run the desired behavior of a system only can be one which is close to an equilibrium, therefore, a severe discrepancy between the actual and the desired behavior of a system is a situation of severe disequilibrium. Severe disequilibriums are caused either by the system itself (i.e., the policies of different sub-systems do not harmonize) or by outside pressures, which are often the result of the interaction of the system with other autonomous systems with totally or partly conflicting goals. Spiral loops represent the ability of goal oriented social systems to *recognize complex and problematic behavior patterns*, to *generate and select strategies* that will create structural changes and to *implement and redefine strategies* . Spiral loops, therefore, contain the *strategic knowledge base* of social systems, which allows these systems to reflect upon their own behavior and the behavior of interacting systems.

Spiral loops portray the strategic decisions of social systems to keep a systems structure (a given policy set) or to change an existing systems structure. There are two kinds of spiral loops depending on the kind of structural change generated:

1. Spiral loops that add or delete system elements with their feedback connections *(hypercycles).*

2. Spiral loops that change feedback connections between existing system elements *(recausalization loops).*

The two kinds of spiral loops very often occur together as will be shown later.

To understand the concept of spiral loops in detail, it is useful to look at how these loops represent the "bounded rational" information processing mechanisms of strategic decision making. Spiral loops are always composed of three sets of rules, which sometimes may be interwoven (Merten 1985, 407-408):

1. A decision rule, which assigns *when* the critical load of a system is attained (rule of critical load).

2. A decision rule, saying *what to do* if the critical load of the system is attained (rule of strategy generation and strategy selection).

3. A decision rule describing *how to implement* the new strategy (rule of strategy implementation).

The *rule of critical load* normally consists of two sub-rules: a rule for problem (pattern) recognition and a rule for activating the strategy generation and strategy selection process (Powers 1973,180).The rule for problem recognition is the heart of the rule of critical load. This rule can basically be defined either as an *early warning system*, which is able to identify possible problems in the future (anticipative problem recognition) or as an *alarm system* for existing problems (reactive problem recognition). If the strategic problem has occured before and if the symptoms are known, then the rule of problem recognition in its special form comes into play. If the strategic problem has not occured before, then the general rule of problem recognition has to identify and classify the problem. To represent the process of strategic problem identification in a model we can basically use a wide range of rule based diagnosis systems which are developed in the field of artificial intelligence (Winston 1984). In our *portfolio-simulation model* (see the applications below) we use the *difference-procedure table* which is an essential part of the *general problem solver* (Newell/ Shaw/ Simon 1957; Ernst/ Newell 1969). As we will show later in this article, the *condition-action rules* as well as the *antecedent-consequent rules*, both known as *production rules* in rule-based systems (expert systems), can be used to model the process of problem identification within spiral loops (Newell/Simon 1972; Lindsay/ Buchanan/ Feigenbaum/ Lederberg 1980; Davis/ Lenat 1982; Buchanan/ Shortliffe 1984).

The production rules mentioned before have, however, one disadvantage in common: they do not learn, i.e., they are constant during one simulation run. The next step in methodological development would be to use problem-identification procedures within spiral loops that are able to learn. The work of Minsky, Winston, and others seems to be an excellent starting point for the modelling of learning processes (Minski 1980; Winston 1984). If a problem is identified endogenously by the rule of critical load, then the rules for strategy generation and strategy selection are activated endogenously.

The *rule of strategy generation and strategy selection* determines *how to react* to different situations of (expected) severe disequilibrium. This rule can be connected with the rule of critical load in two ways. One possibility is to connect the process of problem identification with the process of strategy generation and strategy selection directly. In this case, different strategies are defined for different strategic problems in advance. The knowledge is, therefore, represented by these rules in a *problem-action oriented* manner. The general problem solver from Newell, Shaw and Simon basically works this way. We used this kind of knowledge representation in our portfolio-simulation model.

A second way to combine the rule of strategy generation and strategy selection with the rule of critical load is to define it without a direct problem-action connection. In this case there are two possibilities for procedure arrangement: first, different strategy generation and strategy selection procedures are activated in different strategic problem situations. Second, one powerful strategy generation and selection procedure becomes activated in all strategic problem situations. For both of these procedure arrangements, the rules for strategy generation may be separated from the rules for strategy selection as is the case when we use the *generate-and-test paradigm* (Lindsay/ Buchanan/ Feigenbaum/ Lederberg 1980; Brooks 1981), or the processes of strategy generation and strategy selection are modeled together applying *production rules* similar to those used for problem identification. In the last case, we can either use production rules that are constant during one simulation run or we can use production rules which are able to learn.

If a new strategy is selected by the rule of strategy generation and strategy selection, the rule of strategy implementation and the rule of irreversibility are activated. The *rule of irreversibility* represents the fact that once a strategic decision is made it can only be changed with a new strategic decision. In the language of the system dynamics methodology the strategic "yes/no" decisions are defined in level variables (see also Miller/ Galanter/ Pribram 1960, 90-91).

The *rules of implementation* are decision rules which change the structure of a system when a new strategy is selected in order to conserve the new strategy. The rules of implementation themselves can be generated either within the process of strategy generation or they can be foreseen in the structures of the hirarchically lower sub-systems. If they are foreseen in the structures of the subsystems they are activated by condition-action rules, too. The rules of implementation change (activate or deactivate) or redefine policy sets. The rules of implementation normally give a system an "initial kick" in order to start the new strategy (Maruyama 1963, 305). The "initial kick" in business applications, for example, stands for the fact, that the success of a new strategy is not at once measured with the efficiency indicators which we use to measure established business units. The new structure generated with the new strategy gets some time, money and know-how to establish itself before it is measured like the already existing business units. The delays typical of the process of strategy implementation are represented in the rules of implementation, too. The *discrete and at lower hierarchical levels of social organizations irreversible strategic decisions* are normally transposed into a new structure in a *continuous* way.With the implementation of a new structure a new evolutionary stage of system development, i.e. a new set of causal feedback loops with a corresponding policy set, is realized in the model.

If we look at spiral loops as higher level information processing mechanisms, then their integration into the system dynamics concept, in retrospect, can be categorized as an attempt to reunite the two lines in feedback research - the cybernetic thread and the servomechanistic thread (Richardson 1984). In the extended approach, the servomechanistic feedback loop concept of system dynamics is used to simulate the decisions at lower hierarchical levels of social systems in a given phase of system evolution (Richmond 1981, 291a); the spiral loop concept contributes the ability to model the strategic decisions at the top management level of social systems which are responsible for structural change and evolution (Miller/ Gallanter/ Pribram 1960, 90-91; Merten 1986a). The spiral loops normally become activated, when positive feedback loops of a system are *expected* to dominate or *actually* dominate its negative feedback loops for some time or when delays in negative feedback loops are *expected* to create or *actually* create instabilities. Every qualitative change in a system, therefore, is determined by a corresponding (expected) quantitative change (Maruyama 1963, 305). The spiral loops activate a new set of feedback loops which govern the system at the new evolutionary stage until another severe disequilibrium is reached or expected.

From a decision point of view spiral loops are used to represent the fundamental effort of all living systems to stay alive, i.e., to keep their identity (see also Powers 1973). The generation, selection, and conservation of new strategies, represented in spiral loops, is a process of decision making that normally cannot be modeled adequately under the assumption of (objective) rationality. It is very seldom possible to find an optimal strategy or policy for complex social systems which interact with other autonomous social systems.The information used to generate alternative strategies is normally limited; the possible number of strategies is too high; and the capability of strategy makers to forcast the consequences of different strategies and thereby select one of these strategies in an optimal way is limited, too (Simon 1976,1979,1982; Cyert/ March 1963). The process of strategic decision making modeled with spiral loops, therefore, is "bounded rational" as is the decision-making process represented in the policies of traditional system dynamics models (Morecroft 1983, 1985). The strategic knowledge base within the spiral loops may reach the level of the best experts in the field of strategy making in social systems, but even then, strategic decisions derived from this knowledge base would still be just "bounded rational".

With the combined spiral loop and system dynamics approach it is presently possible to simulate autopoietic, self-organizing, and co-evolutionary behavior modes of social systems with their quantitative and qualitative characteristics as we will now show.

Applications of the Spiral Loop Methodology

In this section, a brief sketch will be given of some recent applications of the combined system dynamics and spiral loop approach. The two examples selected here focus predominantly on evolutionary processes on company and market levels. The new methodology, however, is of general applicability to all kinds of "man-made" (social) evolution.

The Evolution of Multibusiness Firms in Duopoly Markets - The Portfolio Simulation Model

In the first example we describe briefly the portfolio simulation model which has been designed to explain the development of diversified firms and to support their portfolio management process (Löffler 1984, Merten 1985, Merten 1986b).The allocation of investment funds in multibusiness firms is typically considered a top management function of highest priority (Simon 1981, 49). In order to demonstrate how the combined system dynamics and spiral loop approach is applied to this problem we will show the portfolio simulation model from three perspectives. First, we briefly describe the portfolio management process and its influence on the development of multibusiness firms. Second, the generic formal structures of the portfolio simulation model with their spiral loops are shown. Third, we will present selected simulation results of the model which show different evolutionary development patterns of diversified firms.

The Descriptive Model of Portfolio Management - The Boston Consulting Group Portfolio Concept

The portfolio management process is typically a complex strategic decision making process, which is determined on the company's side by the actual situation of the conglomerate and its business units, the goals of the conglomerate and the available financial funds for capital investment, and which further has to take into account the actual and expected strategies and potentials of the major competitors in the various markets as well as the general economic situations of the countries where the business units are located. To solve the funds allocation problem, diversified companies normally use some kind of heuristics. One qualitative heuristic, which is used worldwide to support the portfolio management process in multibusiness companies, is the *portfolio concept of the Boston Consulting Group* (BCG) (Henderson 1973,1979).

The essence of the BCG approach is to present the firm in terms of a portfolio of businesses, each one offering an unique contribution with regard to growth and profitability. The firm is then viewed not just as a single monolithic entity, but as composed by many largely independent units whose strategic directions are to be distinctively addressed (Hax/ Majluf 1984, 127).

In order to visualize the particular role to be played by each strategic business unit (SBU), BCG developed the *growth-share matrix*, in which each business is plotted on a four-quadrant grid, like the one shown in figure 3. The horizontal axis corresponds to the relative market share enjoyed by a business, as a way of characterizing the strength of the firm in that business. A cut off point separates businesses of high and low internal strength. The vertical axis indicates market growth, representing the attractiveness of the market in which the business is positioned. A cut off point, defined by the company or its consultants, separates high growth from low growth businesses.

The SBUs of a company are positioned in the so-defined growth-share matrix, as shown with the circles in figure 3. The circles show the contribution of the SBU to the firm, which can be measured in terms of sales or earnings, and is represented by the area within the circles in the matrix.

There are several implications that emerge from this business categorization, the most important one being centered on the transfer of cash among businesses. The businesses in each quadrant have distinct characteristics with regard to cash flow (Hax/ Majluf 1984, 131-133):

1. The "Question Marks.
   These businesses correspond to major untapped opportunities, which appear as very attractive because of the high market-growth rate they enjoy. The Firm however, has not achieved a significant presence (high market share) in the corresponding market. A decision is called for selectively identifying among them those SBUs that can be successfully promoted to a leading position. This is a key strategic decision in this planning approach that carries with it the assignment of large amounts of cash to a business, because reaching a leading position in a rapidly growing market requires committing important cash resources.

2. The "Stars".
   They are highly attractive businesses (high market growth), in which the firm has established a strong competitive position (high relative market share). They generate large amounts of cash, because of their successful status, but at the same time, require a significant inflow of cash resources if the firm wants to sustain its competitive strength in that rapidly growing market. As a result, the final excess of cash contributed to or the deficit required from the overall organization is relatively modest.

3. The "Cash Cows".
   These businesses are the central sources of cash for the organization. Because of their extremely high competitive strength in a declining market, they generate more cash than they can wisely reinvest into themselves. Therefore, they represent a source of large positive cash that could be available to support the development of other businesses within the firm. Incidentally, this fact clearly corroborates that, ultimately, the resource allocation process has to be centralized at a higher managerial level in the organization. Otherwise, the manger of a "cash cow" will tend to reinvest the proceeds of its business in its own domain, suboptimizing the uses of its resources.

4. The "Poor Dogs".
   These businesses are clearly the great losers: unattractive and weak. They are normally regarded as "cash traps," because whatever little cash they generate is needed for maintaining their operations. If there is no legitimate reason to suspect a turnaround in the near future, the logical strategy to follow would be harvesting or divesting.

The primary objectives of the corporation, which are implicit in the conceptualization initially done by the BCG, are growth and profitability (Henderson and Zakon 1980). The argument is that the fundamental advantage that a multibusiness organization possesses is the ability to transfer cash from those businesses which are highly profitable, but have a limited potential for growth, to those which offer attractive expectations for a sustained future growth and profitability.

This philosophy leads to an integrative management of the porfolio that will make the whole larger than the sum of the parts. For this synergistic result to be obtained, a fairly *centralized ressource allocation process* would be required which would produce a *balanced portfolio* in terms of the generation and uses of cash.

Another contribution of the BCG, besides the balanced portfolio idea, resides in their selection of market share to express the desired strategy for each business. The *strategy suggestions*, which can be drawn out of the growth-share matrix are: selective offensive strategies for "question marks," offensive strategies for "stars," defensive strategies for "cash cows," divest or harvest strategies for "poor dogs."

The Formal Portfolio Simulation Model

The development of a diversified industrial company is seen as the result of the interaction of the company with other companies and with its markets (see figure 4). The portfolio management process can be thougth of as a meeting point - an "interface" - between an "inner" environment, the substance and organization of the diversified company itself, and an "outer" environment the surroundings in which it operates (Simon 1981).

The *outer environment* of the portfolio management process is represented in the model by the following assumptions: The competitors of the company are aggregated in the model to one (duopoly situation) and are defined in the formal model with their planning system not with their resource system. The competitors generate their strategies using the growth share portfolio matrix of the BCG. We further assume, that the competitors generate their strategies without information about the strategies of the diversified company in question (Stackelberg dependence position). The development of the five markets, where the companies can have activities, is exogenously given in the model by the life cycles of the products. The marketing, production and R&D policies of the competing companies in the five markets can influence their market shares, but not the market growth generated exogenously by the product life cycles. On the procurement market side the prices for the two competing diversified companies are exogenously given (polypol situation). The demand of the companies can be satisfied without limits in these markets.

The *inner environment* of the portfolio management process is represented in the formal model with the following assumptions: The rule-setting centralized portfolio management process is formulated with spiral loops on the basis of the portfolio heuristic of the BCG. The rule-fulfilling decentralized decision making processes and the resource systems of the SBUs are represented with positive and negative servomechanistic feedback loops which have a level-rate and policy substructure.

The DYNAMO equations 1 through 9 show how the portfolio management process, based on the concept of the BCG, can be formulated with spiral loops (an introduction to the simulation language DYNAMO is given in Richardson/ Pugh 1981; for the equations of the portfolio-simulation model see Merten 1985 and Löffler 1984).

