# Microsimulation - A Survey of Methods and Applications for Analyzing Economic and Social Policy

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Forschungsinstitut Freie Berufe (FFB)

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**Summary**

This essential dimensions of microsimulation as an instrument to analyze and forecast the individual impacts of alternative economic and social policy measures are surveyed in this study. The basic principles of microsimulation, which is a tool for practical policy advising as well as for research and teaching, are pointed out and the static and dynamic (cross-section and life-cycle) approaches are compared to one another. Present and past developments of microsimulation models and their areas of application are reviewed, focusing on the US, Europe and Australia. Based on general requirements and components of microsimulation models a microsimulation model's actual working mechanism are discussed by a concrete example: the concept and realization of MICSIM, a PC microsimulation model based on a relational database system, an offspring of the Sfb 3 Statitic Microsimulation Model. Common issues of microsimulation modeling are regarded: micro/macro link, behavioural response and the important question of evaluating microsimulation results. The concluding remarks accentuate the increasing use of microcomputers for microsimulation models also for teaching purposes.

**JEL:** C80, C81, D10, D30, D31, J20
*Keywords: Microsimulation, Microanalytic Simulation Models, Microanalysis, Economic and Social Policy Analysis*

**Zusammenfassung**

Die essentiellen Dimensionen der Mikrosimulation als ein Instrument zur Analyse und Prognose individueller Wirkungen ökonomischer und sozialpolitischer Politikalternativen werden in dieser Studie übersichtsweise behandelt. Die Prinzipien der Mikrosimulation, die ein Werkzeug der praktischen Politikberatung als auch der Forschung und Lehre ist, werden herausgearbeitet und statische und dynamische (Querschnitts- und Lebenszyklus-) Ansätze miteinander verglichen. Heutige und vergangene Entwicklungen von Mikrosimulationsmodellen und ihre Anwendungsbereiche werden mit Schwerpunkt auf die Vereinigten Staaten, Europa und Australien beschrieben. Auf der Basis genereller Anforderungen und Komponenten von Mikrosimulationsmodellen werden die Mechanismen von Mikrosimulationsmodellen an einem konkreten Beispiel diskutiert: dem Konzept und der Realisation von MICSIM, einem PC Mikrosimulationsmodell auf der Basis eines relationalen Datenbanksystems, eine Weiterentwicklung des Statischen Sfb 3 Mikrosimulationsmodells. Gemeinsame Merkmale der Modellierung von Mikrosimulationsmodellen werden betrachtet: Mikro/Makro-Verknüpfung, Verhaltensreaktionen und die wichtige Frage der Bewertung von Mikrosimulationsergebnissen. Die abschließenden Bemerkungen akzentuieren die zunehmende Verwendung von Mikrosimulationsmodellen auch in der Lehre.

**JEL:** C80, C81, D10, D30, D31, J20

*Schlagworte: Mikrosimulation, Mikroanalytische Simulationsmodelle, Mikroanalyse, Wirtschafts- und sozialpolitische Politikanalyse*

**Microsimulation -**
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# MICROSIMULATION -
# A SURVEY OF METHODS AND APPLICATIONS
# FOR ANALYZING ECONOMIC AND SOCIAL POLICY

**Joachim Merz**

## 1 INTRODUCTION

Simulation models and in particular microsimulation models (MSMs) have been increasingly applied in recent years in quantitative analyses of economic and social policy problems. MSMs analyze the effects of alternative policies on the individual level when new econonmic and social policies are planned or investigated. Because MSMs are concerned with the behaviour of microunits (such as persons within a family/household/firm, tax units or as decision-units in firms or communities), preferably based on a representative sample, they are especially well-suited to analyze the distributional impacts of policy measures of those who are affected by.

Microsimulation (microanalytic simulation) models were increasingly developed and applied in the 60s, 70s and early 80s since Orcutt's (1957) seminal work. Because of financial cutbacks in the midth and end of the 80s, above all in the US Reagan administration, microsimulation based policy advices have to be reduced. In those years researchers focused more on further (micro)econometric analyses and foundation of individual behaviour. Nowadays, and since the beginning of the 90s, a refreshment of microsimulation developments and applications in Europe and other countries worldwide can be observed.

Microsimulation is considered as a forecasting instrument because policy effects can be forecasted by a MSM. When forecasting the direct and side effects of a policy, a baseline simulation is needed to predict the 'no policy' situation. Usually the baseline simulation tries to forecast a 'status quo' development, though it is a matter of interest and definition as to what will, in fact, be the baseline. With alternative scenarios a comparisons of their impacts then show the policy main and side effects. Forecasting the effects of policies on individual behaviour by microsimulation is always conditional forecasting. In the usual ex ante case, forecasts are computed on the basis of distinct conditions described by a certain scenario. Thus, ex ante forecasting is a conditional look into future developments. In the rare ex post case, a given (historic) real world situation is confronted with alternative former interventions. Again, the 'as if' situation tries to identify policy effects that may result from stated conditions.

This paper surveys the essential dimensions of microsimulation models. Section 2 describes principles of microsimulation and outlines their general aims and characteristics. The basic concept of the static approach is compared to dynamic microsimulation approaches with its cross-section and life-cycle models. Section 3 deals with developments and applications of dynamic and static MSMs in the US, Europe, and Australia. Based on general requirements and components of a MSM in Section 4, Section 5 illustrates a MSM's actual working mechanism by a concrete example: the concept and realization of MICSIM, a PC microsimulation model based on a relational database system, which as an offspring of the Sfb 3 Statitic MSM is now further developed at my chair at Lüneburg University. Section 6 deals with common issues of microsimulation modeling: micro/macro link, behavioural response and the important question of evaluating microsimulation results. The concluding remarks accentuate the increasing use of microcomputers for MSMs and the use of MSMs also for teaching purposes.

# 2 PRINCIPLES OF MICROSIMULATION

## 2.1 SIMULATION

It is often the task to analyze the behavioural pattern of an existing or imaginary system. However, many systems are complicated and difficult to examine (if at all) in their real environment. Therefore, a substitute is examined in lieu of the system originally in question. Simulation, then, is the process of imitating the behaviour of system patterns by a model. Simulation as one method of problem-solving becomes attractive when conventional analytic, numeric or physical experimental methods would be too time-consuming, expensive, difficult, hazardous and/or irreversible or even impossible as real world experiments. Since economic and social real world systems in particular are hardly available as an experimental centerfield [as an exception, however, see the New Jersey Income Maintenance real life social experiment in the USA (Rees 1977)], simulation via an appropriate model is a natural candidate to analyze complex system patterns.

Simulation-supported analyses can be useful both in creating theories as well as in examining effects of policy options. Simulations help to create new theories by stimulating the formulation of behavioural hypotheses for the model's purpose. Analyses of the impacts of policy options can be executed if behavioural hypotheses and institutional relationships have been satisfactorily established in a simulation model. The impact analysis follows a certain pattern and aim of investigation. Thus simulation might be defined as a goal-oriented experiment where a model imitates the system of interest.

The structure of a simulation model is mainly determined by relations expressed in mathematically logical relations. There are algebraic equations and decision structures that can be characterized as complex 'if-then' relations in a computer model. If a problem in such a setting is not analytically solvable or is solvable only under circumstances involving extensive effort, a solution is sought by computational experimentation. At times, however, simulated solutions forfeit a global optimal solution.

In deterministic simulations all structural and procedural data are fully determined. In a stochastic simulation some or all of the deterministic relationships are disturbed by random influences. Thus one purpose of stochastic simulation is to account for random influences that might be based on an incomplete model specification or on the randomness of the underlying system of interest.

Simulations are usually conducted on a computer in order to cope better with the complexity of calculations required and often large data bases. Special simulation programming languages, such as GPSS, DYNAMO, CSL, SIMSCRIPT or SIMULA, are becoming popular among users for some years ago. A recent catalogue of micro-, mini- and mainframe simulation software can be found in SCS (1985) or in the software review of the International Journal of Forecasting (1993).

Simulation models support decision-making processes and are being increasingly used in business administration, education and scientific research [Sawaragi, Inone, and Nakayama (1987)]. A firm, for example, may seek a cost-optimal storage policy under different market conditions by simulating various scenarios of ordering and sales policies. Investment decisions under different business cycle scenarios in firm simulations and experimental gaming within experimental economics in such areas as municipal administration or regional planning provide support for instruction and training in private and public enterprises. Flight simulation is now a standard training instrument in aviation (and gaming). In scientific research as well as in the practice of administrative planning, the impacts of alternative measures of tax and transfer policies are analyzed by simulation. In teaching, students may learn about the interdependencies of a national economy or a single enterprise by a computer simulation model. For simulation applications in management sciences, see Koller (1976) and Pidd (1988). Computer simulations in the social sciences are the subject of Harbordt (1974a,b), Norlen (1975), Krupp (1969, 1976), and Orcutt, Merz and Quinke (1986). For a more in-depth description of simulation in general, refer to Gordon (1978), Holst (1979), Bratley, Fox and Schrage (1983), and Neelamkavil (1987).

Computer games, such as Black Jack and other Monte Carlo games, are used to teach simulation techniques on a microcomputer [Macaluso (1983)]. Simulation and gaming is the focus of interest in Crookall, Greenblatt, Coote, Klabbers and Watson (1987). Virtual reality is another new computer aided simulation branch. Schoemaker (1978) analyzes computer networks by the simulation approach. Modeling and simulation of systems themselves with the aid of computers is the specific subject of Neelamkavil (1987).

Finally, the growing field of artificial intelligence is linked to the simulation approach: the knowledge of an expert system and its specific problem-solving strategies is a matter for simulation analyses [Waterman (1986), Gale (1986), and Elzas, Ören, and Zeigler (1986)].

## 2.2 MICROSIMULATION - GENERAL AIMS AND CHARACTERISTICS

Simulation can be based on macro, meso (group, cell), and microinformation. Macroeconomic aggregates of a nation wide economy, like consumption, savings, overall social security expenses etc. form the basis for macroeconomic models underlying macrosimulation experiments. Recent surveys of econometric macromodels are Langer, Martiensen and Quinke (1984) for Germany, Ichimura and Ezaki (1985) for Asia, and Pindyck and Rubinfeld (1986, Chapt. 14) for the US. The meso level takes some societal groups gathered in 'cells' as the unit of interest (e.g. population aggregated in different age and/or other socioeconomic groupings). Group simulation then is changing the respective cell numbers by adequate transition matrices (like in the Grohmann, Hain and Kiel (1981) Frankfurt Group Simulation Model).

In contrast to the macro and meso type simulation models, MSMs are directly concerned with the individual units: microunits, i.e., persons, families, households, tax units, decision units in firms, firms itselves, unions etc. in their respective associations. These microunits are identified by characteristics such as age of an individual, number of children in a family, income and transfers of a household and/or a respective tax unit, employment structure of a firm, etc. These characteristics are then modified in the MSM depending on their individual behaviour and the institutional relationships in which they operate. The individual impacts of economic and social policies on the microunits concerned can thus be directly analyzed with focus on distributional effects. In addition, the microunits' characteristics before/after simulation may be aggregated ad libidum according to need. Aggregates from a MSM may serve as interacting variables in linked micro-macro simulation strategies (see Section 6)].

Early foundations and applications of microanalytic models are given in Orcutt (1957) and Orcutt, Greenberger, Korbel and Rivlin (1961), who developed and established the microsimulation concept. Summaries and applications are refered in Krupp and Wagner

(1982) and Orcutt, Caldwell, and Wertheimer II (1976, Chapt. 1). Greenberger, Crenson, and Crissey (1976, Chapt. 4) compare the strategy of microanalytic modeling with other quantitative methods and models employed for policy analyses. Further developments in the late 70s are demonstrated by Bergmann, Eliasson, and Orcutt (1980) in their Swedish conference volume, and also in the two-volumes by Haveman and Hollenbeck (1980a,b). The volume 'Microanalytic Simulation Models to Support Social and Financial Policy' [Orcutt, Merz, and Quinke (1986)] depicts and discusses more current developments in the US and Europe. In that volume Orcutt (1986), Krupp (1986), Hoschka (1986) and Caldwell (1986) also discuss general aspects of the microsimulation approach. Lewis and Michel (1990) focus on microsimulation techniques for tax and transfer analysis. Merz (1991) provides a recent general survey of microsimulation principles, developments and applications. Spahn, Galler, Kaiser, Kassella and Merz (1992) deal with microsimulation in tax policy in general and for Germany in particular. A recent more general book about the politics of modeling in federal policymaking is Kraemer, Dickhoven, Tierney and King (1987).

The mentioned refreshment of microsimulation modeling and application in Europe, the US and Canada, and recently in Australia is observable from a series of actual international microsimulation conferences and volumes, like the international conference on 'Prospects and Limits of Simulation Models in Tax and Transfer Policy' in Germany (Brunner and Petersen 1990), the OECD panel on microsimulation 1990 in Paris, France (OECD 1990), the 'Survey of Microsimulation Models' by Mot (1991) with emphasis on Dutch MSMs, the STICERD/-LSE workshop on developments in MSMs in London, UK (Hancock and Sutherland 1992), the European Society of Population Economics ESPE Gmunden sessions on microsimulation 1992, Austria, the US 1992 microsimulation conference for policy analysts and model builders November 1992 in Washington D.C. [Society of Government Economists (1992)], the 49th Session of the International Statistical Institute in Firence, Italy, with its session on microsimulation and evaluation of economic and social programmes [Merz (1993a)], the 1990 workshop on 'Tax-Benefit Models and Microsimulation Methods' at the University of New South Wales, Australia [Bradbury (1990)], and the December 1993 special IARIW conference on 'Microsimulation and Public Policy' of the Australian Statistical Office and the University of Canberra in Canberra, Australia. Last, but not least in our brief overview of survey volumes/conferences: The US National Research Council recently investigated and evaluated the uses of MSMs for social welfare programs to improve information for social policy decisions (Citro and Hanushek 1991a,b). This investigation is also of further interest for our evaluation discussion in Section 6.

## 2.3 STATIC VERSUS DYNAMIC MICROSIMULATION

Microsimulation models may be divided into two main types of models: static and dynamic with dynamic cross-section and life-cycle (longitudinal, cohort) MSMs. The general ideas and principles of these typical models will be discussed in the paragraphs to follow.

### 2.3.1 STATIC MICROSIMULATION

Systematic variation of regulations on the basis of typical cases is the starting point of static microsimulation. Analyses of changes in a conditional structure with such 'calculators' have been made in many fields of administration, business and science for many years. Until recently, for example, alternative tax regulations are still simulated based on typical cases chosen by tax administrators.

In static microsimulation, certain behavioural relations and institutional conditions of a microdata base of a certain time period are systematically varied. The microdata base usually is comprised of cross-section information, i.e. microunit information gathered at a certain point in time, preferably as a representative sample. An example of such a cross-section data base is the German 'Income and Consumption Survey' (Einkommens- und Verbrauchsstichprobe) that accounts for microdata from approximately 50,000 households. A systematic variation of tax law characteristics and the analysis of corresponding effects on income distribution would be a typical setting for a static microsimulation based upon cross-section data.

Static microsimulation naturally is connected with the time period of the cross-section data. Temporal extrapolation to actualize the data or to forecast the sample into the future, called aging of the sample, however, is available in more recent static MSMs. In such a 'static aging' procedure the sample data of a cross-section are usually adjusted by re-weighting the microunits' characteristics to future aggregate data (though they might be adjusted in principle to past margins, too). A detailed discussion of structural adjustments in static and dynamic MSMs and a survey of adjustment in major MSMs is given in Merz (1986a) and Merz (1994c) with an adjustment of microdata by the minimum information loss principle. An optimal adjustment by a Kalman filter procedure and the optimal control methodology is proposed in Merz (1983b).

In static aging, the structure of the sample itself, including for example age and number of microunits, is not modified. The temporal adjustment of the demographic structure is reached exclusively by re-weighting the available information due to exogeneous given aggregate (control) data of another time period.[1] After re-weighting a sample, one microunit will then represent a certain number (given by the new weights) of respective units in the whole

1 Impacts on other non-adjusted variables must also be considered in this process. An adjustment of unemployment figures, for example, must lead to an adjustment in occupational figures.

population. Within static aging, the relations among the variables (i.e., the structure) of each microunit are generally maintained. An overall structural change is expressed by a changed weight of each microunit, respectively, of each association of microunits (e.g., families, households). Thus, the cross-section after simulation (t + v, v=0,1,2,...) contains the same number of microunits (n) as the cross-section before simulation (t) (Exhibit 1).