The *strategic positioning* of the SBUs is represented in the model with four rules of critical load. An SBU is qualified by the first rule of critical load as a "poor dog" position (DOG(M) if its market growth (MAWA(M)) is 10 per cent per year or less and its relative market share (MAAT(M)) is 1 or less. A minimum capital investment is necessary (KAPBIN>0) in "poor dog" positions for the positioning of SBUs.

```
DOG.K(M)=CLIP(1,0,CLIP(1,0,.1,MAWA.K(M))                    1,  A
*CLIP(1,0,1,MAAT.K(M))*CLIP(0,1,0,KAPBIN.K(M)),1)
```

DOG	POOR DOG POSITION	(DL)
M	MARKET INDEX	(DL)
CLIP	DYNAMO MACRO (WHEN/IF DECISION FUNCTION)	(DL)
MAWA	MARKET GROWTH	(1/YEAR)
MAAT	RELATIVE MARKET SHARE	(DL)
KAPBIN	ACCUMULATED CAPITAL INVESTMENT	(DM)

SBUs with a high market growth but a low relative market share are qualified by the second rule of critical load as "question mark" positions (QUE(M)), if the company already has investments in this business.

```
QUE.K(M)=CLIP(1,0,CLIP(0,1,.1,MAWA.K(M))                    2,  A
*CLIP(1,0,1,MAAT.K(M))*CLIP(0,1,0,KAPBIN.K(M)),1)
```

QUE	QUESTION MARK POSITION	(DL)

SBUs are qualified as "star" positions (STA(M)) by the third rule of critical load, if their market growth and their relative market share are high.

```
STA.K(M)=CLIP(1,0,CLIP(0,1,.1,MAWA.K(M)                     3,  A
*CLIP(0,1,1,MAAT.K(M)),1)
```

STA	STAR POSITION	(DL)

Finally, SBUs with a low market growth and a high relative market share are positionated by the fourth rule of critical load as "cash cow" positions (COW(M)).

```
COW.K(M)=CLIP(1,0,CLIP(1,0,.1,MAWA.K(M)                     4,  A
*CLIP(0,1,1,MAAT.K(M)),1)
```

COW	CASH COW POSITION	(DL)

If an SBU is qualified by one of the four rules of critical load, than a *norm-strategy* (BCG strategy suggestion) becomes activated, which is defined for the specific strategic problem. For each of the four strategic problems one norm-strategy is defined in the model. The norm-strategy generated for "poor dog" positions (MSTDOG(M)) is divestment (SFADOG(M)=.8); we invest in SBUs which are qualified as "question marks" (SFAQUE(M)=1.15); we also invest in "star" positions (SFASTA(M)=1.05) and we try to hold "cash cow" positions (SFACOW(M)=1). Instead of using one quantified multiplicator to represent each norm strategy, it is also possible to formulate for each strategic situation a different policy set (see Löffler 1984). Equations 5 to 8 show how the four strategies are defined with strategic multiplicators (rules of strategy selection and strategy generation).

```
MSTDOG.K(M)=DOG.K(M)*SFADOG                                5,   A
SFADOG=.8                                                  5.1, C

    MSTDOG    POOR DOG NORM-STRATEGY                       (DL)
    SFADOG    POOR DOG STRATEGY FACTOR                     (DL)

MSTQUE.K(M)=QUE.K(M)*SFAQUE                                6,   A
SFAQUE=1.15                                                6.1, C

    MSTQUE    QUESTION MARK NORM STRATEGY                  (DL)
    SFAQUE    QUESTION MARK STRATEGY FACTOR                (DL)

MSTSTA.K(M)=STA.K(M)*SFASTA                                7,   A
SFASTA=1.05                                                7.1, C

    MSTSTA    STAR NORM STRATEGY                           (DL)
    SFASTA    STAR STRATEGY FACTOR                         (DL)

MSTCOW.K(M)=COW.K(M)*SFACOW                                8,   A
SFACOW=1                                                   8.1, C

    MSTCOW    CASH COW NORM STRATEGY                       (DL)
    SFACOW    CASH COW STRATEGY FACTOR                     (DL)
```

The top-down management factor (MAORFU(M)) takes the value of the norm strategy for an SBU with an information delay as shown in equation 9.

```
MAORFU.K(M)=DLINF3(MSTDOG.K(M)+MSTQUE.K(M)                 9,   A
+MSTSTA.K(M)+MSTCOW.K(M),MPWZ)
MPWZ=2                                                     9.1, C

    MAORFU    TOP-DOWN MANAGEMENT FACTOR                   (DL)
    MPWZ      TIME TO CHANGE STRATEGY                      (YEARS)
```

The top-down management factor alters the bottom-up generated budgets and functional policies of the SBUs taking the financial constraints of the conglomerate into account (rule of strategy implementation). The bottom-up generated budgets are based on different kinds of information, like forecasts of the market development, information about competitors, and information about the company's costs and the capacities in the SBUs. The four spiral loops used to represent the portfolio management process are typically *recausalization loops*, because they can only change feedback connections within existing SBUs or between the portfolio management and the SBUs.

The spiral loops used to represent the establishment of new businesses and the divestment of old businesses (*hypercycles*) are defined outside the portfolio matrix (see for a detailed discussion of this second type of spiral loop the "know-how transfer model," presented later in this article). The activation of new SBUs with high market growth, where we are presently not in (market share =0) is dependent on the portfolio structure of the company. We invest in a new SBU with high market growth, if the portfolio structure shows too many old SBUs and if we do not already have a new SBU ("question mark" position). We divest SBUs totally which are in "poor dog" positions, when their losses exceed a maximum acceptable level. We also divest "question mark" positions, when they generate losses and the financial situation of the company is critical. SBUs with low market growth where we are not yet in, or where we are out, are qualified as markets which are not interesting for the company. We do not invest in these markets.

Selected Results From the Portfolio Simulation Model

The formal portfolio simulation model helps us to explain the evolution of multibusiness firms in duopoly markets and it also can be used as a simulation game and a strategic decision support system (Merten 1986b). The results of two model tests will be presented in order to demonstrate the ability of the model to generate different development patterns of a diversified firm over a period of 20 years (for the complete results see Löffler 1984).

To show the *qualitative* and *quantitative* changes typical of the development of diversified firms, we present the results of the portfolio-simulation model in three types of plots. The comparative dynamic portfolio plots show the development of the SBUs in the portfolio matrix over a 20 year (240 month) period in steps of four years.The sizes of the circles in these plots show us the percentage of earnings an SBU contributes to the total earnings of the conglomerate. The numbers used to draw the circles characterize the SBUs. The second type of plot shows us the evolutionary pathes of the SBUs in a portfolio matrix in a dynamic way. Besides these two new forms of plots, the DYNAMO plots are also available. The DYNAMO plots show us the development of various variables of the SBUs and of the conglomerate over time.

The two model tests selected examine the influence of different *competitive strategies* on the development of the diversified company. The exogenously given product life cycles are assumed to be the same for both tests. We assume in the *first competitive strategy test* that the diversified company in question as well as its competitors generate their strategies according to the rules of the BCG portfolio heuristic. The only difference in the strategic behavior of the companies is to be seen in the fact that the diversified company in question anticipates the strategies of the competitors (Stackelberg independence position), whereas the competitors do not antizipate (Stackelberg dependence position) . The results of this model run are shown in figures 5 through 7.

As figure 5 shows, the diversified company has four SBUs in the starting period. The SBUs are positioned in the portfolio matrix as follows: SBU 1 is in a "question mark" position; SBU 2 is a "star"; SBU 3 is qualified as a "cash cow"; and SBU 4 is in a "poor dog" position. The offensive strategy followed by SBU 1 increases its relative market share and leads to its positioning as a "star" after 4 years (period 48). The growth strategy of SBU 2 improves its "star" position in the first four years. The "cash cow" position of SBU 3 can be hold with a defensive strategy during the same period, and the SBU 4 becomes divested as a "poor dog." After 8 years (period 96) the company consists of five SBUs, because a new SBU has been established in the fast growing fifth market. By period 144 the company has four SBUs again. SBU 4 has been totally divested. After 20 years (period 240) the company still has four SBUs: one is positionated as a "star" (SBU 5) and the other three SBUs are "cash cows". The size of the circels in figure 5 also indicates the shifts in the cash flow streams. In the first four years SBU 1 and SBU 2 need more financial funds than they can earn. These funds are provided by SBU 3 and SBU 4.

Figure 6 shows us the development of the SBUs in a dynamic view. This figure neatly visualizes the structural changes during the development of the company, which are generated by the hypercycles of the model. SBU 4 is divested and SBU 5 is newly established.

In figure 7 we can see the development of the turnover of the conglomerate (UMSATG), which is the result of the addition of the turnovers of the five SBUs (UMSATZ(1)-UMSATZ(5)).The importance of the turnovers of the different SBUs changes in the 20 year period. In the starting period SBU 3 has the highest turnover; later on SBU 1 and SBU 2 dominate; at the end of the simulation run the turnover of SBU 5 is highest.

In the *second competitive strategy test* we assume that the competitors act opposite to the investment suggestions typically derived from the porfolio matrix of the BCG. In this case the competitors divest "question mark" positions; they try to hold "star" positions; and they invest in "poor dog" and "cash cow" positions. The results of this competitive strategy test are shown in the figures 8 through 10.

Figure 8 shows that we have the same starting position as we had in the last test and that the development of the SBUs is also similar to the first test until period 96. The declining demand in the markets of SBU 1 and SBU 2, generated by the exogenous product life cycles, leads to a repositioning of these two business units so that what were once "star" products become "cash cows" and, for the competitor, what were once "question marks" become "poor dogs".The atypical offensive strategies of the competitors in "poor dog" positions together with the companies defensive strategies in "cash cow" positions influence the development of the two business units and of the conglomerate from period 96 on in a negative way. The competitors win market shares in these two markets with their offensive strategies, which cause overcapacities by the company in question and a rise in its costs per unit and its prices. Because of the rise in price the company loses further market shares to its competitors which causes further cost and price increases. At the end of the simulation run SBU 1 is in a "poor dog" position and becomes divested. SBU 2 is still in a "cash cow" position but with a strong tendency towards a "poor dog" position. The porfolio atypical behavior of the competitors does not change the development of the "cash cow" position SBU 3 dramatically. The development of SBU 5 over the twenty years period is slightly better, because the defensive strategies of the competitors make it easier for the company to establish this SBU in a "star" position.

Figure 9 is a dynamic representation of the development of the SBUs with the portfolio atypical behavior of the competitors.

In figure 10 we can see the influence of the atypical behavior of competitors on the total turnover of the conglomerate and on the turnover of the SBUs. The aggregated turnover of the company is 25 per cent less than in the first test. This decline is predominantly caused by the 70 per cent decline in the turnover of SBU 1 and the 40 per cent decline in the turnover of SBU 2. This decline in turnover can not be compensated with the 10 per cent increase in the accumulated turnover of SBU 5. After 20 years (period 240) 55 per cent of the conglomerates turnover are generated in SBU 5: this is 20 per cent more than in the basic run. The high turnover percentage of SBU 5 indicates a high risk concentration within the conglomerate, which can cause severe difficulties in the company's future development.

If we now compare the results of the two model tests, we can conclude, that it is very important for a diversified company to have the right expectations about the behavior of the competitors in duopoly markets. The simulations also show that it may be extremely dangerous for a company to follow the investment suggestions typically drawn from the Boston Consulting Group portfolio matrix, if competitors choose a course of action that is contradictory to normative situations.

The two tests of the portfolio simulation model additionally demonstrate, that alternative evolutionary developments of multibusiness firms can be simulated with the combined spiral loop and system dynamics approach. The new approach further allows us to look at the "growth" of a firm not just in a quantitative but also in a qualitative way. The structural changes within the portfolio of multibusiness firms, shown explicitly with the portfolio simulation model, are typically a point of major concern in the strategic portfolio management process of diversified companies.

The Evolution of Multinational Corporations in Less Developed Countries - The Know-how Transfer Model

The know-how transfer model has been developed to explain and to help us to improve the process of *technology and management transfer* by multinational corporations (MNCs) of the assembling industries (i.e., automotive, electrical and mechanical engineering industries) to less developed countries (Merten 1985, Merten 1986a). This process is presently seen as problematic from the point of view of the MNCs as well as from the point of view of the less developed countries (LDCs), and is considered as one of the main issues in the future development of the Third World (UNCTAD 1972, United Nations 1971,1973).

To show how the combined system dynamics and spiral loop approach is applied to this problem we will give a brief overview of the know-how transfer model. First, we will show essential parts of the descriptive model of know-how transfer. Second, we will show the generic structures of the formal mathematical model of know-how transfer which is developed with the new methodology. Third, we will present selected simulation results of the model.

The Descriptive Model of Know-how Transfer

The know-how transfer process is an *evolutionary process* which predominantly is determined by three simultaneous interaction processes:

1. The interaction of the multinational corporations and the less developed country.
2. The interaction of the competing multinational corporations within the LDC market.
3. The interaction of the strategic group of multinational corporations with the strategic group of local corporations in the LDC market.

Figure 12 shows how these three interaction processes from the view of an MNC can generate *alternative internationalization patterns* (see for a complete description of the internationalization process and its empirical patterns, Merten 1985; Merten 1986a).

There are four activity levels (four stages of evolution) empirically relevant in the process of market-oriented internationalization of the MNCs in the LDCs. The home market supply activity level is x_0, where the parent company (PC) of the MNC delivers to the developed country (DC) market. The export activity level is x_1, where the parent company delivers to the developed country market and exports to the less developed country (LDC) market. The foreign production activity level is x_2, where the parent company delivers to the developed country market and the affiliated company (AC) supplies the LDC market. Finally, the foreign R&D activity level is x_3, where the parent company delivers to the developed country market and the affiliated company delivers its locally developed and produced products to the LDC market. The "jump" from one activity level to another which is called system evolution, is generated by the three strategic internationalization decisions (export-, foreign production- and foreign R&D decision) of the MNC. The strategic decisions of the MNC are determined by its own activities and by the activities of the interacting system elements (the LDC government, the national and multinational competitors in the LDC market and the buyers of the MNC product in the LDC).

Figure 12 shows the market-oriented internationalization process with special reference to the technique, management and capital transfers. In figure 13 we assume a complete transfer process with use-how transfers at the export stage, make-how transfers during the foreign production phase, and think-how transfers accompaniing the foreign R&D activity.

The Formal Model of the Know-how Transfer Process

The generic structure of the formal model of know-how transfer, which has been developed with the combined system dynamics and spiral loop approach on the basis of the descriptive model of know-how transfer, is shown in figure 13 and can be explained as follows (for the complete equations of the model see Merten 1985):

1. There are four *activity levels* of the model which represent the four *evolutionary stages of the system*. Each activity level is composed of a set of positive and negative feedback loops which have a level-rate and policy substructure.

2. There are three *spiral loops* of the model which represent the *evolutive decision rules* (strategy making) at the top management level of the multinational corporation. Each spiral loop is composed of a rule of critical load, a rule of strategy generation and strategy selection, and a rule of strategy implementation.

The *four activity levels* of the model represent the four evolutionary stages of internationalization and know-how transfer: the home market supply stage, the export stage, the foreign production stage, and the foreign R&D stage (see also figure 11). Each activity level of the model can be looked at as a complete system dynamics model for *one* evolutionary stage of development. At each activity level a different set of causal loops with the corresponding level-rate and policy substructures is active. The higher activity levels of the model are part of the knowledge bases of the interacting autonomous systems at the lower activity levels.

The "jump" from one activity level to another, which is called system evolution, is generated endogenously by the three internationalization spiral loops of the model. These logical loops represent the ability of social systems to change their structures qualitatively themselves. The knowledge stored in the three spiral loops represents the knowledge of the management of the MNC which is normally used to derive internationalization decisions in reality. All the information processed within the inference nets of the spiral loops (i.e., their data bases) is either generated by the feedback loops of the model or it is represented by constants.

In order to demonstrate how spiral loops are used to formulate the strategic internationalization decisions of the MNCs in the know-how transfer model, we show the spiral loop (hypercycle) representing the foreign production decision of the MNC from a feedback point of view and a decision tree point of view. The export decision and the foreign R&D decision of the MNC are defined in a similar way with spiral loops (see Merten 1985; Merten 1986a).

The *foreign production spiral loop* in figure 14 shows what happens if the feedback loops which are activated by a positive export decision generate exponentially growing exports.

The rising exports of the MNCs, which are also the rising imports of the LDC, result in the LDC's enacting an import substitution policy (tariffs) when a threshold value is reached (rule of critical load of the import substitution spiral loop of the LDC). The increasing tariffs of the LDC cause the MNCs to raise the prices of products in the LDC market, which result in a reduction in the market share of the strategic group of MNCs. The decline in the MNCs' market share results in the LDC's decreasing its orders from the MNC parent company from the LDC and reduces the MNC exports . A reduction of the MNC exports is at the same time a reduction in the LDC imports. The decreasing imports, however, do not reduce the tariffs of the LDC because these are established to protect the local producers and/ or to force the MNCs to produce locally (strategy of the LDC generated by the LDC import substitution spiral loop1). The tariffs of the LDC, therefore, normally increase either until the MNCs are out of the LDC market or until they make a foreign production decision.

The MNC normally makes a foreign production decision (AUIVEF) when the tariffs (ZOLLSA) reach a maximal acceptable level (MAXZOS) (rule of critical load AUEN1 of the foreign production spiral loop of the MNC). In large and rapidly growing LDC markets the MNC formulates an anticipative foreign investment decision when the forecasted demand of the LDC (PRBEDA) reaches a level that seems to make foreign production economically possible (BEDAEF) (rule of critical load AUEN2 of the foreign production spiral loop of the MNC). The two rules of critical load shown in figure 14 from a feedback point of view are illustrated in figure 15 in the upper branch of the *foreign production decision tree.* Figure 15 also shows that a positive foreign production decision (AUIVEF=1) will be generated endogenously in the model when the rule of strategy generation (AUSIEN) represented in the lower branch of the decision tree fires (AUSIEN>0). The rule of strategy generation fires when all foreign investment decision criteria are fulfilled, i.e., all decision variables within the rule become one.

The risk decision factor (RISAEF) becomes one when the country risk of the LDC (RISI(2)) is lower than the maximal acceptable risk (MAXRIS). The country risk is a variable computed by the model; the maximal acceptable risk represents the experience (knowledge) of the MNC risk management gathered in previous LDC activities.The maximal acceptable risk is defined as a function of the LDC demand. The competition decision factor (WPMNEF) is computed as one when the market share of the MNC in the LDC (MAAT(2)) is greater than or equal to a minimum market share (MIWEPO). The demand decision factor (BDAIEF) is one when the forecasted demand of the LDC market (PRBEDA) equals a minimum demand (MINBED) or is greater than this. The financial decision factor (FIPAEF) is computed as one when the financial reserves of the MNC parent company (STRB(1)) are greater than or equal to a minimum level (MINSBA). Another precondition for a positive foreign production decision is that the growth decision factor (EDRAEF) is one. EDRAEF becomes one when the MNC desires to grow (EDRUCO≥MINEDA).

In addition to these five condition action rules the whole inference net of the export spiral loop is part of the foreign production spiral loop (dashed lines in figure 15). A positive foreign production decision will be generated by the foreign production spiral loop only when the MNC had exports to the LDC before, i.e., a positive export decision (EXPOEF=1) was made before. On the output side of the foreign production decision tree a positive foreign production decision is a precondition for a positive foreign R&D decision generated in the foreign R&D spiral loop (AUFEEF). All three strategic internationalization decisions modeled with spiral loops are, therefore, part of one large inference net. The direct dependence of later strategic decisions on earlier strategic decisions, which is typical for the know-how transfer process, is, however, not characteristic of spiral loops.

A positive foreign investment decision generated in the inference net in figure 15 causes the activation of the rules of implementation which are neccessary for establishing a foreign production. One of these rules (see figure 14) activates the starting production capacity of the foreign plant. If the starting production facility of the MNC in the LDC is established, then the orders from the LDC switch from the parent company (PC) to the affiliated company (AC). This causes the activation of the local production structures of the AC (see dashed lines in figure 14) and the deactivation of the export structures of the PC. The price of the MNC in the LDC market is now calculated on the basis of the costs of the affiliated company. The tariffs of the LDC have no more influence on the price of the MNC products and on the price of the strategic group of MNCs products in the LDC market . The MNCs' market share in the LDC will, therefore, rise again and the newly established affiliated company will therefore increase its production which makes decreasing unit costs of the AC possible.

The spiral loops of the model represent the rule-setting strategic decisions in the process of internationalization. Further model assumptions are represented in the servo-mechanistic feedback loops and the initial states of the model.

The corporation in the basic run of the model is considered a typical German assembly industry MNC. The MNC produces a complex, technically standardized investment product at the parent company using an assembly process that is capital and know-how intensive. We assume further that the MNC produces only one product (or one product group) and that it already has experience with investments in third world countries (assumption of a well developed strategic and operational knowledge base concerning activities in LDCs).

The model's assumptions underlying the competition situation in the DC and LDC markets are as follows: The MNC competes in both markets with other MNCs which are aggregated to one competitor in each market (a duopoly situation). In the basic run of the model we assume a competitive intensity of zero between the MNCs in both markets (duopoly peace case). Concerning the competition of the strategic group of MNCs with the strategic group of local corporations, which are also aggregated to one competitor, we assume in both markets a duopoly situation with a Stackelberg solution.

In the basic run of the model we assume further that the developed country is West Germany and the underdeveloped country is the Philippines. The demand in both countries for products of the assembly industries is derived from their real GNP and their degree of industrialization. The development of the GNP and the development of the industrial sector are exogenously generated in order to be able to simulate different development scenarios easily. The strategies and policies of the LDC which influence the activities of the MNCs are modeled endogenously.

As well-developed indicators of know-how flows are not available, a range of proxies has been used to build a mosaic picture with each adding different elements to the picture. The finished product exports were used as indicators for the use-how transfers; the machine and parts transfers as well as the manager and license transfers were proxies for the make-how transfers; and the transferred patents were used to estimate the think-how transfers. In order to make the three qualitatively different kinds of know-how transfer comparable, all indicators were weighted differently according to their importance (Merten 1985, 750-753).

Selected Results from the Know-How Transfer Model

The formal model of know-how transfer allows us to analyze the evolutionary processes of internationalization and know-how transfer in their *qualitative* and *quantitative* dimensions. The model can additionally show the implications of these prosesses for the multinational corporation (affiliated company, parent company and conglomerate), the markets in the developed and less developed countries, and the economies of the less developed and developed countries. Plots 1 through 14 (figures 16-19) show the behavior of selected model variables of the know-how transfer model for a period of 30 years (for the complete results and the validation of the model see Merten 1985).

In plots 1 and 2 (figure 16) the know-how transfer process to the Philippines is shown together with the strategic internationalization decisions of the multinational corporation. The model generates an export decision of the MNC in period 0, a foreign production decison in period 6 and a foreign R&D decision in period 21.The use-how transfers peak in period 5. The decline of use-how transfers after period 5 is caused by the import substitution strategy of the LDC. The make-how transfers reach their peak in period 9, three years after the foreign production is established in the LDC. The think-how transfers peak during the first years after the R&D facilities in the LDC are established. Figure 16 neatly visualizes the qualitatively different types of know-how transfer and it also shows the know-how transfer volumes, which are measured with the above described indicators. Figure 16 additionally shows that it takes more than 25 years until the affiliated company in the LDC is able to develop, produce and sell its own products.

To identify strategies and policies which make the know-how transfer process faster and simultaneously more efficient for the interacting MNC and the LDC, we made six sets of model tests. We will next show the results of three of these test sets.We selected these three groups of model tests not only to show the impact of different strategies on the know-how transfer process but also because they demonstrate the capability of the model to generate alternative evolutionary know-how transfer processes.

In a first test group, the *country tests*, we examined the know-how transfer process for 12 different LDCs all of which had a GNP between 20 and 100 billion dollars in 1982. With these tests we tried to find out which economic conditions of the LDCs support the know-how transfer process, and we further wanted to show in which LDCs foreign production of the MNCs is presently most profitable. Figure 17 shows the results of the country tests for the Philippines, Turkey, Nigeria, and Columbia.

All four country tests show roughly analogous know-how transfer patterns over the thirty year period. There are, however, some important differences between the know-how transfer processes in these four countries. In the case of Turkey the foreign production decision is generated in period 5; in the other three countries this decision is generated by the foreign production spiral loop in period 6. The foreign R&D decision is generated by the model in the simulation run for Turkey in period 19; in the run for the Philippines in period 21; in the Columbia model run in period 24; and in the model test for Nigeria in period 26. For Turkey the make-how transfers show a double peak (periods 9 and 11), and they have also a double peak in the case of the Philippines (periods 9 and 12) but with a clearly smaller second peak. In the internationalization activities in Columbia and Nigeria the make how transfers have only one clear visible peak, and for both countries this peak is in period 9.

If we look at the accumulated know-how transfers over the thirty year period, we can see that these are highest in the case of Turkey with 4,547 units, following the Philippines with 4,470 units , Columbia with 4,325 units and Nigeria with 4,255 units. These results show that the know-how transfer process is faster in the Turkish market than in the other three markets. These results also indicate, besides others, that an investment of the MNCs in the Turkish market will yield the best results. The advantage of the Turkish market in comparison to the markets of the Philippines, Columbia and Nigeria is pre-dominantly in the higher market potential for assembly industry products.

In the *multinational corporation strategy test set* we examined the influence on the know-how transfer process of different competitive and internationalization strategies of the assembling industry MNCs (see figure 18).

With the *competitive strategy tests* we investigated the competitive strategies typical for Japanese, US-American, and German MNCs in LDC markets. In a first test we examined the "cash star" strategy, which is typical for German MNCs. Companies following a "cash star" strategy basically try to find a compromise between a short-term profit-maximization strategy and a long-term growth strategy. In a second model run we tested the short-term profit-oriented "cash and go" strategy which is typical for US-American MNCs. In the "star maker" test we examined the long-range growth strategy, which Japanese MNCs typically follow. In all three competitive strategy tests, we assumed that the MNCs actually compete with each other in the DC and LDC market (a duopoly war case with a Stackelberg solution). Further, we assume that the LDC is the Philippines.

As the results in figure 18 indicate, the "cash star" strategy has a positive influence on the know-how transfer process and the market-oriented internationalization process. With this strategy the know-how transfer process becomes faster and reaches 4,700 accumulated know-how units within 30 years, which is 230 units more than in the basic run. In figure 18 we can also see the negative influence of the "cash and go" strategy on the know-how transfer process, which is much slower than in the basic run. In this case the foreign R&D decision was made after 23 years; in the basic run, it was made after 21 years. After 30 years the accumulated know-how transfer is 3,912 units, which is 558 units less than in the basic run and 800 units less than in the "cash star" strategy case. Figure 18 also shows how the "star maker" strategy changes the know-how transfer process. With this strategy much more know-how is transferred from the PC to the AC than is the case with a "cash and go" and "cash star" strategy. After 30 years the accumulated know-how transfer reaches 5,983 units, i.e. , 1,600 units more than in the basic run.

Unlike plots 7 through 9 in figure 18, which show the results of competitive strategy tests, plot 10 in figure 18 shows the results of a change in the internationalization strategy of the MNC. In this model test we assumed that the MNC does not invest in foreign production in the LDC in reaction to the import substitution strategy of the LDC. Further we assumed that the competing MNC invests in the LDC market. As plot 10 shows, the know-how transfer process is completed after 10 years of use-how transfer. The accumulated know-how transfer is 473 units after 30 years. We lost the LDC market to the competing local and multinational companies. From period 10 on, the PC delivers only to the DC market (activity level x_0 of the model).

The model behavior shown in plot 10 can also be generated by a parameter change in the foreign production spiral loop. If we, for example, reduce the maximal acceptable risk in the rule of strategy generation in the foreign production spiral loop from 60 per cent to 50 per cent, we get the same result.

The system dynamics model with spiral loops allows us to test the sensitivity of the strategic parameters used in the spiral loops, and the model also helps to make their importance explicit to the strategic decision makers in social systems. Unlike the models formulated by the Brussels school (Prigogine/ Stengers 1984; Allen/ Engelen/ Sanglier 1984), the know-how transfer model is not sensitive in critical situations to an external stochastical noise, but it is sensitive to marginal changes in the strategic parameters of its endogenously interacting autonomous system elements. The sensitivity of the strategic parameters in the model realistically represents the sensitivity of these parameters in social systems.

With a third test set, the *less developed country tests*, we examined the model behavior generated by different development scenarios for one LDC and by different economic strategies for the same LDC - the Philippines (see figure 19).

First we examined optimistic and pessimistic development scenarios for this country. In the optimistic scenario, which is called a "take off" scenario, we assume that the average annual growth in the GNP for the Philippines is 6.35 per cent instead of 4.5 per cent in the basic run. We further assume that the industrialization process of the Phillipines is faster, and the population growth is slower than in the basic run. Figure 19 shows the model behavior for this development scenario. Unexpectedly the know-how transfer process is very simmilar to the one in the basic run of the model. After 30 years the accumulated know-how transfer is 4,661 units, that is only 200 units more than in the basic run of the model.

In the pessimistic development scenario for the Philippines, which is called a "break down" scenario, we assume that the GNP grows on the average 2.27 per cent per year, which is 2.23 per cent less than in the basic run. We further assume that the industrial sector of the Philippines grows slower. Figure 19 shows that the know-how transfer process changes drastically in this development scenario. The MNC does not establish a foreign R&D in the Philippines in this case, i.e., no think-how is transferred. The model remains at the foreign production activity level x_2. The total accumulated know-how transfer is 4,072 units after 30 years, which is 400 units less than in the basic run and 600 units less than in the "take off" scenario.

In plots 13 and 14 (figure 19) we show the impact of changes in the LDC economic strategy towards MNCs on the know-how transfer process.

In the "market economy" strategy test we investigated the influence of the economic behavior of the LDC according to the rules of the market economy. In this model run we assume during the foreign production and foreign R&D phase that: (1.) the LDC does not limit royalities and fees of the MNCs, (2.) it does not restrict the local financing of the MNCs, and (3.) it does not establish local content regulations. Plot 13 shows the positive influence of the market economy on the Philippine know-how transfer process. The make-how transfers during the foreign production and foreign R&D phase nearly double, and the accumulated know-how transfer reaches 7,463 units after 30 years. This is nearly 3,000 units more than in the basic run. The foreign R&D decision of the MNC is in this case later than in the basic run, because the LDC does not limit the MNC transfers of royalities and fees and thereby generate a blocked currency at the AC. The MNC is in this case not forced by LDC politics to establish local R&D facilities in the LDC, but it is forced by its own production requirements.