A static aging procedure is relatively well-suited for short- and medium-range forecasts, provided it can be assumed that the characteristics of the population under examination do not change rapidly. If the demographic structure essentially changes, which is particulary likely in the longer run, the use of 'dynamic aging' in the framework of dynamic microsimulation will be more appropriate.

### 2.3.2 DYNAMIC MICROSIMULATION

In principle, the main difference between a dynamic MSM and a static one is the aging procedure. Whereas in static MSMs aging is done by re-weighting, in a dynamic MSM each microunit is aged individually by an empirically based survival probability.

***Dynamic Cross-Section Microsimulation***

In dynamic cross-section microsimulation individually based aging by survival probabilities is applied for each microunit of an entire (representative) sample. In addition to a microunit's survival, a child (or children) could be born within a simulation period or a family and household situation might be changed by marriage, divorce or other occurrences. Thus, individual dynamic demographic aging will alter the size of the

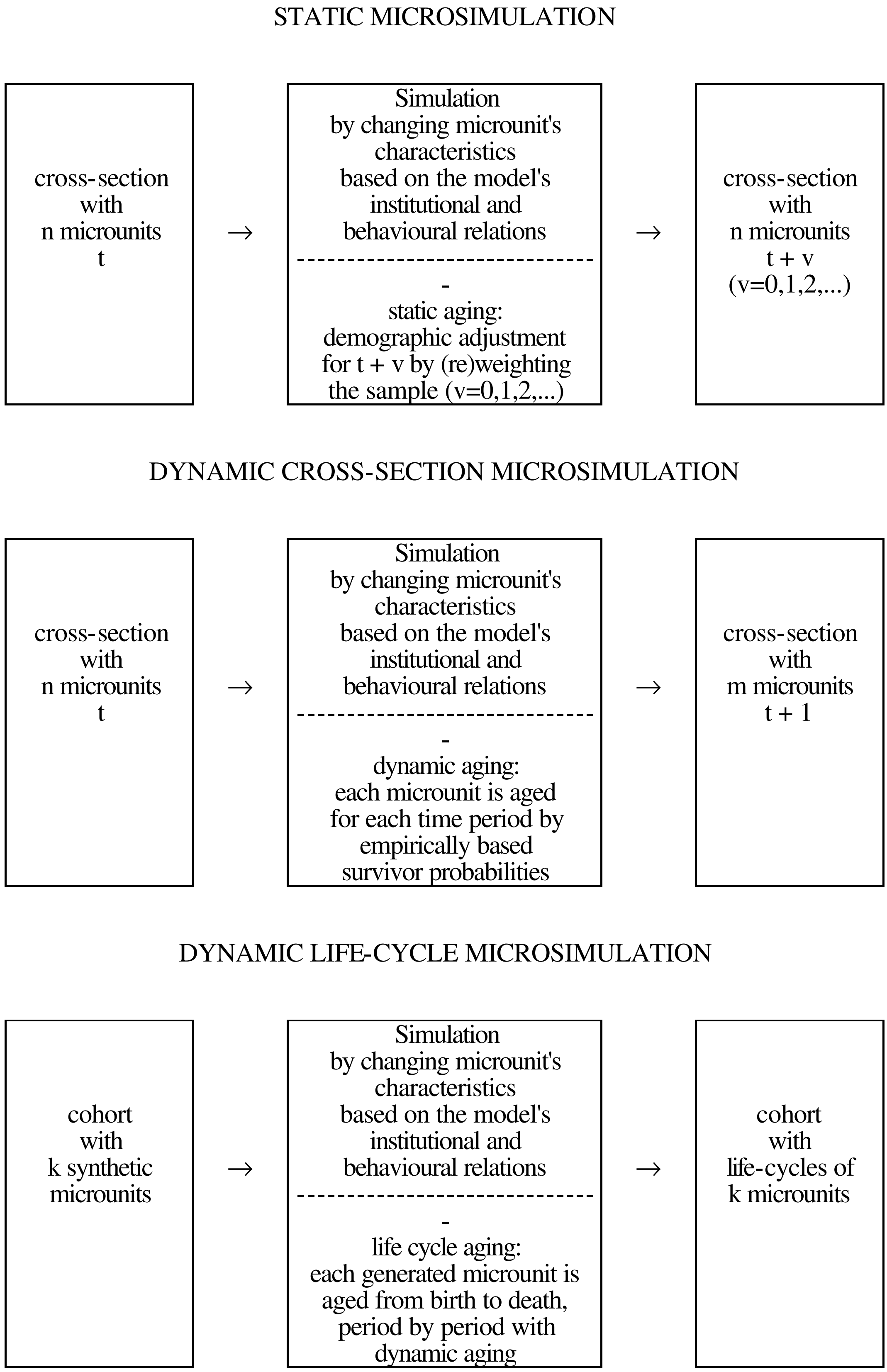


**Exhibit 1: Static, and dynamic cross-section and life-cycle microsimulation**

cross-section under investigation; in general, the cross-section after simulation (t+1) does not contain the same number of microunits (n and associations thereof) as the cross-section before simulation (t) (Exhibit 1).

Because dynamic microsimulation directly affects demographic characteristics of microunits, side effects on the behaviour of further microunits may be directly accounted for; e.g., if a child is born, this might immediately affect the mother's labour force participation in a simulation period. Those demographic (side) effects are captured in the static case only in a final reweighting of another respective family type.

***Dynamic Life-Cycle Microsimulation***

Whereas the dynamic (cross-section) microsimulation is individually forecasting all microunits of a given sample, dynamic life-cycle or longitudinal microsimulation creates a cohort of 'synthetic' microunits with complete life cycles from birth-to-death. Thus, a dynamic life-cycle MSM does not forecast the characteristics of real sample units but the assigned characteristics of synthetic microunits. All characteristics of a synthetic microunit are determined by the behavioural and institutional modules of the MSM.

A complete life-cycle of a synthetic microunit is simulated period-by-period and may include information on spouse and children if the microunit has married and brought up children during its lifetime. A number of simulated life-cycles then constitute a sample of a certain cohort.

The overall advantage of this type of microsimulation is the availability of information on the complete individual life-cycle of each 'sample' member. This is of interest for life-cycle analyses of earning patterns with both income from former gainful employment and, later, income from pension security systems. In contrast to the life-cycle model, the cross-section model will produce also many microunits with an incomplete life-cycle; some microunits are still living or have died in an earlier simulation period. Thus, the number of microunits involved in the life-cycle MSM is reduced to those microunits of real full life-cycle interest. Correspondingly, the expenses are only a fraction of a comparable full cross-section simulation. Within the MSMs of the Sonderforschungsbereich 3 (Sfb 3, Special Collaborative Program 3) 'Mikroanalytische Grundlagen der Gesellschaftspolitik (Microanalytic Foundations of Social Policy)' at the Universities of Frankfurt and Mannheim, the life-cycle simulation uses the same substantive modules as the dynamic cross-section MSM. Exhibit 1 outlines the procedures of the dynamic cross-section, dynamic life-cycle, and static microsimulation approaches.

## 2.4 RELATIONS BETWEEN STATIC AND DYNAMIC MICROSIMULATION MODELS

As mentioned, dynamic MSMs include institutional and behavioural relationships and, in particular, demographic relations. A static MSM may also include behavioural relationships. This is the case when the microunits of a cross-section are processed through certain modules that generate further characteristics of the corresponding unit. As an example, imagine a sample that does not contain any information about labour force participation, hours of work, or changes therein for the simulated year. An appropriate module could then determine individual labour force participation data from estimated hypotheses that were based upon socioeconomic characteristics. Thus, with respect to behavioural relationships, there is no divergence in general between static and dynamic simulation according to socioeconomic behaviour. However, and as discussed, there are differences according to changes in demographic behaviour.

A static simulation model may be connected to a dynamic model in another way; systematic parameter variations within a static model may be based on forecasted cross-sections produced by a dynamic MSM. In addition, a demographic structure forecasted by a dynamic MSM may serve as future aggregate data for re-weighting initial sample weights in a static model. In general, this will reduce computing expenses since dynamic microsimulation of new alternatives for all periods between the sample and the future period of interest can be eliminated.

The primary advantage of static versus dynamic MSMs is that static models are less expensive. Even if substantial modules (such as education, labour force, income, and expenditure modules) are integrated into a static simulator in the same way as into a dynamic model, the static approach is less expensive because time-consuming simulation of demographic processes with interactions among members of different microunit associations (like marriages) - more general: market processes - are omitted. In addition, the complex demographic aging relations do not need to be estimated when developing a MSM. As a consequence only relatively few dynamic MSMs (described in the following paragraph) have been developed and employed worldwide for economic and social policy analyses.

# 3 DEVELOPMENTS AND APPLICATIONS OF MICROSIMULATION MODELS

In the following paragraphs a characterization of main developments and applications of dynamic and static MSMs in economic and social policy analyses is tried. Because of the increased number of developed MSMs worldwide I apologize to all those modelers and models which are not captured in this survey.

## 3.1 DYNAMIC MICROSIMULATION MODELS

In the United States examples of major dynamic MSMs are the 'DYNAmic Simulation of Income Model' (DYNASIM) [Orcutt, Caldwell, and Wertheimer II (1976)] and its updated version, DYNASIM II. The latter is applied, for example, in linked micro-macro simulation with the ICF macromodel [Wertheimer II, Zedlewski, Anderson and Moore (1986)]. DYNASIM's predecessor is MASH [Sadowsky (1976)]; its offsprings are MICROSIM or MASS. MICROSIM was developed at Cornell University (Caldwell and colleagues) and the Policy Research Group, Inc., Washington D.C. MASS was developed at Yale University [Orcutt, Glazer, Jamarillo and Nelson (1976)]. Further versions of MASS are used to analyze wealth accumulation and distribution [Orcutt and Smith (1979)] as well as in the Retirement Security Simulation Study (RSSS) conducted by the Institute for Social Research (ISR) at the University of Michigan [Juster (1982)]. The RSSS simulation project incorporates a micro-macro linkage between MASS and the macro model MALTHUS. Linked micro-macro simulation models are rarely used , e.g. to forecast regional energy demand in the US [Caldwell, Greene, Mount, Saltzman and Broyd (1979)] and for investigating the income distribution effects of fiscal policies in the FRG [Merz (1978)]. Caldwell (1993) describes validation and uses of Cornell University's CORSIM 2.0 follow up version of the above mentioned MICROSIM, a dynamic microanalytic simulation model of the United States.

In Canada a dynamic cohort (life-cycle) MSM, DEMOGEN with synthestic family histories for a single cohort has been developed by Statistics Canada [Wolfson (1990)] with new and further efforts for several user-friendly PC-versions.

Tab. 2a

Tab. 2a

In the United Kingdom LIFEMOD, another dynamic life-cycle MSM, is developed [Falkingham and Lessof (1992)] and used for tax and transfer policy analyses [Falkingham and Harding (1993)]. PENSIM is a dynamic MSM for pensioner income developed at the UK Department of Social Security [Ball (1992)].

In the Nordic States an increased microsimulation engagement can be observed in recent years [for Sweden see Eriksson (1992), for Denmark Hansen (1992) or for Finland Salomäki (1993)]. In Norway MOSART from Statistics Norway was developed as a dynamic MSM to analyze labour market and public pensions [Andreassen, Frederiksen and Ljones (1993)]. In Denmark, the dynamic and static version of the Ministry of Finance LOVMODEL is under almost daily policy advice use for a broad range of policy questions [Ökonomiministeriet (1991), Hansen (1992, 1993), Baekgaard (1993)]. Exhibit 2a provides further information of major dynamic MSMs.

In Germany, within the 'Social-Political Indicator and Decision System' (SPES) project, already in the 70s Hecheltjen (1974) developed a dynamic micromodel to analyze demographic effects and occupational activities in the FRG. Steger (1980) developed a dynamic micromodel to analyze demographic effects and household formation. The successor of SPES, the Special Research Collaborative Program 3 (Sonderforschungsbereich 3, Sfb 3), Microanalytic Foundations of Social Policy, at the Universities of Frankfurt and Mannheim spend a lot of efforts to develop dynamic and static MSMs. The Dynamic Cross-Section Sfb 3 Microsimulation Model [e.g., Galler (1980) and Galler and Wagner (1986)] was applied, for instance, to examine financial and income distribution effects of alternative options for the 1984 old-age security reform in the FRG [Krupp, Galler, Grohmann, Hauser, Wagner (1981) and Galler (1981, 1990)]. Within these Geman pension reform analyses the Dynamic Life-Cycle Sfb 3 Microsimulation Model [Wagner (1983), Hain and Helberger (1986)] was developed and used for specific earnings/retirement history analyses. Using relational databases within a new dynamic microsimulation approach but based on the Sfb 3 Dynamic Microsimulation Model Galler (1992) more recently analyzed kinship networks and the demand of care for the elderly.

Also in Germany, at Darmstadt University, a dynamic MSM has been under development [Heike, Hellwig, Kaufmann and Appendino (1986)]. DAISI is a dynamic MSM developed to analyze family formation processes [Kaufmann, Quitmann, Schulz, Simm and Strohmeyer (1984)]. Exhibit 2b provides further information of major dynamic MSMs in Germany.

Tab. 2b

Further European developments of dynamic MSMs are given in the Netherlands with MIKROPOLIS and NEDYMAS [Mot (1991) provides an overview of Dutch MSMs]. With NEDYMAS Nelissen (1993) runs dynamic microsimulation for a social security and lifetime income distribution analysis. In Hungary a microsimulation project is now under development with dynamic and static models [Zafir (1987), Szivos (1993)].

In Australia at NATSEM, the new microsimulation National Centre for Social and Economic Modeling at the Faculty of Management of the Canberra University, Ann Harding and her crew are developing new dynamic and static MSMs. Their DYNAMOD follows a different approach to the aging of a population than all the other dynamic models [Antcliff (1993), Gruskin (1993), Harding (1990, 1993)]. Instead of annual survival probabilities, DYNAMOD uses survival functions to predict hypothetical realisation times for the occurrence of events potentially affecting an individual. A 'crystal ball' then stores all these possible futures. If an event for a person may have effects on further events (like pregnancy on labour force participation) a new possible future is created for that person each time he or she experiences such an event.

All these dynamic MSMs focus on the private household sector. Only a few MSMs focus on firms. The few firm sector MSMs include the dynamic micro-to-macro Swedish model MOSES [Eliasson (1985, 1986, 1993), Ballot and Taymaz (1993)] and static MSMs of the industrial and agricultural sector developed by the Hungarian Ministry of Industry (1987) and the Hungarian Ministry of Agriculture, which will be discussed further in the next section. Further information about major dynamic MSMs are compiled in Exhibit 2a,b.

## 3.2 STATIC MICROSIMULATION MODELS

The systematic variation of regulations on the basis of typical cases is the starting point of static microsimulation. Analyses of changes in a conditional structure with such 'calculators' have been made in many fields of administration, business and science. Until recently alternative tax regulations were still simulated based on typical cases chosen by tax administrators.

When typical cases are simulated, adjustments may lead to partially representative results, but do not of course account for the untypical cases, which are not considered in such a synthetic data base of typical cases. Recent static MSMs therefore increasingly use a representative sample. These real sample based MSMs account for untypical cases, too, and in addition should perform representative distributional results for a whole population.

Because in the last 30 years the US were the leading developers of MSMs with many policy advice applications, the following survey of developments and applications is divided for the US and for Europe and Australia, where microsimulation started 15 to 20 years or even later.

### 3.2.1 STATIC MICROSIMULATION MODELS IN THE US AND CANADA

Based on Orcutt's seminal new type of socioeconomic microsimulation models [Orcutt (1957), Orcutt, Greenberger, Korbel and Rivlin (1961)], alternative tax tariffs on the basis of microdata were evaluated in the US and in the 1960s with a static model developed at the Brookings Institution in cooperation with the US Treasury Department by Sadowsky (1977) and Pechman (1965). Static MSMs were further developed by McClung (1970) and Wilensky (1970) for the analyses of negative income taxation and family support programs. These models became instrumental in policy determination after further development by the Urban Institute in Washington, D.C. There the caseload and the distributive effects of many welfare and health programs were studied. The computer package RIM (Reforms in Income Maintenance), a comprehensive simulation program for static microsimulation, was developed at the Urban Institute toward the end of the 1960s. The study was commissioned by the Department of Health, Education and Welfare, the predecessor of the current Department of Health and Human Services.