In a second LDC strategy test we assumed that the government of the Philippines nationalizes the AC of the MNCs in period 15 (see figure 19 plot 14). The know-how transfer process is interrupted by the nationalization of the AC and it becomes zero in period 15. The know-how transfer accumulated after 30 years is 2,512 units, which is nearly 2,000 units less than in the basic run. The market-oriented internationalization process of the MNC is over, too. The MNC has to go back to the home market supply activity level .

The results of the LDC scenario and strategy tests show that different evolutionary behavior modes of the know-how transfer model are *not* caused by an exogenous stochastical noise in the LDC demand function, but they can be generated by drastic changes of this function or by drastic changes in the economic strategy of the LDC.

Methodological Conclusions

This work suggests that a combination of the spiral loop concept with the servo-mechanistic system dynamics paradigm is an adequate methodology for the simulation of social system evolution. The spiral loop concept which is based on new developments in evolutionary theory and in the field of artificial intelligence is used to represent the ability of goal oriented social systems to change their structures qualitatively themselves in order to stay alive and keep their identity in (expected) extreme disequilibrium situations. With spiral loops we do not optimize a social system or parts of it; spiral loops are used to model the "bounded rational" strategic decision-making process in social systems which is responsible for structural change and evolution. The servo-mechanistic feedback loop concept and the concept of shifting loop dominance are used to model the decentralized "bounded rational" decision making processes in social systems that are responsible for quantitative changes in interaction processes. Every qualitative change in a social system is determined by a corresponding (expected) quantitative change.

The work reported here demonstrates the potential of a combined system dynamics and spiral loop approach for two important social system applications. More work needs to be done in the areas on which the spiral loop is methodologically based like the research fields of pattern recognition, strategy generation, strategy selection and the learning of social systems. To determine the methods strengths and limitations, more work also needs to be done in applying this general methodology to specific problems in social system evolution.

The integration of spiral loops into the system dynamics approach is one more step towards "intelligent" simulation models of social systems. At the end of this methodological line of development we will be able to develop system dynamics models which can endogenously generate qualitatively new structures and behavior modes of social systems which did not exist before. This kind of simulation models, which will be realized within the next few years, will have the cabability of learning from their own experience, deriving decisions from numerical as well as from written knowledge bases, and, further, they will have the capability of rewriting their initial model structures.

This work opens a line of research that could contribute further to broadening the applicability of the system dynamics approach in the social sciences. The combination of intelligent logical loops with servo-mechanistic causal loops makes it possible to look at problems in social systems from an evolutionary and conservative perspective, from a strategic and operational perspective, from a discrete and continuous as well as from a quantitative and a qualitative point of view. In addition the models formulated with the new approach allow us to examine the influence of all kinds of exogenous (stochastic) changes in parameter values on evolutionary processes.

Notes

(1) The suggestion to represent the decision making process of social organizations at higher hierarchical levels with logical loops and the decision making process at lower hierarchical levels with servomechanistic loops was first articulated by Miller/ Galanter/ Pribram as a result of their "Tote unit" experiments. The context for their discussion was the learning of motor skills and habits, such as learning to fly an airplane: The input to an aviator, for example, is usually of a continuously varying sort, and the response he is supposed to make is often proportional to the magnitude of the input . It would seem that the good flier must function as an analogue device, a servomechanism. The beginner cannot do so, of course, because his plans are formulated verbally, symbolically, digitally, and he has not yet learned how to translate these into the continuous, proportinate movements he is required to make. Once the subplan is mastered and turned over to his muscles, however, it can operate as if it were a subprogram in an analogue computer. But note that this program, which looks so continuous and appropriately analogue at the lower levels in the hierarchy, is itself a relatively stable unit that can be represented by a single symbol at the higher levels in the hierarchy. That is to say, planning at the higher levels looks like the sort of information-processing we see in digital computers, whereas the execution of the Plan at the lowest levels looks like the sort of process we see in analogue computers (pp. 90-91).

(2) It is important to recognize that the spiral loop sketched in figure 2 has the same generic structure as the feedback loop implicitly used by system dynamicists in the process of model conceptualization and policy making. The process of policy making, for example, can be represented with a simillar spiral loop consisting of the following elements: model structure, problematic behavior (model results), discrepancy between the desired and the problematic behavior and structural change. The strategic knowledge base of the spiral loop is in this case represented by the experience and knowledge of the model builder (see Forrester 1961, 45). The spiral loops introduced in this article make a formal mathematical representation of the rules of structural change possible.

References

Allen, P.M.; Engelen, G.; Sanglier, E. (1984): Self-Organizing Dynamic Models of Human Systems, in: Frehland, E.(ed.), Synergetics, From Microscopic to Macroscopic Order, Berlin: Springer, 150-171.

Ashby, W.R. (1962): Principles of the Self-Organizing System, in: Foerster, H.; Zopf, G.W. (ed.), Principles of Self-Organizing, Oxford, 255-278; reprinted in Buckley,W.(ed.), Sociology and Modern Systems Theory, Englewood Cliffs (N.J.): Prentice-Hall, 108-118.

Ashby, W.R. (1952): Design for a Brain, New York/ London: John Wiley and Sons.

Beer, S. (1959): Cybernetics and Management, London:English Universities Press.

Beer, S. (1972): Brain of the Firm, London: Allen Lane,The Penguine Press.

Bigelow, J.D. (1978): Evolution in Organizations, Case Western Reserve University, PhD Thesis.

Brooks, R.A. (1981): Symbolic Reasoning Among 3-D Models and 2-D Images, in: Artificial Intelligence, Vol.17, August.

Buchanan, B.G.; Shortliffe, E.H. (1984): Rule-Based Expert Programs: The MYCIN Experiments of the Stanford Heuristic Programming Project, Reading (Mass.): Addison-Wesley.

Cyert, R.M.; March, J.G. (1963): A Behavioral Theory of the Firm, Englewood Cliffs (N.J.): Prentice-Hall.

Davis, R.; Lenat, D.B. (1982): Knowledge-Based Systems in Artificial Intelligence, New York: McGraw-Hill.

Dyllick, T. (1982): Gesellschaftliche Instabilität und Unternehmensführung, Bern/ Stuttgart: Paul Haupt.

Eccles, J.C.; Zeiher, H. (1980): Gehirn und Geist, München: Fischer.

Eigen, M.; Schuster, P. (1979): The Hypercycle: A Principle of Natural Self-Organization, Heidelberg: Springer.

Eigen, M.; Winkler, R. (1985): Das Spiel. Naturgesetze steuern den Zufall, München/ Zürich: R.Piper.

Ernst, G.; Newell, A. (1969): GPS: A Case Study in Generality and Problem Solving, New York: Academic Press.

Forrester, J.W. (1961): Industrial Dynamics, Cambridge (Mass.): M.I.T. Press.

Forrester, J.W. (1971): Behavior of Social Systems, in: Weiss, P.A.(ed.), Hierarchically Organized Systems in Theory and Practice, New York: Hafner, 81-122.

Hax, A.C.; Maljuf, M.S. (1984): Strategic Management. An Integrative Perspective. Englewood Cliffs (N.J.): Prentice-Hall.

Hayek, F.A. (1972): Die Theorie komplexer Phänomene, Tübingen: J.C.B. Mohr.

Henderson, B.D. (1973): The Experience Curve Reviewed, IV. The Growth Share Matrix of the Product Portfolio. The Boston Consulting Group, Perspectives, No 135, Boston (Mass.).

Henderson, B.D. (1979): Henderson on Corporation Strategy, Cambridge (Mass.): Abt Books.

Henderson, B.D.; Zakon, A.J. (1980): Corporate Growth Strategy. How to Develop and Implement It, in : K.J. Albert (ed.), Handbook of Business Problem Solving, New York: McGraw-Hill, 1.3-1.19.

Jantsch,E. (1979): Die Selbstorganisation des Universums. Vom Urknall zum menschlichen Geist, München: Carl Hanser.

Lenski, G.; Lenski, J. (1978): Human Societies, 3rd ed., New York: McGraw-Hill.

Lindsay, R.; Buchanan, B.; Feigenbaum,E.; Jushua, L. (1980): Applications of Artificial Intelligence for Chemical Inference. The DENTRAL Project, New York: McGraw-Hill.

Löffler, R. (1984): Portfolio Simulation als Ansatzpunkt der strategischen Unternehmensplanung, unveröffentlichte Diplomarbeit, Universität Mannheim.

Maruyama, M.(1963): The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes, in: American Scientist, 51 (1963), 164-179.

Maturana, H.; Varela, F. (1980): Autopoiesis and Cognition, in: Boston Studies in the Philosophy of Science, No. 42, Dordrecht/ Boston/ London: D. Reidel.

Merten, P.P. (1985): Know-how Transfer durch multinationale Unternehemen in Entwicklungsländer. Ein System Dynamics Modell zur Erklärung und Gestaltung von Internationalisierungsprozessen der Montageindustrien, Berlin: Erich Schmidt.

Merten, P.P. (1986a): Know-how Transfer by Multinational Corporations to Developing Countries. A System Dynamics Model With Spiral Loops. Proceedings 1986 System Dynamics Conference, Sevilla: System Dynamics Society.

Merten, P.P. (1986b): Portfolio-Simulation. A Tool to Support Strategic Management, Working Paper WP 1808-86 Alfred P.Sloan School of Management, Massachusetts Institute of Technology, Cambridge.

Mesarowic, M.D.; Macko, D.; Takahara, Y. (1978): Theory of Hierarchical, Multilevel Systems, New York/ London: Academic Press.

Miller, G.A.; Galanter, E.; Pribram, K.H. (1960): Plans and the Structure of Behavior, New York: Henry Holt.

Milling, P. (1981): Systemtheoretische Grundlagen zur Planung der Unternehmenspolitik, Berlin: Duncker & Humblot.

Minsky, M. (1980): K-lines: A Theory of Memory, Cognitive Science,vol 4, no 1.

Morecroft,J. (1983): System Dynamics: Portraying Bounded Rationality, in: Omega 11(2), 131-142.

Morecroft, J. (1985): The Feedback View of Business Policy and Strategy, in: System dynamics Review, Vol 1, No.1, 4-19.

Muir, D.E. (1986): A Mathematical Model/ Computer Simulation of Adaptive System Interaction, in: Behavioral Science, Volume 31, 1986, 29-41.

Nelson, R.R.; Winter, S.G. (1982): An Evolutionary Theory of Economic Change, Cambridge (Mass.): Harvard University Press.

Newell, A.; Shaw, J.C.; Simon, H.A. (1957): Preliminary Description of General Problem Solving Program - I (GPS - I), Report CIP Working Paper 7, Carnegie Institute of Technology, Pittsburgh, PA.

Newell, A.; Simon, H.A. (1972): Human Problem Solving, Englewood Cliffs (N.J.): Prentice-Hall.

Pask, G. (1972): An Approach to Cybernetics, London: Allen Lane, The Penguin Press.

Patil, R.S.(1981): Causal Representation of Patient Illness for Electrolyte and Acid-Base Diagnosis, MIT/ LCS/ TR-267, Laboratory of Computer Science, Massachusetts Insitute of Technology, Cambridge (Mass.).

Powers, W.T. (1973): Behavior: The Control of Perception, Chicago: Aldine.

Prigogine, I.; Stengers,I. (1984): Order Out of Chaos. Man's New Dialogue with Nature, New York: Bantam.

Probst, G.J.B. (1981): Kybernetische Gesetzeshypothesen als Basis für Gestaltungs- und Lenkungsregeln im Management, Bern/ Stuttgart: Paul Haupt.

Rassmussen, S.; Mosekilde, E.; Sterman, J.D. (1985): Bifurcations and Chaotic Behavior in a Simple Model of the Economic Long Wave, in: System Dynamics Review, Vol.1, No.1, 92-110.

Reynolds, T.D. (1974): Homeostasis of Behavior, in: Schering, L.E.; Halberg, L.E.; Pauly, J.E. (eds.), Chronobiology, Tokyo: Igaku Shoin.

Richardson, G.P.; Pugh III, A.L. (1981): Introduction to System Dynamics Modeling with DYNAMO, Cambridge (Mass.): M.I.T. Press.

Richardson, G.P. (1984): The Evolution of the Feedback Concept in the American Social Science, Ph.D. dissertation, System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology.

Richmond, B. (1981): Endogenous Generation of Structural Change in System Dynamics Models: An Illustration From Corporate Context, Proceedings 1981 System Dynamics Conference, Andersen, D.F.; Morecroft, J.D.(ed.), 291a-291m.

Riedl, R. (1980): Biologie der Erkenntnis, Berlin/ Hamburg: Parey.

Röpke,J. (1977): Die Strategie der Innovation, Tübingen: J.C.B. Mohr.

Simon, H.A. (1962): The Architecture of Complexity, in: Proceedings of the American Philosophical Society, 1962, S.467ff.

Simon, H.A. (1976): Administrative Behavior, 3rd ed., New York: The Macmillan Company.

Simon, H.A. (1979): Rational Decision Making in Business Organizations. American Economic Review 69(4), 493-513.

Simon, H.A. (1981): The Sciences of the Artificial, 2nd ed., Cambrige (Mass.): M.I.T. Press.

Simon, H.A. (1982): Models of Bounded Rationality II: Behavioral Economics and Business Organizations, Cambridge (Mass.): M.I.T. Press.

Tschdijian, E. (1976): The Third Cybernetics, in: Cybernetica, Nr.2, Namur.

UNCTAD (1972): Guidelines for the Study of the Transfer of Technology to Developing Countries. A Study by the UNCTAD Secretariat, New York.

United Nations (1971): World Plan of Action for the Application of Science and Technology to Development, New York.

United Nations (1973): Multinational Corporations in World Development, St/ECA/190, New York.

Winston, P.H. (1984): Artificial Intelligence, 2nd ed., Reading (Mass.): Addison-Wesley.

Zahn, E. (1979): Strategische Planung zur Steuerung der langfristigen Unternehmensentwicklung. Grundlagen zu einer Theorie der Unternehmensplanung, Berlin: Duncker & Humblot.

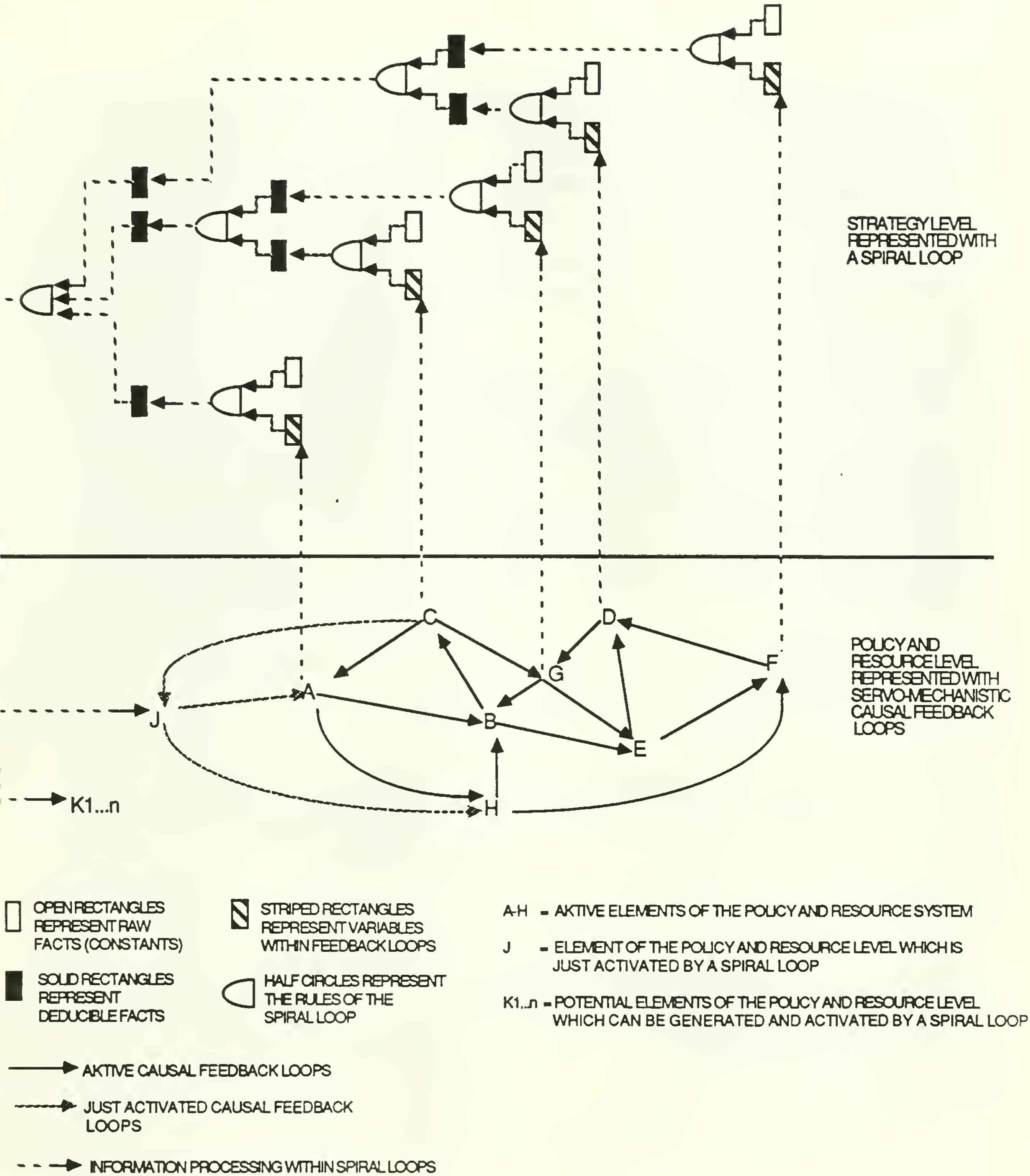


FIGURE 1: The Representation of a Social System with Spiral Loops and Servo-mechanistic Causal Feedback Loops

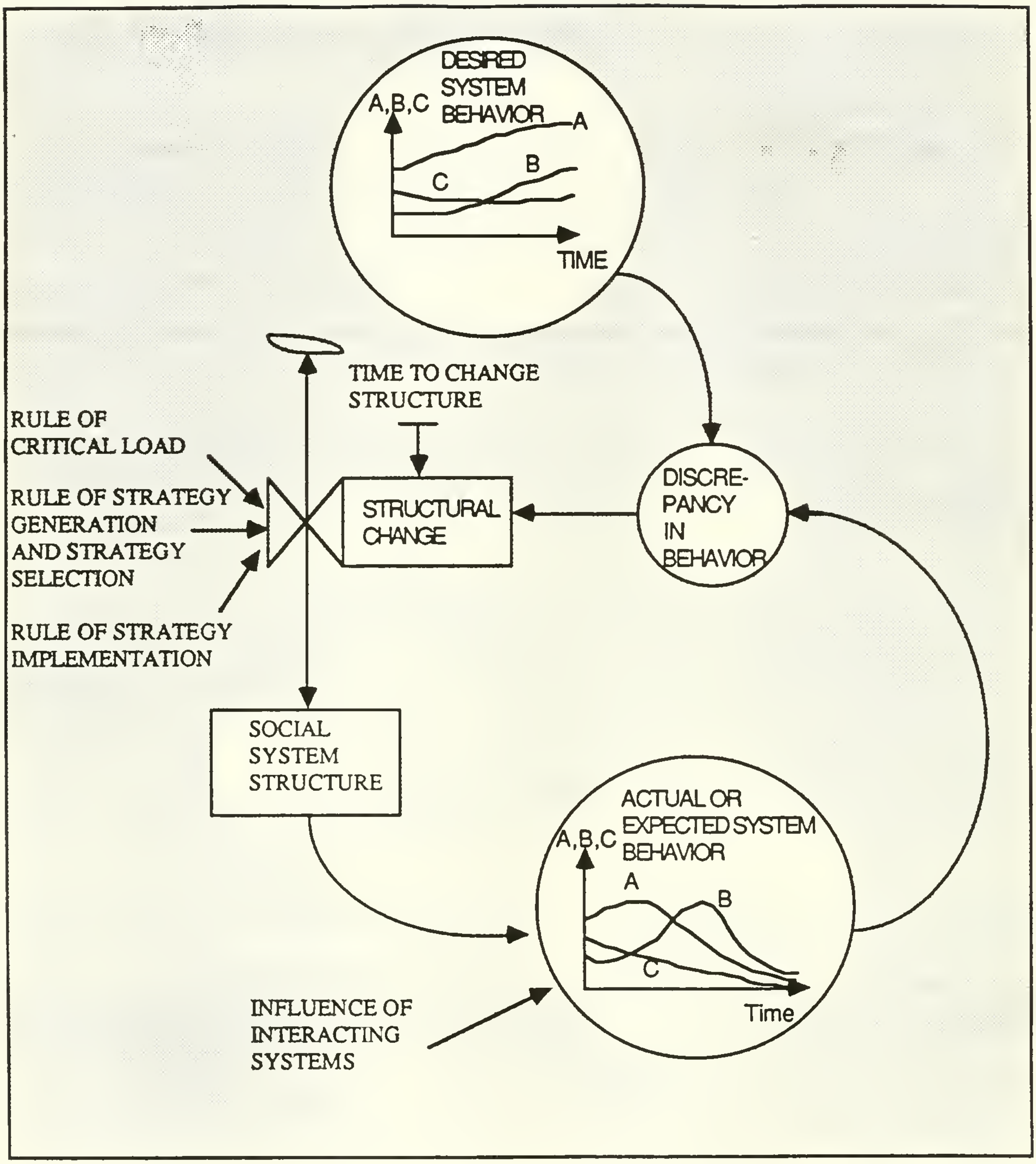


Figure 2: The Structure of a Spiral Loop

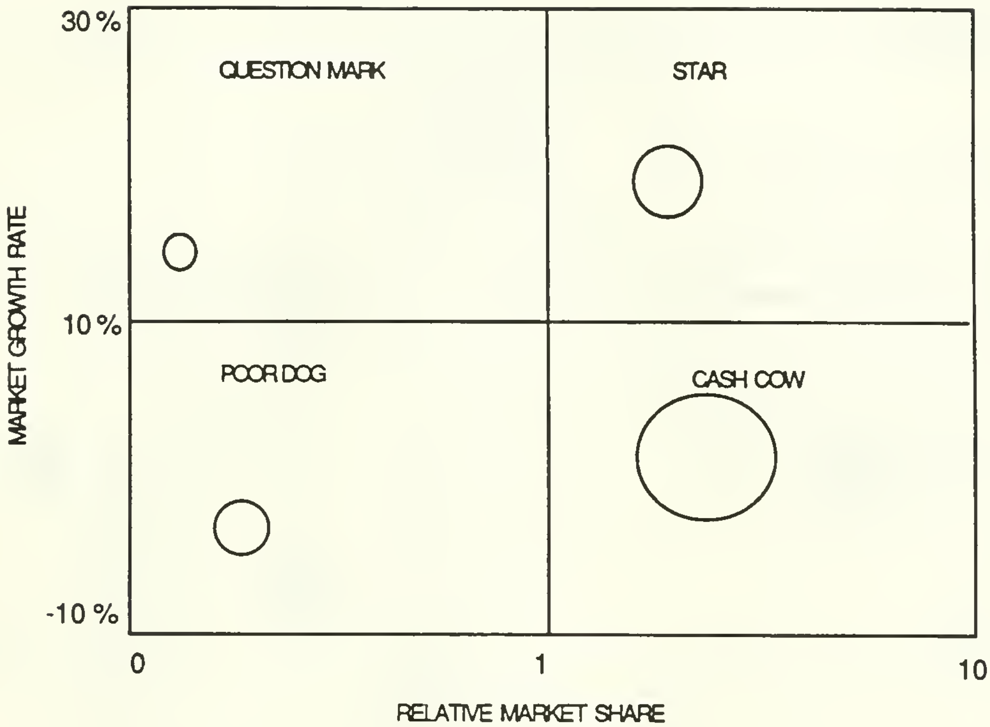
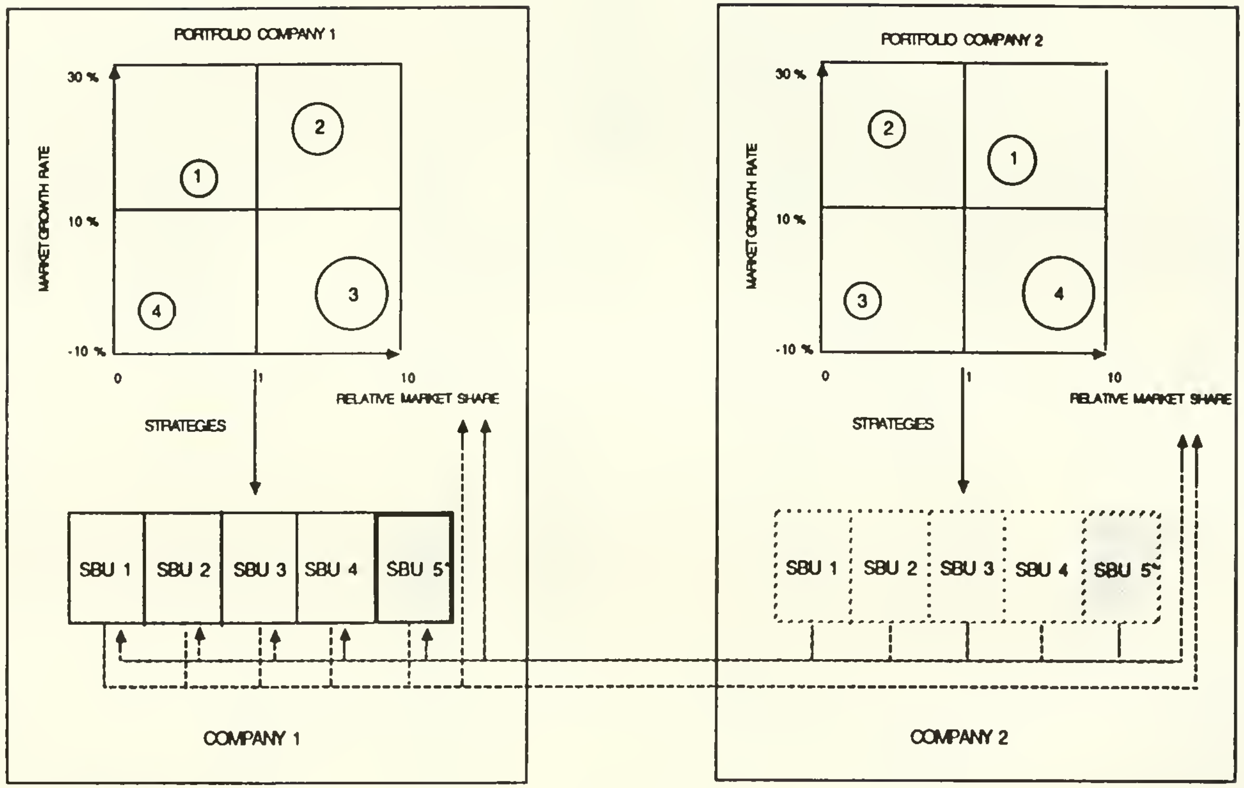


FIGURE 3: The Growth-Share Portfolio Matrix of a Diversified Company



* not yet activated

Figure 4: The Generic Structure of the Portfolio-Simulation Model

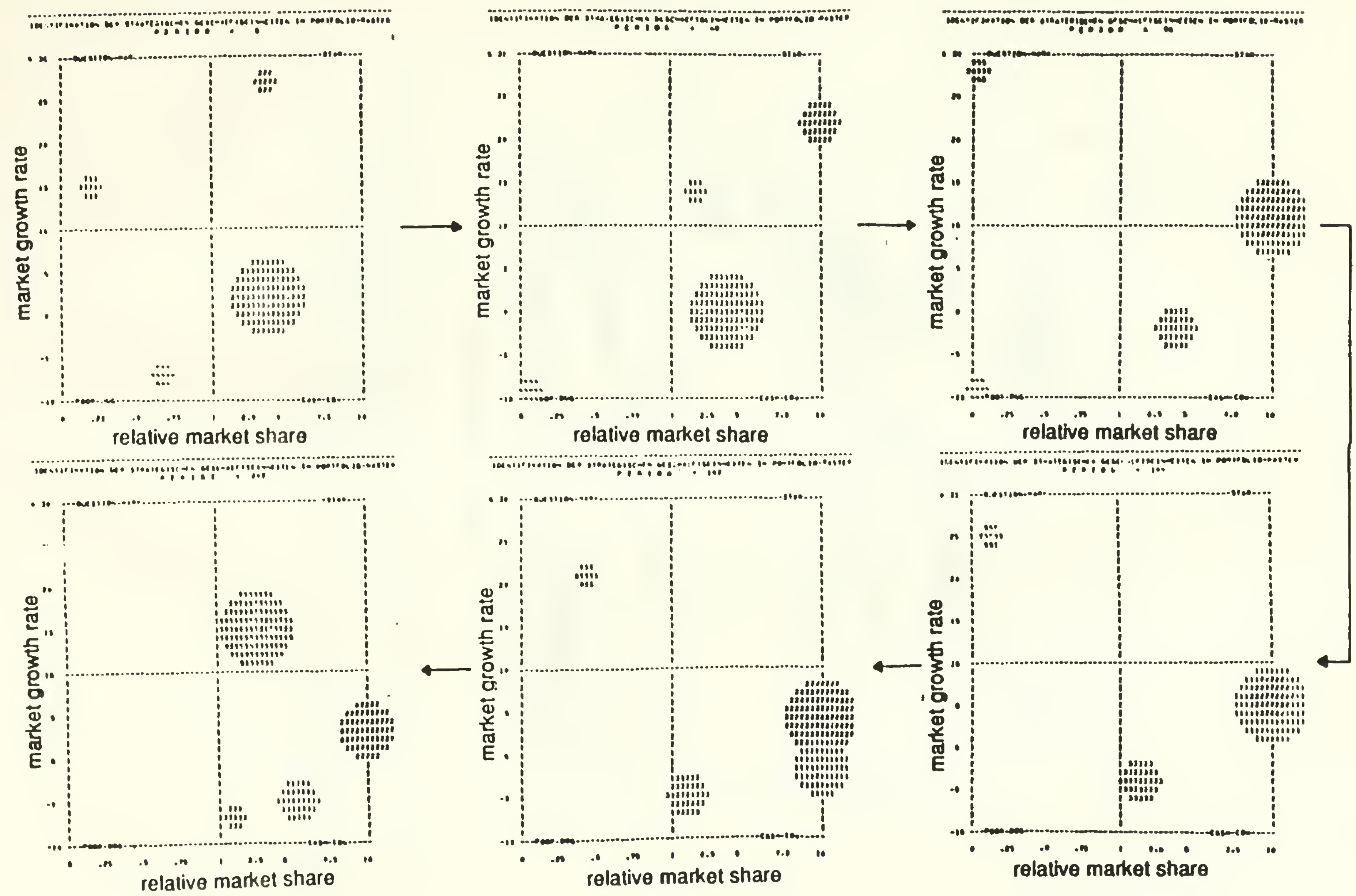


Figure 5: Portfolio Development in the Case of Portfolio Typical Reactions of Competitors (Comparative Dynamic View).