Since about 1976, TRIM (TRansfer Income Model), an updated version of RIM, and the expanded TRIM2 [Webb, Michel and Bergsman (1990)] are perhaps the most widespread static MSMs in use in government agencies as well as in other institutions in the US. The TRIM/TRIM2 package allows for an adjustment in the population development ('static aging') in short- and medium-range simulations. It also makes it possible to simulate a variety of income transfer programs. TRIM has been used, for example, in analyzing the effects of tax reform, negative income tax, food stamps, aid to families with dependent children (AFDC), and national housing allowances.

Improvements in the TRIM system were made in order to evaluate the behavioural response to reforms in the social security system. A further development is the MATH model (Micro Analyses of Transfers to Households), developed in collaboration between Mathematica Policy Research (MPR) and the Hendrickson Cooperation. Originated in the mid seventies the MATH model is further developed and still used for public policy advices and analyses [Beebout (1986)].

Tab. 2c

Tab. 2c

The Comprehensive Human Resources Data System (CHRDS) is a MSM designed to assess the distributional impact of energy policies [King (1980)]. CHRDS uses a synthetic data base in which parts of the Census Public Use Sample, the Census of Housing and the Panel Study of Income Dynamics were merged. This microsimulation relies on MATH to age the population and to generate economic characteristics that include taxes and transfers.

The KGB model [Betson, Greenberg and Kasten (1982)] of the Department of Health, Education and Welfare is similar in its basic structure to the TRIM model but specifically includes additional behavioural equations for labour market relationships. The STATS model (Simulated Tax And Transfer System) was developed in the mid-1970s for the Health and Human Services Department's Office of Research and Statistics. This model is used mainly in such fields as welfare services and social security. Also in the 1970s, the 'Personal Income Tax Model' of the US Treasury Department was based upon earlier developments of the OTA (Office of Tax Analysis). As in the TRIM, MATH and KGB models, the OTA model also allows for 'static aging', an adjustment to future control data achieved by re-weighting the sample. In the beginning of the 1980s TAXSIM, a static MSM with behavioural response on tax policies, was developed in a National Bureau of Economic Research (NBER) project. Behavioural simulation methods in tax policy analysis (including TAXSIM) are summarized in Feldstein (1983).

A more recent model is the Unemployment Insurance model (UI model) of the Urban Institute, making possible representative analyses of unemployment insurance for the US as a whole, as well as for single states. Based on the aged data from files of the TRIM model, the National Health Insurance model (NHI model) in addition allows for demographic adjustment with data from the Social Security Administration as control variables.

In Canada Michael Wolfson and colleagues at Statistics Canada developed a user-friendly PC static MSM called SPSD/M (Social Policy Simulation Data base and Model) [Wolfson (1990)]. Recent microsimulation modeling experience with T1/TTSIM at the Department of Finance in Canada is given by Gupta and Kapur (1993).

In recent years the microsimulation approach has been used in other branches, too, like in the branch of residential energy analyses. Cowing and McFadden (1984) describe the Oak Ridge National Laboratory (ORNL) Residential Energy Consumption model and the Electric Power Research Institute Residentials End-Use Energy Planning System (REEPS) model. Both models simulate energy-related economic activities at the household level. The ORNL model begins each period with an exogenous given population broken down into age and income groups. The ORNL model thus is not a full dynamic MSM with total endogenous demographic processes. It could be described as a (static) 'group' model with some transitional relations for forecasting purposes. The REEPS model is similar in its technique because it uses a probabilistic technique to generate a synthetic sample (as the microsimulation base) for each forecasted year.

Another group of computer simulation models focuses on urban location. In these models the borderline is fluid between (static) microsimulation with microunits (typical cases or sample units) and the above mentioned group simulation (mesosimulation) with microunits gathered in certain socioeconomic cells. Some of them are econometric simultaneous equation models. Urban location models are similar to land-use forecasting models derived from gravity type models such as DRAM [Putman (1983)] and integrated land-use forecasting models like CATLAS [Anas (1983)]. Another emphasis is on housing market models with explicit solutions to the supply and demand processes of a market. Examples are the early urban housing market model for the San Francisco Community Renewal Program [Little (1966)] and, more recently, housing models developed by the Urban Institute [DeLeeuw and Struyk (1975)]; Ozanne and Vanski (1980); Struyk and Turner (1983)]; and the NBER and Harvard Urban Development Simulation model [NBER-HUDS, Kain and Apgar (1985)]. Stahl (1985a) discusses the conceptional framework of housing market models. A comprehensive survey of recent urban location simulation models is given in Kain (1987).

Further information and references about major static MSMs in the US are compiled in Exhibit 2c, divided according to the subject of investigation, data base, simulation unit, special characteristics, field of policy advice, and model developers.

Characteristic features of the recently developed static MSMs in the US and Canada are the growing number of incorporated behavioural hypotheses (e.g. for individual labour force participation and hours supplied) and also more or less elaborate methods for the demographic and economic adjustment within an extrapolation or 'static aging' of the initial microdata base.

### 3.2.2 STATIC MICROSIMULATION MODELS IN EUROPE AND AUSTRALIA

In Europe static MSMs are used mostly by government agencies to study taxation issues that arise in the field of personal income tax [OECD (1977), p.6]. However, some OECD countries have worked on establishing MSMs for corporate taxes in the business sector. A recent survey of microsimulation of tax effects is provided by the OECD. Microsimulation of transfer and social policy effects will be surveyed by the OECD Working Party on Social Policy [OECD (1990)]. Nowadays, almost all European countries have MSMs for personal income taxation at their disposal: Austria, Denmark, Finland, France, Germany, Great Britain, Italy, the Netherlands, Norway, and Sweden. MSMs for business taxation are in use only in Great Britain, France, and Norway. In Great Britain, static personal income tax MSMs were developed by the government relatively early (1937/38). Since 1950, the British revenue office conducts an annual random sample of individual taxpayers with a sample size of approximately one million cases each year [Lietmeyer (1986)].

The British TAXMOD static MSM [Atkinson and Sutherland (1988)] is designed to examine a variety of such tax-benefit policies as the introduction of a basic income guarantee or the costs of changes in a specific particular tax rate. TAXMOD, developed at the Suntory-Toyota International Centre for Economics and Related Disciplines (ST/ICERD) at the London School of Economics and Political Sciences (LSE), was used to analyze separate taxation of spouses [Atkinson and Sutherland (1986)]. The recently established new Microsimulation Unit at the Department of Applied Economics, University of Cambridge under Tony Atkinson and Holly Sutherland provide further actual microsimulation policy advice with user-friendly PC models [for their actual activities see e.g. their microsimulation workshop, Hancock and Sutherland (1992)].

In the Netherlands, now for a many of years, microsimulation and static MSMs in particular like the SCP Micro-Model, ExpertiSZe, the model of Siegers and Grift, or MICROS are developed. They are discussed in Mot (1991) and Mot and van 't Eind (1992).

The Swedish system of personal income taxation during the period 1952-1971 is described by Jakobsson and Normann (1974). This early tax simulation model consists of a micro part and an aggregated part and allows distributional analyses for individuals partitioned into ten categories (synthetic micro-data). As mentioned, the Nordic states recently spend increasingly efforts in the microsimulation and in particular in the static microsimulation business. Besides Denmark [Ministry of Economic Affairs, Hansen (1992, 1993)], which also runs dynamic MSMs, Finland [TUJA MSM, Government Institute for Economic Research (VATT), Salomäki (1993)] and Sweden [Ministry of Finance, Eriksson (1992), Eklind, Eriksson, Hussenius and Müller (1993)] develop and apply static MSM in tax and transfer policy investigations.

In West Germany during the early 1970s, the pros and cons of MSMs versus group simulation models were discussed at University of Frankfurt by researchers working on the SPES project (SPES: Social Political Decision and Indicator System). Klanberg (1975) and other members of the SPES projects staff made an early attempt to analyze income tax and poverty on a microdata base. These first steps were followed within the static microsimulation approach by analyses of pension insurance issues, conducted by Brennecke (1976) and Hamacher (1978). Following this work, static simulations on utilization of health services based on health data from Infratest (1970-77) were analyzed by Brennecke (1981).