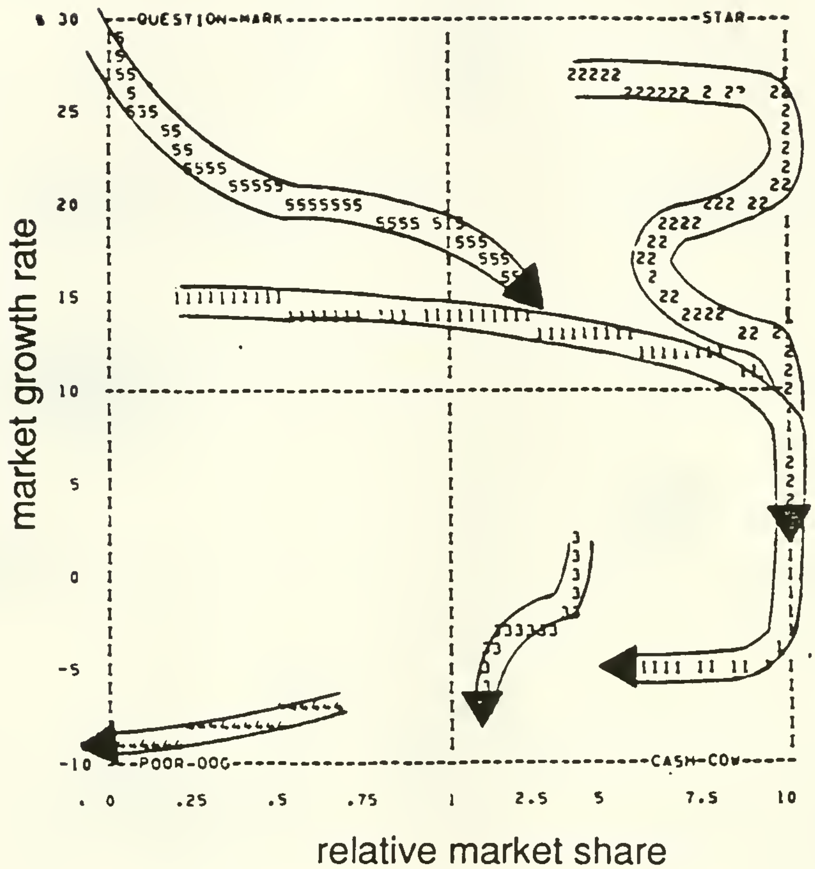


Figure 6: Portfolio Development in the Case of Portfolio Typical Reactions of Competitors (Dynamic View).

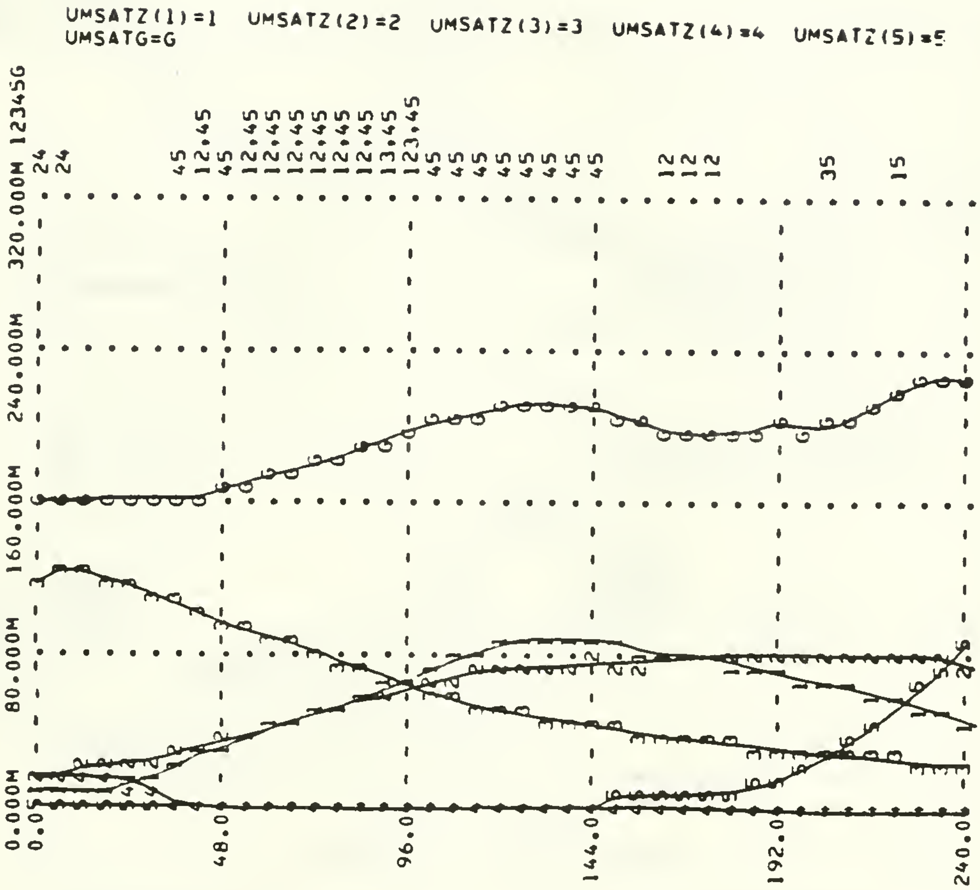


Figure 7: The Development of the Turnover of the Conglomerate in the Case of Portfolio Typical Reactions of Competitors.

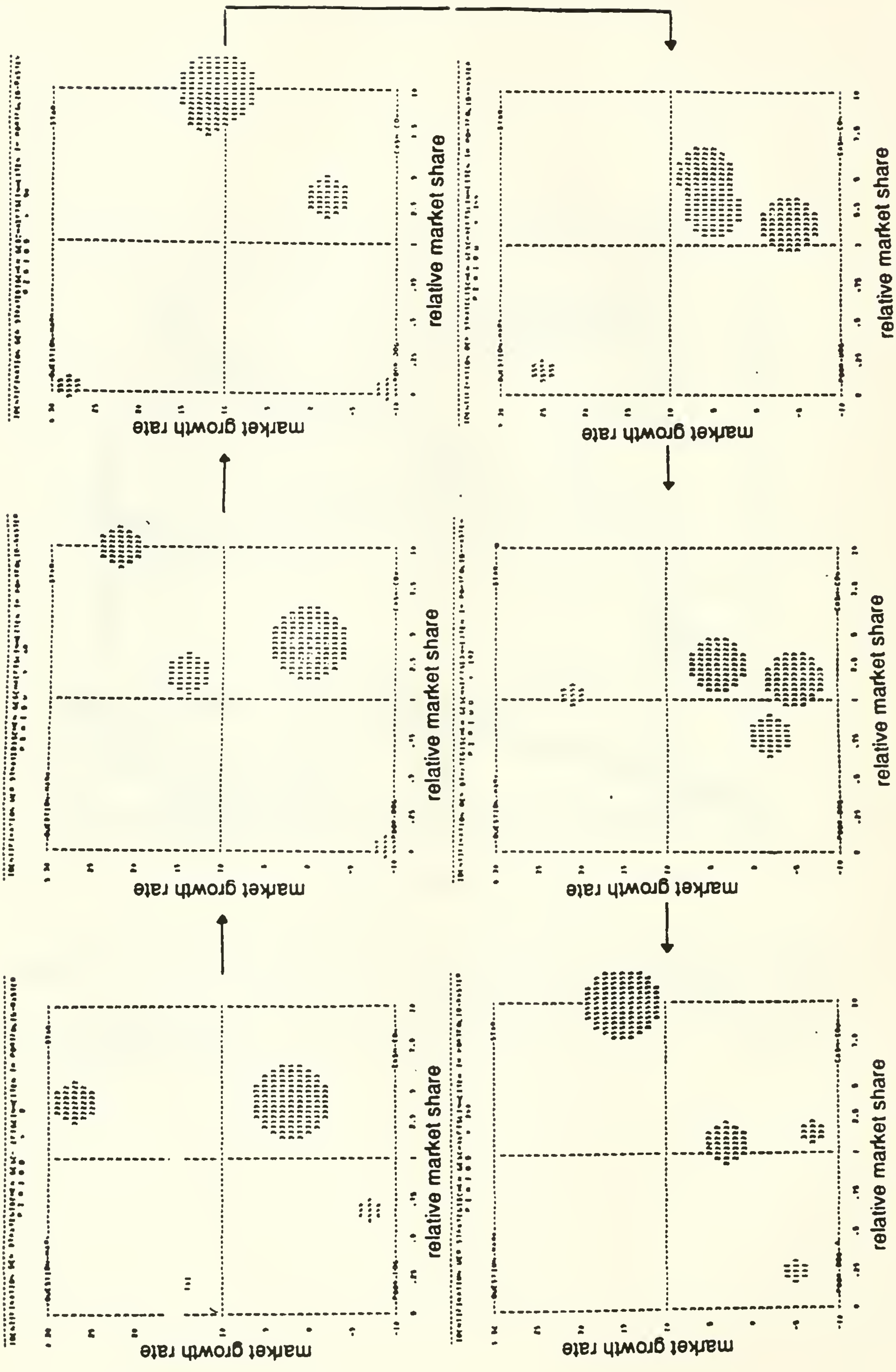


Figure 8: Portfolio Development in the Case of Portfolio Atypical Reactions of Competitors (Comparative Dynamic View)

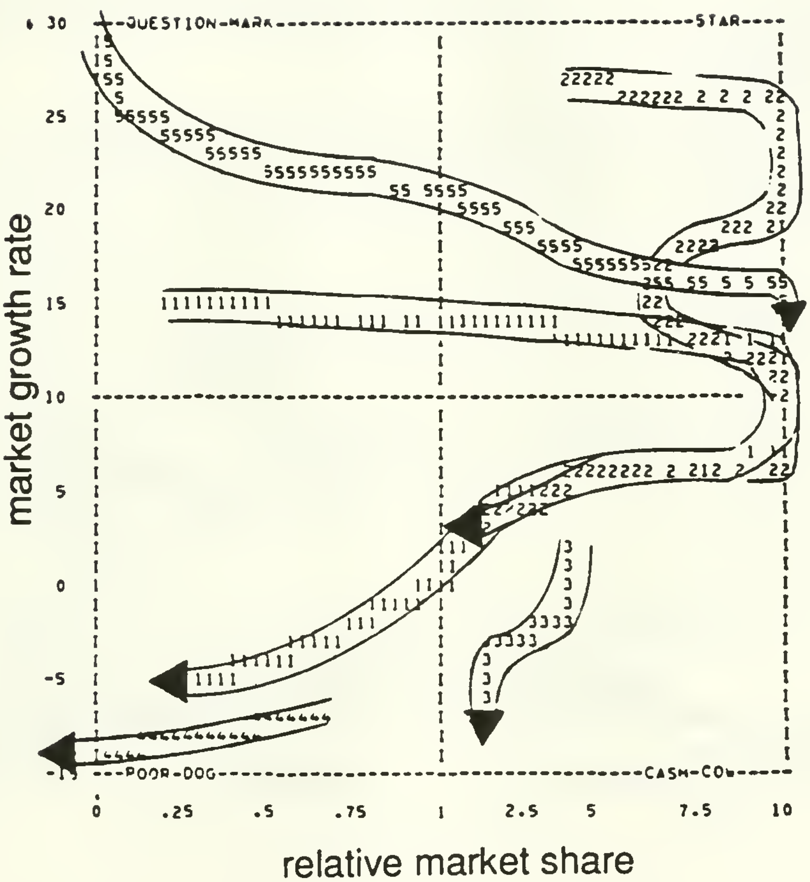


Figure 9: Portfolio Development in the Case of Portfolio Atypical Reactions of Competitors (Dynamic View).

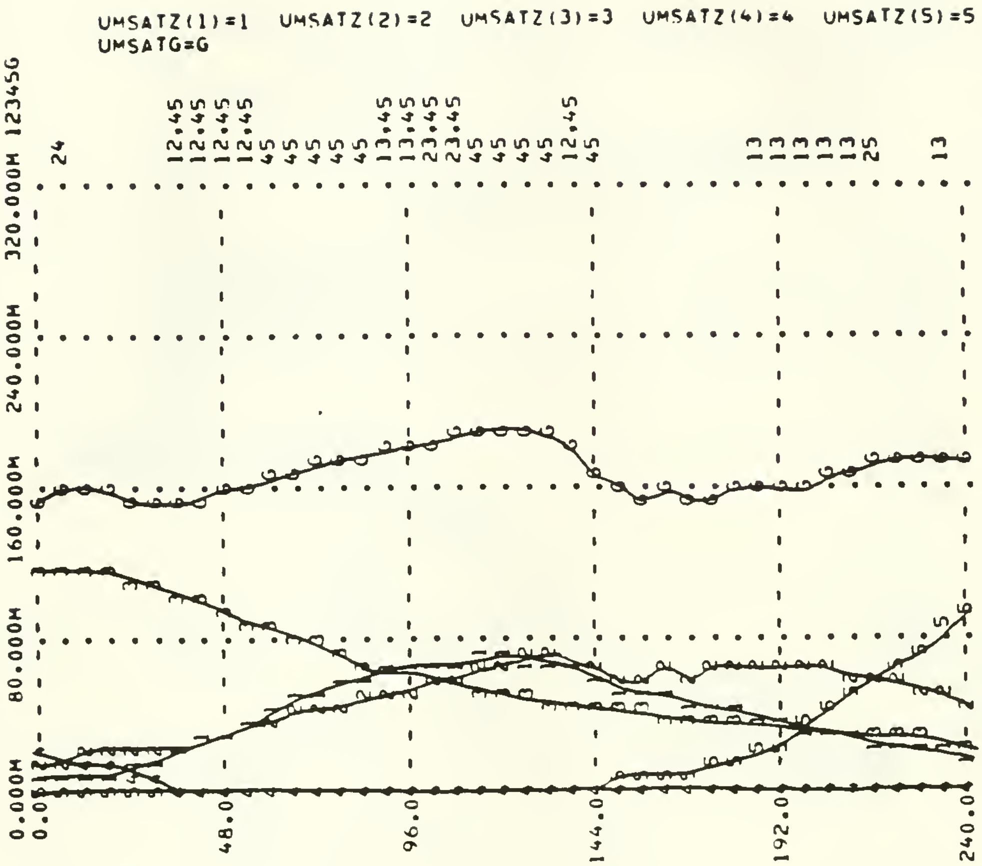


Figure 10: The Development of the Turnover of the Conglomerate in the Case of Portfolio Atypical Reactions of Competitors.

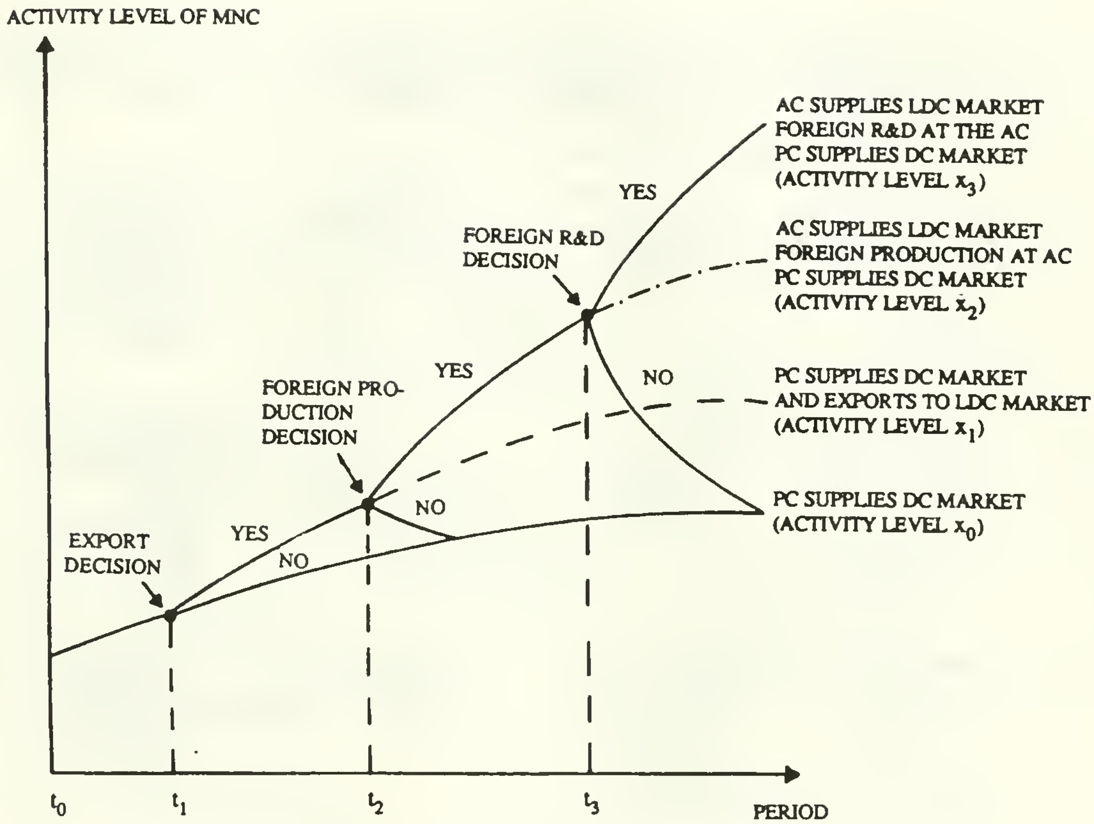


Figure 11: The Evolution of Multinational Corporations in Less Developed Countries.

TRANSFER OBJECT / TRANSFER PHASE	TECHNICAL- AND TECHNOLOGICAL KNOW-HOW	MANAGEMENT KNOW-HOW	CAPITAL
EXPORT PHASE - INDIRECT EXPORT - DIRECT EXPORT	SERVICE- AND PRODUCT TECHNIQUE TRANSFER	MARKETING MANAGEMENT KNOW-HOW TRANSFER	CAPITAL TRANSFER TO A SMALL EXTENT FOR BUILDING UP A SERVICE- AND DISTRIBUTION SYSTEM
	USE-HOW TRANSFER		
FOREIGN PRODUCTION PHASE - ASSEMBLING - FULL PRODUCTION	PRODUCT- AND PROCESS TECHNIQUE TRANSFER	PRODUCTION- AND ORGANIZATION MANAGEMENT KNOW-HOW TRANSFER	CAPITAL TRANSFER TO FINANCE ASSETS LOCAL FINANCING OF WORKING CAPITAL
	MAKE-HOW TRANSFER		
FOREIGN R&D PHASE - APPLIED R&D - BASIC R&D	TECHNOLOGY AND TECHNICAL KNOW-HOW TRANSFER TO DEVELOP PRODUCTS AND PROCESSES	R&D MANAGEMENT KNOW-HOW TRANSFER	NEARLY NO CAPITAL TRANSFER BECAUSE OF LOCAL SELF-FINANCING OF AC
	THINK-HOW TRANSFER		

Figure 12: The Process of Know-how Transfer in the Course of the MNCs Evolution in LDCs.

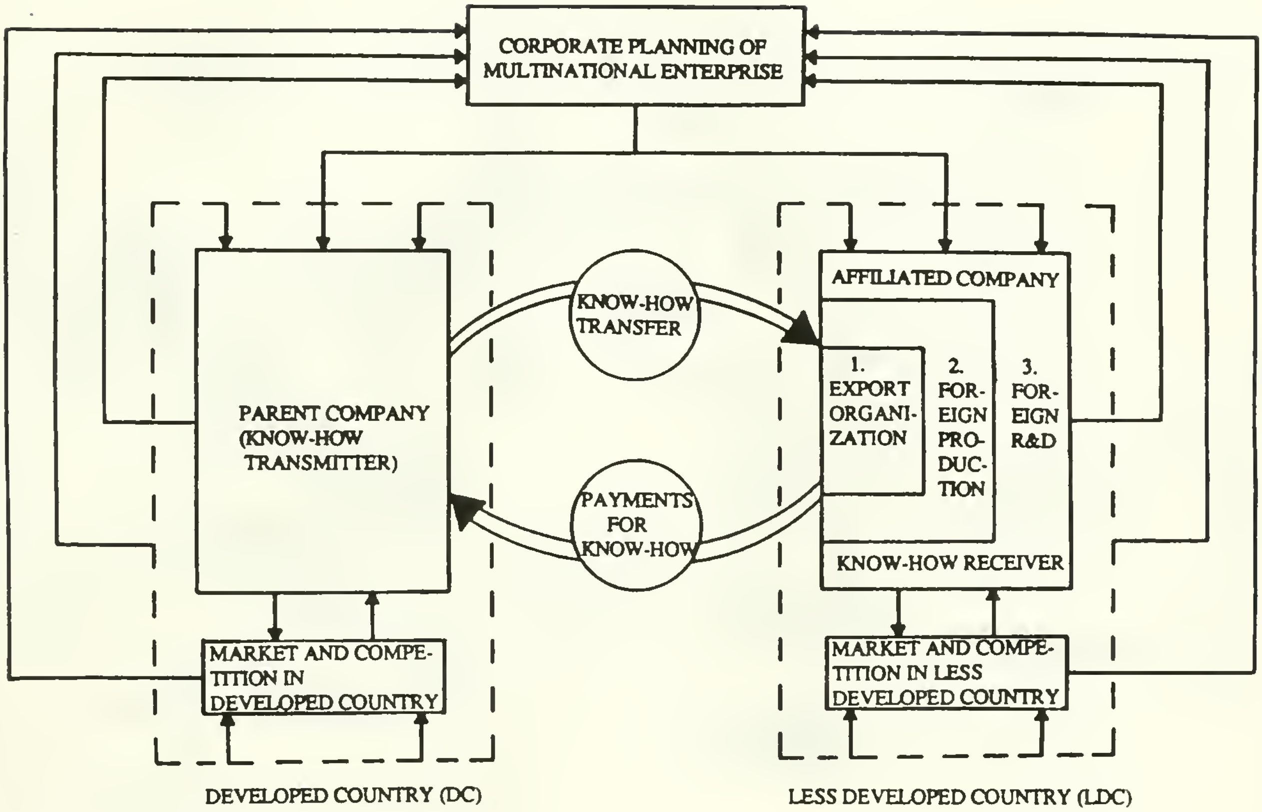


Figure 13: The Generic Structure of the Know-how Transfer Model.

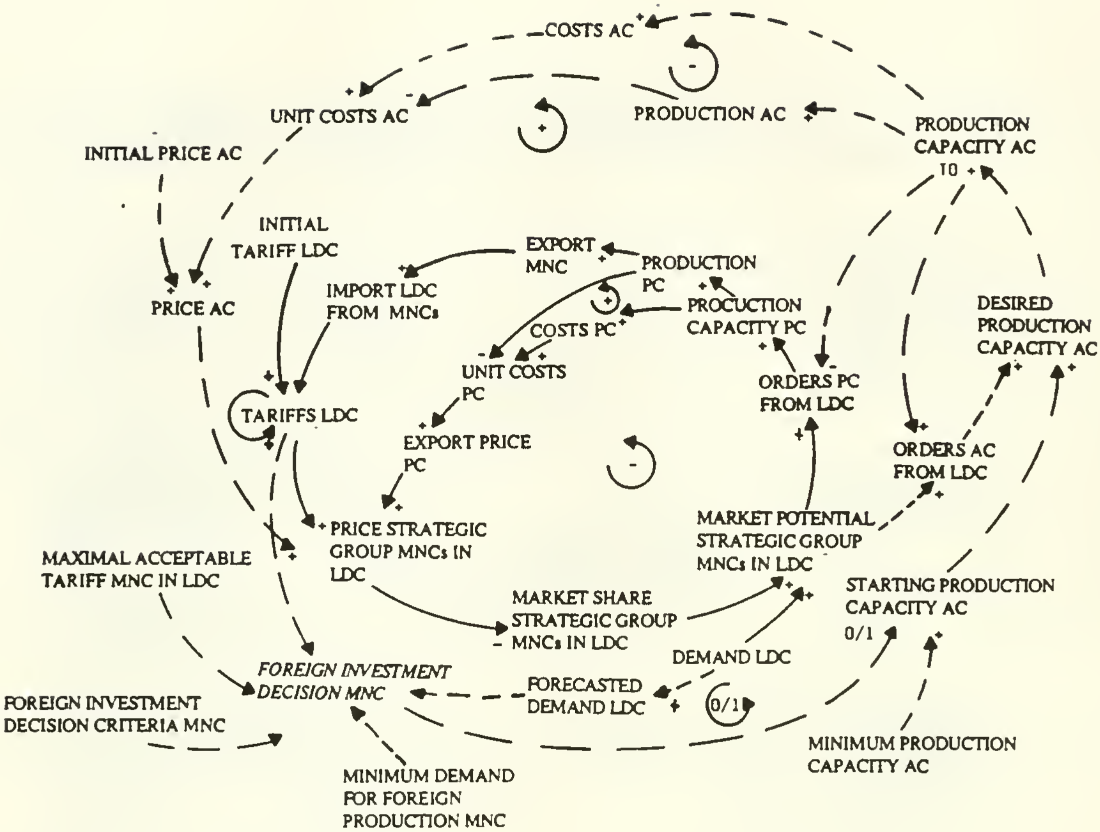


Figure 14: The Foreign Production Spiral Loop of the MNC.

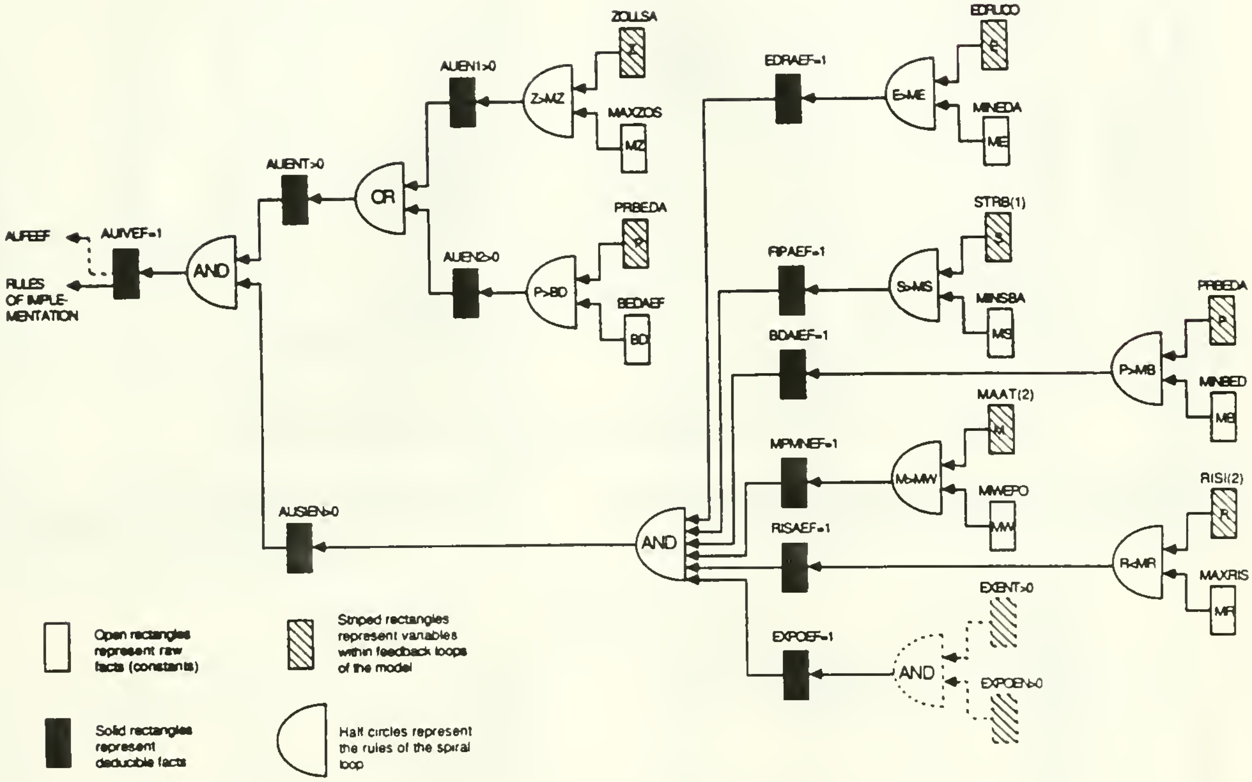


Figure 15: The Foreign Production Decision Tree.