Within the Sfb 3 more recent approaches in static microsimulation encompass child allowances, child bearing and retirement pensions, reduction of hours of work and effects of the recent 1990 German reform on the formal and informal economy: Heldmann's (1985) static simulations probe the distributive effects (within certain welfare brackets) of child allowance reductions and other selected reform proposals. Engel and Rolf (1985) described efforts to use static simulation to arrive at calculations of retirement pensions for women by including, along with their employment income, the value of their work in raising children. They gave special attention to the specific case in which the pension system itself compensates a mother with a child-upbringing allowance. The effects of reductions in the working hours with and without income compensation were analyzed by Galler and Wagner (1986) with data of the Sfb 3 Transfer Survey.

Based on the Sfb 3 Secondary Occupation Survey, Merz (1987, 1989a) analyzed private household income through market and non-market activities, incorporating the shadow economy. The impacts of the recent 1990 German tax reform on multiple labour supply in the formal and informal economy is the specific topic of Merz (1989a,b, 1990, 1993c). The Static Sfb 3 MSM, mainframe and the PC-version MICSIM, used for these studies will be further described in Section 5 to illustrate the working mechanisms of a static MSM.

Among early static MSMs used in the FRG the housing allowance model of the "Industrieanlagen-Beratungsgesellschaft Ottobrunn" [IABG (1974)] is to be mentioned. It is applied to simulating a housing allowance system of the Federal Ministry of Housing [Dick (1986)]. Other housing market models are used in private institutions [GEWOS (1982)]. A summary of the 1979 Heidelberg Workshop on housing simulation models [Bundesminister für Raumordnung, Bauwesen und Städtebau (1981)] offers a survey of the area. More recent microeconomic models of housing markets are presented in Stahl (1985b). His book describes the Ifo Housing Market Model [Behring and Goldrian (1985)] and the Dortmund Housing Market Model [Wegener (1985)]. Some of the housing market models are econometric equilibrium/disequilibrium models using synthetic household and dwelling units. For all the housing market models, the borderline is fluid between 'pure' static microsimulation with individual and group simulation, with groups of individuals as simulation units.

The Federal Ministry of Finance uses a microanalytic model for analyses of income tax reform proposals [Lietmeyer (1986)]. The VDR (Verband Deutscher Rentenersicherungsträger, German Society of Statutory Pension Insurances) considered 'individual cases' in its forecasting model for the analysis of the 1984 German Pension Reform Act [Müller and Steeger (1981)]. Using microdata, this model computes group averages for certain cells as units of a group model. BASYS, a static MSM to analyze the health service sector [Dennerlein and Schneider (1982) and Vetterle (1985)], re-uses process data from mandatory health insurance information. Refer also to Brennecke (1984) on static Sfb 3 microsimulation analyses of the public health sector.

For governmental planning purposes, the BAFPLAN model [Bungers (1978) and Bungers and Quinke (1986)] was developed by the GMD [Gesellschaft für Mathematik und Datenverarbeitung mbH (Bonn), Society for Mathematics and Data Processing] in collaboration with the German Ministry of Education for analyzing the performance of the BAföG (Bundesausbildungsförderungsgesetz, Educational Assistance Training Act). The Ministry of Youth, Family and Health Affairs has further developed APF by the GMD [Gyarfas (1988) and Quinke (1988)]. APF is a simulation instrument for analyzing and planning the equalization of family burdens. This static MSM analyzes distributive effects and tax shortfall estimates caused by transfer law changes on the basis of synthetic data for a broad spectrum of family types. For practical uses of MSMs in tax policy analyses Spahn, Galler, Kaiser, Kassella and Merz (1992) recently provide a report for the German Ministry of Finance with a survey of activities and possibilities of tax microsimulation analyses under strict privacy of data restrictions.

In Austria the tax simulation model INZIDENZ was developed and used for wage and income taxes [Rainer and Leitner (1990)].

In Hungary several microsimulation activities were introduced shortly after 1985. Within the Hungarian Central Statistical Office, the Hungarian MSM was developed in several dynamic and static versions [Zafir (1987), Futo (1987), Szivos (1993)]. Parts of this work were done in collaboration with the Darmstadt University microsimulation group [Heike, Hellwig, Kaufmann and Appendino (1986)]. Based on household expenditure statistics and merged labour data as well as income data, effects of transfers, wage, and social policies were simulated. A second Hungarian static microsimulation project is concerned with the examination of invisible income [Eltetö and Vita (1987)]. Whereas these microsimulation activities are concentrated on households and persons, two other projects simulate firm behaviour. The effects of tax regulations applicable to industrial firms (with data on 400 firms) were investigated by the Hungarian Ministry of Industry (1987). Tax effects on agricultural firms (with data on 150 firms) have been a topic of static microsimulation by the Hungarian Ministry of Agriculture [Finta (1987)].

Tab. 2d

Tab. 2d

Tab. 2d

Legende 2s-2d

In Israel a static microanalytic simulation model has been under development in Israel for evaluation of integrated changes of taxes and transfers [Habib (1986)].

In Australia, as mentioned, new microsimulation efforts are undertaken at NATSEM of the Canberra University. STINMOD is the new PC static MSM, which is based on SAS and its ability for user-friendliness [Paul, Percival, Cox and Lambert (1994)]. Australian MSMs outside and before NATSEM are discussed in the sequence of workshop at the Social Policy Research Centre (SPRC) of the University of New South Wales [Bradbury (1990)]. More than 20 more or less sophisticated Australian tax-benefit models are discussed in the overview by Gallagher (1990). As to Bradbury (1990), the organisation most prominent in microsimulation in Australia has been the National Institute of Economic and Industry Research (NIEIR); King, Foster and Manning (1990) provide the respective overview. Symons and Warren (1993) use the microsimulation approach to model and analyze consumer behavioural response to commodity tax reforms. Miller and Leaver (1993) describe the Australian Bureau of Statistic's static MSM. Exhibit 2d supplies additional information on the European and Australian static MSMs.

# 4 REQUIREMENTS AND COMPONENTS OF MICROSIMULATION MODELS

After the overview of developments and applications of MSMs, some insights of how MSMs actual work will be discussed. For a better understanding of the way in which a MSM operates, its general requirements and elements are briefly summarized. Requirements for a MSM include:

(1) the provision of an appropriate microdata base (with tools for merging several data bases) and the inclusion of necessary macrodata;
(2) the construction of micro- and macromodules including institutional regulations and behavoural response that compute certain characteristics of microunits;
(3) the simulation of the micromodel itself in modifying micro- and macrodata (parameter variations);
(4) the adjustment of microdata (either before or after the simulation operations) to fit given control data (adjustment problem);
(5) the evaluation of the executed simulation, whether it is the result of a single simulation or the results from a number of (stochastic or deterministic) simulations.

Tab. 3

In addition, each of the above-mentioned requirements should be met with careful attention to efficiency and ease of use.

A further detailed breakdown of the above requirements is prevented in Exhibit 3. It is to be noted that specific support for module construction (including econometric packages for hypothesis-testing and formulation) is not generally included in microsimulation installations, though it would be a further helpful step to aid comprehensive policy analysis that includes model building. For a more detailed explanation of the requirement profile, refer to Merz (1985b).

## 5 MICSIM - AN EXAMPLE OF A PC - MICROSIMULATION MODEL BASED ON A RELATIONAL DATA BASE SYSTEM

To illustrate a MSM's working mechanisms based on the just discussed general requirements, a concrete example, MICSIM - a PC microsimulation model, is now described. MICSIM, the recently new developed PC-version of the Static Sfb 3 Microsimulation Model [Merz and Buxmann (1990)], as well as the Static Sfb 3 Microsimulation Model in its mainframe version [Merz (1986b, 1994a)], have been developed according to the principle of interacting mainly on a substantive, content-orientated, logical level. This principle is supported by a relational data base system. The data handling applies both to single microdata files and also to control data that are important to the static simulation handling. Such a data base system provides data integrity, centralized and uniform data storage, retrieval and handling as well as separation of the logical structure from the physical storage of data. A further advantage of such a system, together with a relatively easy and similar processing of different microdata files[2], is its user-friendly nature and its ability to represent hierarchical and other relational structures (e.g., individuals within families and/or households). Codd (1970), Schmidt and Brodie (1983) and Diemer (1989) further discuss the specific characteristics and pros and cons of relational data base structures in general.

2 E.g., microdata files of official statistics, own survey data, or independently arranged microdata files (merged initial data, result files of dynamic/static microsimulations or synthetic cases).

Following the short discussion in the previous section there are four main requirements for a static MSM (Exhibit 4):

(1) simulation control programme (STATIC)
(2) model operations (SIMULA)
(3) adjustment, static aging of microdata (ADJUST)
(4) evaluation of simulation (EVAL).

These four central modules are supported by a relational data base system in different ways; above all, the model operations, the specific simulation changes (SIMULA) and parts of the evaluation task (EVAL) can be formulated by the data base system's statements. The simulation control program itself in the mainframe-version is written in FORTRAN 77 and in the PC-version, MICSIM, in C. The control program uses a relational database system (mainframe: SYSTEM 1022, PC: ORACLE) by a host language interface (mainframe: SYSTEM 1022, PC: Pro*C).

ADJUST is a FORTRAN 77 program package [Merz (1993b, 1994a)] which ages the microdata by simultaneous adjustment (reweighting for a set restrictions) of a specific nonlinear equation system. The Static Sfb 3 Microsimualtion Model is interactively designed and implemented on a DEC 1091 (mainframe) and an (IBM compatible) PC as MICSIM; the user is led, menu driven, throughout all possible tasks of a (static) microsimulation.

The simulation control program regulates the sequence and interaction among the three modules, model operations (SIMULA), adjustment of microdata (ADJUST) and evaluation of the simulation (EVAL). System-supported, the user has the option to perform single tasks within one module or to run a sequence of desired modules. Thus, with the ability processing each single module alone, MICSIM is a general instrument to analyze microdata. Exhibit 4 describes the structure of MICSIM.

The following short and non-technical description of MICSIM is presented from a user's perspective.

Tab. 4

## 5.1 SIMULATE ALTERNATIVE POLICIES: SIMULA

The user may have chosen the simulation task out of the three possibilities. SIMULA focuses on model operations, i.e., on how systematic variations in the parameters change the characteristics of microunits and their relationships. After having defined the desired microdata file for examination, the user may decide which relational type of data (e.g., household, family and/or individual data) he wants to process. To store simulation results, simulation variables are placed in a separated file. It is important that the variables themselves need to be defined only on the logical (substantive) level; their relations within the microdata file under investigation are internally organized by the system.

Then the user could move on to the relational data base system. The user is able to interactively employ all data base system commands and features (mainframe: SYSTEM 1022, PC: SQL/SQLPLUS commands). In order to change the characteristics of the microunits and to assign desired values to the simulation variables, the variables (called by names) have simply to be combined with algebraic operations. As a special feature of the set theoretical approach of the data base system, the simulation may use merely a subset of microunits (selection) and/or variables (projection). A logical description of the selected filter characteristics will define the chosen subset. The system will then execute the simulation for the desired subset. After carrying out these tasks, the user is led back into the control mode.

The user may then decide to include his own modules (e.g., C procedures, FORTRAN sub-routines, SQL/SQLPLUS[3] modules) and to inform the system of the desired module sequence. Again, only a subset of microunits (e.g., welfare recipients) or the whole microunit file may be subject to variation within the user-defined modules. The modules, of course, change the variables according to the questions under investigation. These modules should be carefully arranged for problem adequacy and real-life conformity. Such modules, which may be a part of the Dynamic Sfb 3 Microsimulation Model (e.g., to change the microunit characteristics referring to education, income, transfers, etc.), are relatively easily embedded in the static microsimulator as programmed (in FORTRAN 77, PASCAL etc.) sub-routines or modules written in SQLPLUS (MICSIM, PC-version). Even demographic changes could be incorporated. In this case, MICSIM is considered as a general purpose (static/dynamic) microsimulation model.

3 The systematic use of SQL/SQLPLUS in connection with ORACLE as it is used in the MICSIM PC-version, is discussed in Finkenzeller, Kracke and Unterstein 1989.

## 5.2 ADJUSTMENT OF MICRODATA: ADJUST

As a next step, the user may proceed to adjust the microdata (ADJUST). According to need, the microdata before and/or after simulation may be adjusted. An adjustment of a microdata file is necessary when the microdata sample is not appropriately representative. Adjustment is the reweighting of non-aggregate microdata to fit given aggregate (control) data and an important component of any static MSM as its static aging procedure. These aggregate data may be derived from other statistics (including other aggregate sample information).

***Simultaneous adjustment***

The task of a demographic simultaneous adjustment is to compute one adjustment (weighting) factor for each microunit that has to fit simultaneously all control data restrictions (of a sample' year or as future totals) after aggregation. The simultaneous adjustment procedure ADJUST is based on information theory through the Minimum Information Loss (MIL) principle [Merz (1994c, 1993b, 1985a)]. The nonlinear optimization problem subject to the aggregate constraints minimizes an entropy distance function between given old and desired new adjustment factors. This procedure in particular ensures positive new weighting factors. Since a demographic adjustment factor finally represents a actual number of microunits, positive (non-zero) resulting factors are important. Zero factors would eliminate the respective microunits for further analyses.

The MIL principle leads to an optimization problem under constraints. The problem is solvable with a Lagrangian approach, leading to the solution of a nonlinear equation system. For this purpose, a fast modified Newton-Raphson procedure has been developed. This modified procedure was able to reduce the computing expense for different sized microdata bases (e.g. with over 60,000 microunits and up to 250 simultaneous binding constraints) by over 75% compared to the regular Newton algorithm.

**Generating the information matrix**

An iterative process is necessary to solve the above optimization problem under constraints with its nonlinear equation system. For such an efficient iterative process, a sample information matrix S has to be generated which consists only of the restricted household and personal characteristics (as rows). Each column of the information matrix represents the respective restriction characteristics for one microunit (e.g. a household).

For each restriction the user has to define only the logical condition with data base system commands (e.g. for a certain household type) and the final aggregate (margin) which has to be achieved after reweighting the sample. MICSIM then automatically generates the rectangular information matrix with its specific characteristics.

**Iterative solution of the nonlinear adjustment problem**

After generating the information matrix, the FORTRAN 77 adjustment package ADJUST respectively ADJUST-PC solves the problem. After convergence of the procedure and respective statistics, the new set of adjustment factors is available and can be integrated into the microdata file when needed. ADJUST-PC [Merz (1993b)] as a stand-alone efficient program package for large microdata files is available from the author by request.

**Economic aging**

In addition to a demographic adjustment simultaneously fulfilling pre-specified conditions, a static MSM should also include an adjustment in the economic variables. Economic variables, such as certain incomes and expenditures, are inflated (weighted) by an 'economic multiplier'. Such an easily defined multiplier is one factor which is identical for all microunits.

## 5.3 EVALUATION OF MICRODATA: EVAL

As a final task, the user may now evaluate his simulation and/or microdata file. Functions of the data base system itself (min, max, frequencies etc.), user-defined functions (e.g., correlations and other statistics) via the data base language (e.g., PC-version MICSIM: SQL/SQL-PLUS) and/or some supplied descriptive statistics are all offered by the corresponding menu. Recently more distributional measures are captured.

In addition, the microdata may be easily processed through a more powerful statistic package, like SPSS. A SPSS system file with information on variable names and values may automatically be generated. If data are needed for further econometric packages like LIMDEP, an ASCII file may be automatically dumped.

In summary, MICSIM aided by a relational data base system is a user-friendly powerful simulator able to process the three main tasks of a MSM: simulation, adjustment and evaluation. These days at my chair at the University of Lüneburg, MICSIM is getting a new graphic surface in using Visual C++ also to get rid of memory problems stemming from the former SAA standard overall management. After finishing these tasks, MICSIM will be made available for those who are interested in.

MICSIM as the Static Sfb 3 Microsimulation Model[4] recently has been applied to 1990 German tax reform and labour market policies affecting market and non-market labour supply activities of private households. The underlying question is on incentive/disincentive results of

4 For an example of a concrete (mainframe) application of the Static Sfb 3 Microsimulation Model on the basis of Sfb 3 Transfer Survey, refer to Merz (1985b).

such tax reform measures. The combined dynamic and static microsimulation analyzes the effects on individual income strategies including shadow economic activities in illicit work and household production [Merz (1989a,b, 1990, 1993c)].