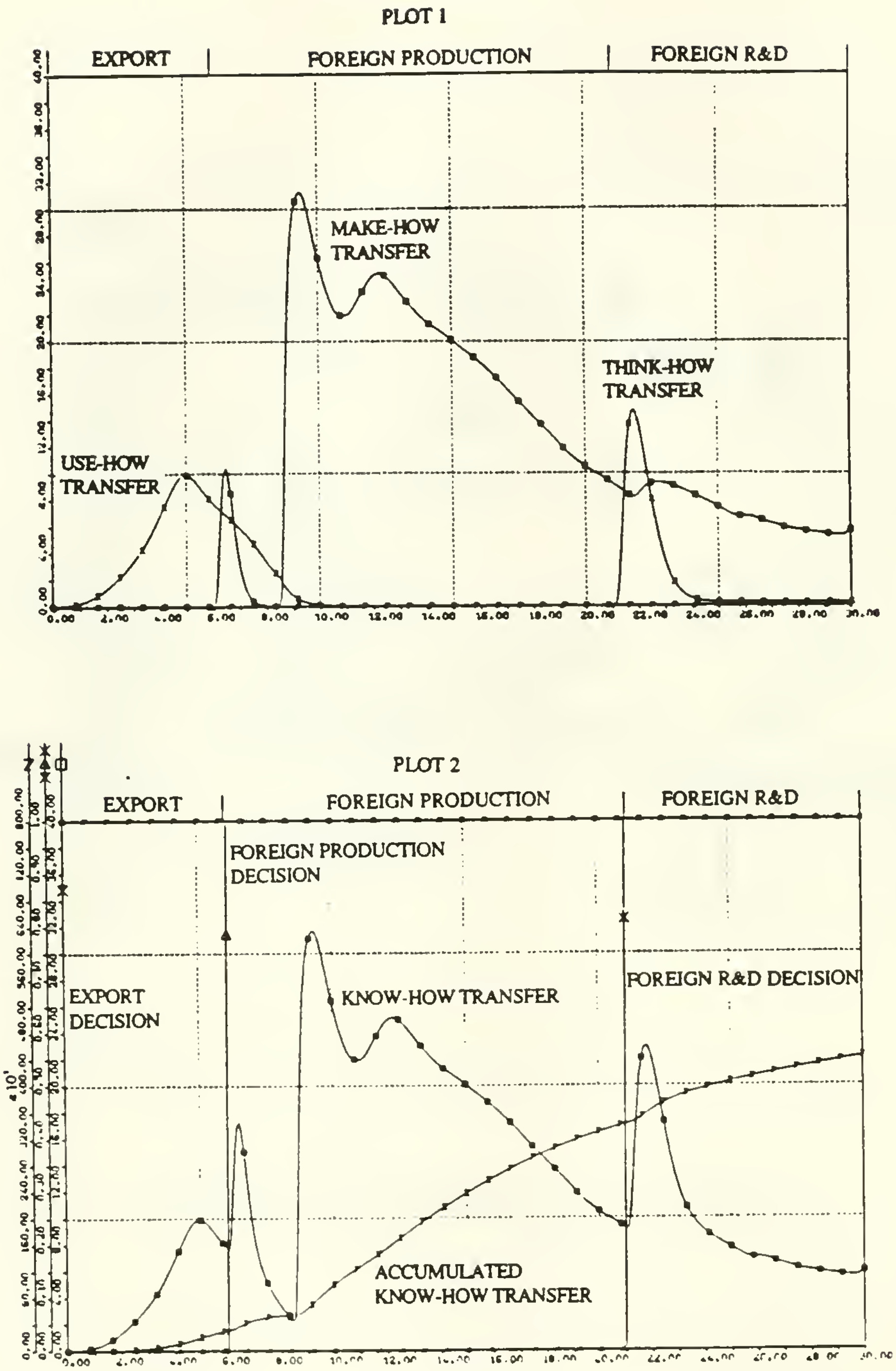


Figure 16: The Know-how Transfer Process to the Philippines (Basic Run Results)

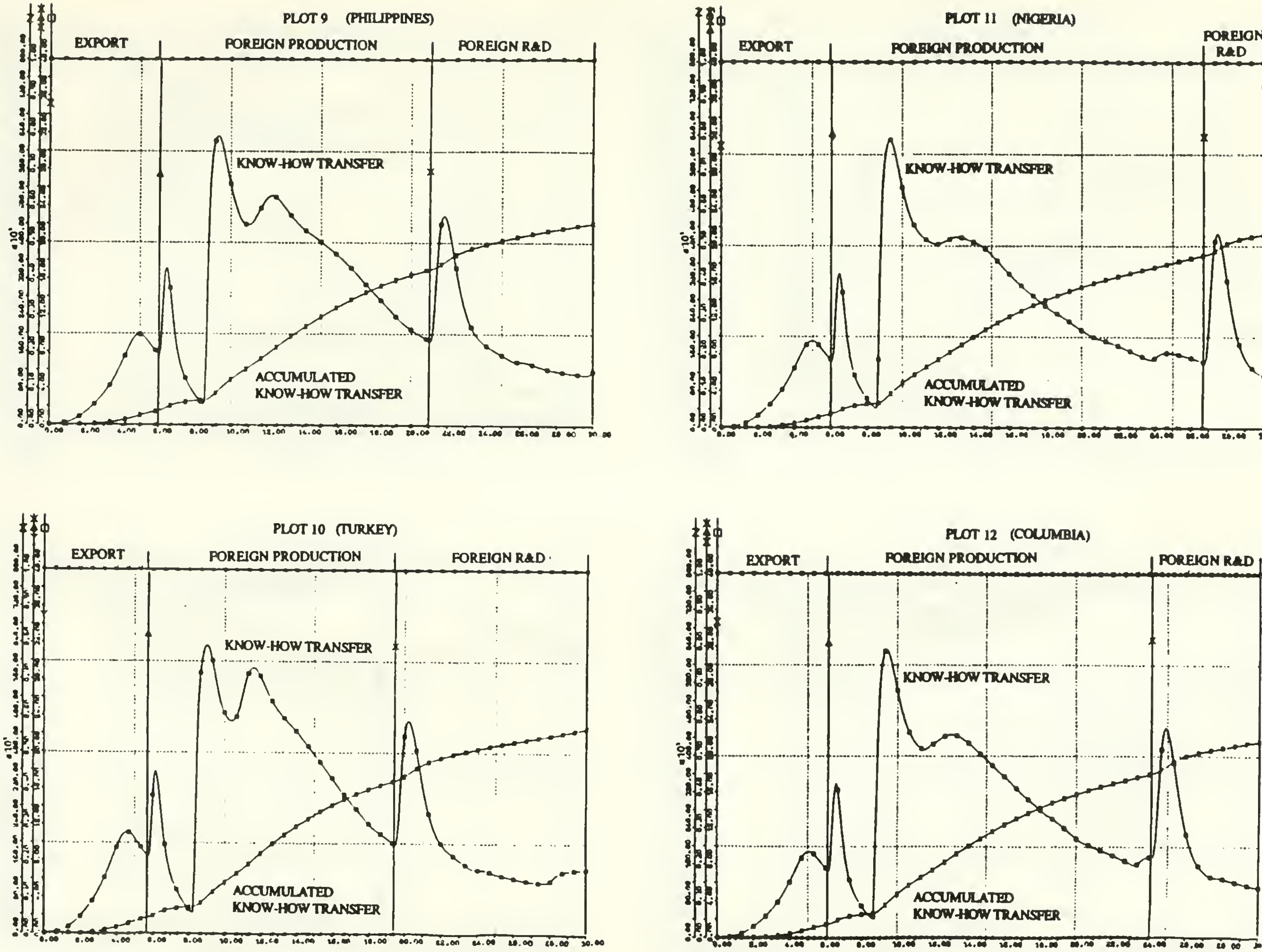


Figure 17: Simulation Results of the Country Tests (Philippines, Turkey, Nigeria, Columbia).

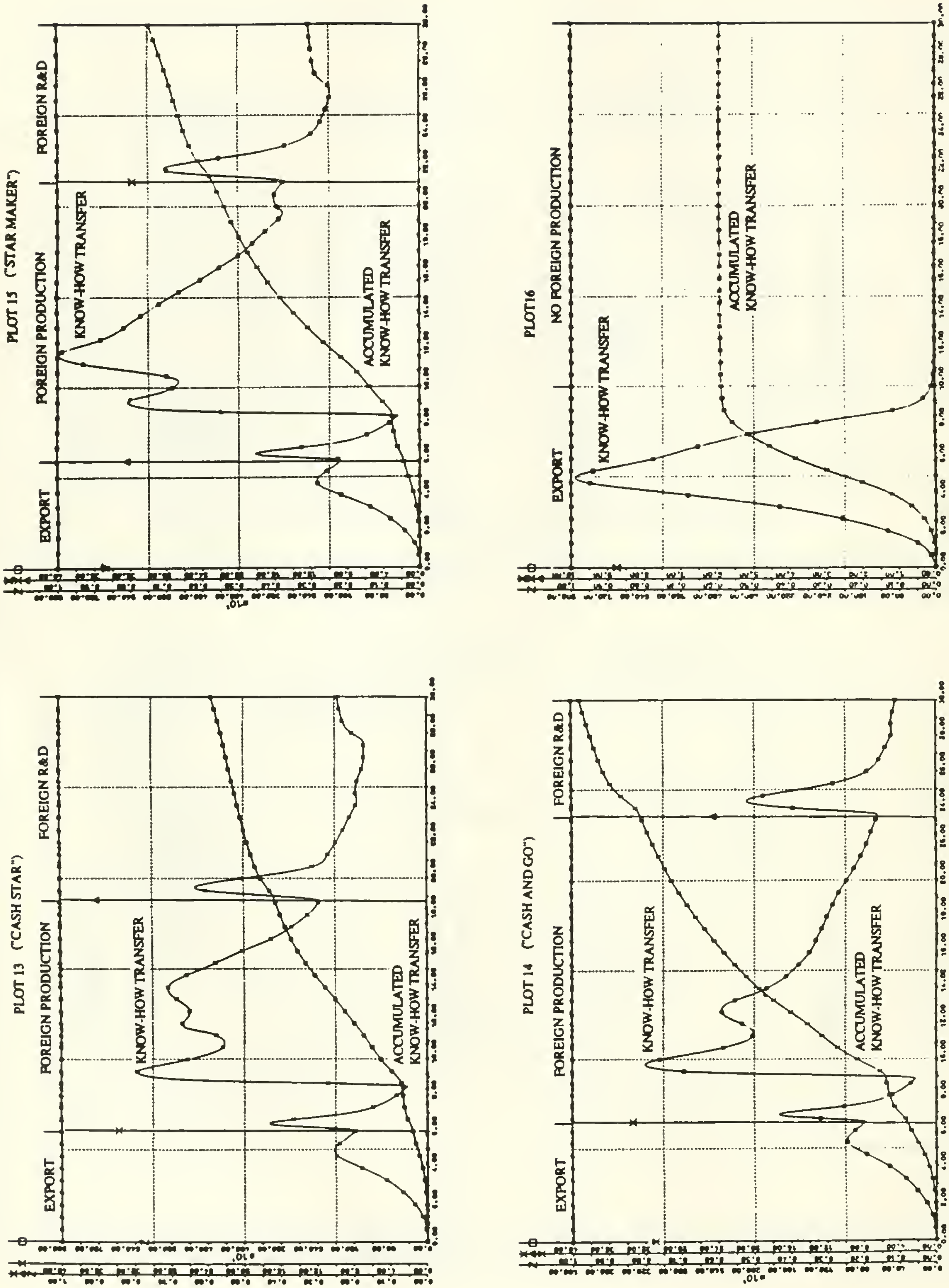


Figure 18: Simulation Results of the MNC Strategy Tests.

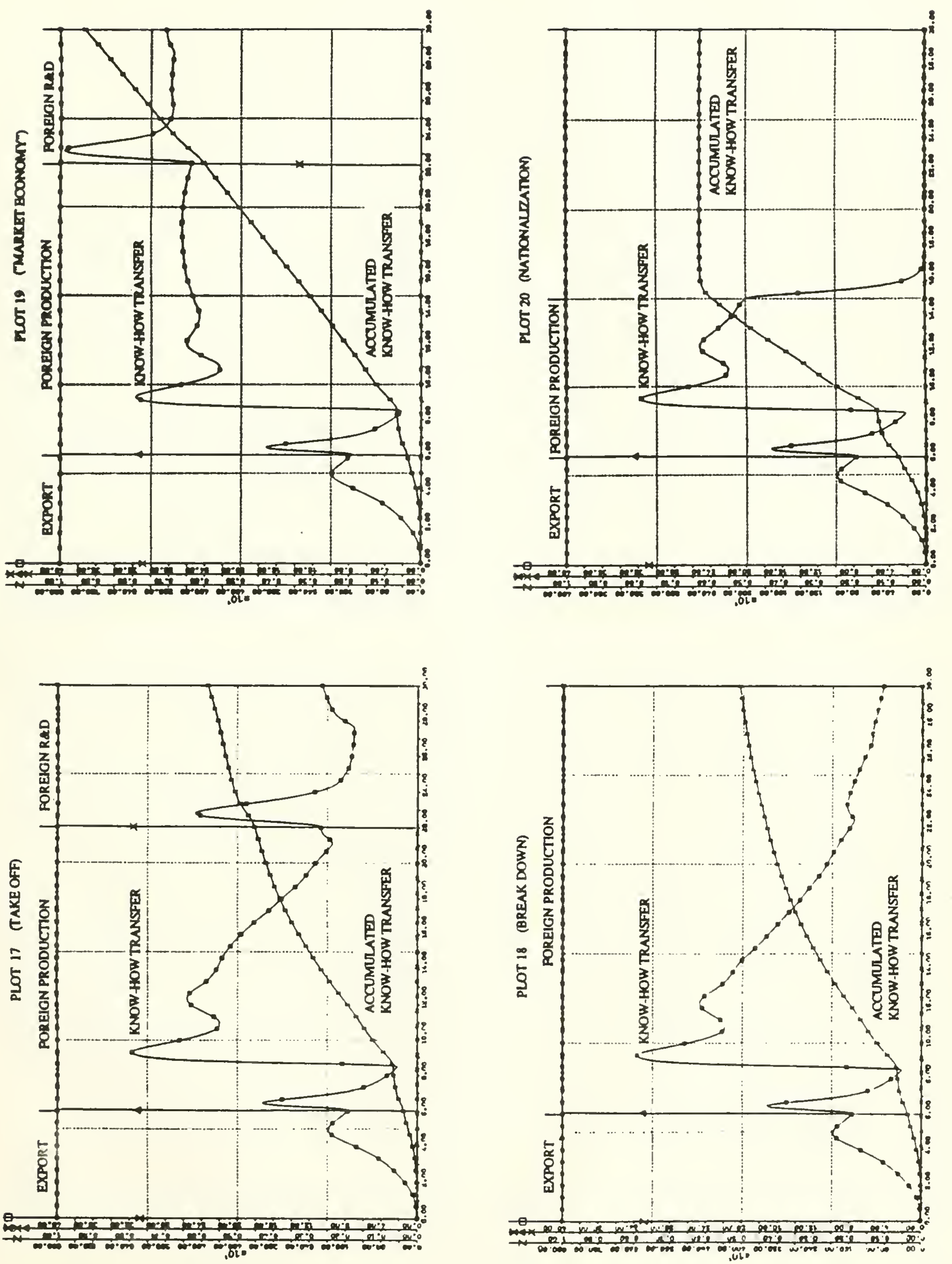


Figure 19: Simulation Results of LDC Scenario and Strategy Tests.