# 6 COMMON ISSUES: MICRO/MACRO LINK, BEHAVIOURAL RESPONSE AND EVALUATION OF RESULTS

In my recent paper [Merz (1993a)] I pinpointed a 4M-strategy: microanalyses by microtheory, microdata, microestimation and microsimulation. Embeded within this more general setting, micro/macro link, behavioural response and evaluation of microsimulation results play an important role in microsimulation modelling and will be discussed therefore in what follows.

## 6.1 MICRO/MACRO LINK

As we have seen, nowadays, there is a widespread use of MSMs to analyze economic and social policy. Nevertheless, as also Guy Orcutt pinpointed in his opening adress and discussion contribution of the recent 1993 Canberra microsimulation congress, we are still on the road to the original idea to simulate individual household, firm and governmental community behaviour in their regional combined setting. We are still at the very infancy to combine the sectors at a regional level, however, some very first steps in the micro/macro link business has been done.

With respect to micro/macro link there are two main procedures to connect models and information: first, a recursive and second an interdependent procedure. In the recursive procedure aggregated information from the micromodel (like taxes) are included in the macro model as macro exogeneous variables. Then the usual non-linear equation system of the macro model is iteratively solved for one period in time. Vice versa, some macro information (like (regional) unemployment quota) may be exogeneous to the micro model. In the interdependent procedure aggregated micro information is put in the macro model, macro variables are put in the micro model and so on until in one period of time the iteration process solved the iterated combined micro/macro relations via the non-linear macro equations. These interdependencies have to be computed again in the next simulation period. Because at least in the interdependent case a lot is to do conceptually and computationally, worldwide only some few approaches are known like those of Merz (1978), Caldwell, Greene, Mount, Saltzman and Broyd (1979), Galler (1980), or Caldwell (1983, 1986).

## 6.2 BEHAVIOURAL RESPONSE

Modeling direct and indirect impacts of tax and transfer programs needs institutional regulations and behavioural response of those individuals who are affected by some policy. All MSMs have incorporated more or less detailled institutional regulations to compute individual caseloads of different program schemes. More seldom the question is asked and modelled if actually and how new regulations will indeed affect individual behaviour. To model behaviour response and further feedback structures microeconometric work is essential. However, in combining (economic) theory and available data researcher often reaches rather quick the borderline of knowledge. The principle shortcut, that simply there is no observation available of an alternative situation is at the same time a genuine strength of microsimulation: the simulation process might give reasonable intervalls of possible behavioural outcomes.

Panel surveys (like the US Panel Study of Income Dynamics, PSID, or the German Socio-Economic Panel, GSOEP) are of particular importance for estimating behavioural response, because behavioural changes can be estimated by panel-microeconometrics when following a distinct person's life over subsequent periods. In general, individual transitions from one state to another with respective events - like entering the labour market, being eligible for certain social programmes etc. - can be estimated more adequate with panel than with cross-sectional data.

A further treatment of behavioural response is given in Nakamura and Nakamura (1990), Hagenaars (1990) by treating female labour supply in MSMs, and Slemrod and Shobe (1990) by discussing the important issue of using panel data in the analysis of behavioural response. Behavioural MSMs are discussed at the 1990 German conference [Brunner and Petersen (1990, part 5)] including applied general equilibrium models. The topic is also included at the 1993 Australian Canberra conference with its session 3 on common issues: micro/macro links, firm behaviour and behavioural response still to be published.

## 6.3 EVALUATION OF MICROSIMULATION RESULTS

The development, maintenance and running of MSMs require a great deal of personal and material resources. The quality of the overall results is heavily dependent on all of its components: getting and preparing (merged) microdata, incorporating a social programme's detailed institutional regulations with all its interdependencies with other social security schemes, estimation of behavioural relations with adequate microdata, programming the system, testing and validation, and often inadequately regarded: making the model and the results accessible and understandable to non-specialist users including time-consuming full documentation. Any evaluation of microsimulation results has to deal with all of these prerequisite components.

Though MSMs are existing now for over 30 years, and are requiring much effort and great expense, it is astonishing, that they have not been the focus of a major evaluation since a study by the US General Accounting Office in 1977 (although single developers provide some information by their own).

However, the US National Research Council recently investigated and evaluated the uses of MSMs for social welfare programs to improve information for social policy decisions (Citro and Hanushek 1991a,b). Although the National Research panel concluded "that microsimulation models are important to the policy process, and we anticipate that the need for the kinds of detailed estimates that they can best generate will grow, not diminish, in future years" (page 10) they "identified two major deficiencies that demand attention if policy models ... are to provide cost-effective information to the legislative debates of the future. The first problem (one of long standing) is lack of regular and systematic model validation ... The second problem (of more recent origin) is underinvestment and consequent deterioration in the scope and quality of needed input data for policy models" (page 3).

With concern to the validation of the results of MSMs, by additional sensitivity analyses, variance estimation, and evaluation by an explicit loss function, I will add the following integrity aspect when producing the microsimulation results: Programming all the rules and mechanisms of a MSM with any problem-oriented language in C, FORTRAN or any other language might yield pure programming mistakes and runtime errors when sequentially handling all microunits of a sample. A more reliable and data integrity tool given by modern (relational) database system languages like SQL should be considered which avoid such programming mistakes by reliable and structured accesses to the data. In addition and combined with SQL-type query languages, according to the set theoretical approach, such a procedure with integrity operates only on the persons/households and variables which are of interest (see as an example the above MICSIM PC microsimulation model).

The validation of microsimulation results is a demanding task also in another aspect. Since microsimulation is based and conditioned on individual sample survey information, the different impacts of social policy changes, almost in principle, cannot be evaluated using the same sample. Even as a real world experiment, a one-to-one personal comparison of alternative policies for the same set of people seems to be not feasible. However, there are real world social policy experiments (see the mentioned New Jersey Income Maintenance Experiment [Rees (1977)] that theoretically would allow comparisons between similar samples under different policy situations.

One possibile way to evaluate a MSM is to validate individual ex post forecasts on a more aggregate level. However, evaluation of microsimulation results by the modelers are rather rare; exceptions are e.g. evaluations of the DYNASIM model [Orcutt, Caldwell and Wertheimer II (1976, Chapt.11)] and of the Sfb 3 microsimulation analysis of the former

German Pension Reform act [see Helm and Lempert (1982), Helm (1982) evaluating the ex post prediction accuracy of the models 1969-1978 results].

The recent 1993 Canberra microsimulation conference spent its session 'Getting the data right' to this topic and on the statistical reliability in microsimulation in particular [Pudney and Sutherland (1993)].

## 7 CONCLUDING REMARKS

The fundamental principles of MSMs, developments and applications in the US, Europe, and Australia have been discussed in this paper. Based on a generalized profile of microsimulation requirements, the mode of operation of a static microsimulation was briefly illustrated using MICSIM, the PC version of the Static Sfb 3 Microsimulation Model. Common issues on micro/macro link, behavioural response and the important task of evaluating a microsimulation results closed up this survey.

The suitability of using microsimulation as an instrument with which to analyze policy impacts at the individual level depends on its problem-solving adequacy and real-life conformity in modeling and simulation. This is supported by the microanalytical approach in particular which enables differentiated analyses on the basis of individual behavioural equations and individual institutional arrangements. Even when reproducing institutional regulations in detail through appropriate modules, extensive effort has to be made to adequately model and estimate behavioural relationship at the micro level. Since the object of every simulation is to examine the main and side effects of alternative policies, the modeling procedure itself should take care of primary as well as secondary impacts. It is my hope, that more research on interdependencies of individual behaviour and feedbacks will further broaden the usefulness of MSMs.

When compared to private household microsimulation analyses, firm microsimulation models and analyses will hopefully increase. This includes the behaviour of certain groups linking both sectors like self-employed and liberal professions and persons in the service sector, groups, which also are of particular interest for our institute's research at the University of Lüneburg.

Since the late 80s MSMs are increasingly available on microcomputers like TAXMOD, the Social Policy Simulation Database/Model (SPSD/M) of Statistics Canada with newer versions or the discussed MICSIM model as a new PC-version of the (Static) Sfb 3 Microsimulation Model. MICSIM as a general purpose microdata processing and MSM is used in particular to analyze panel data of the German Socio-Economic Panel of the Sfb 3/DIW. MICSIM is now being further developed at my chair at the University of Lüneburg to analyze policy effects with particular regard to self-employed and professions. Further examples are the mentioned new Australian PC microsimulation models STINMOD (using SAA development tools) or DYNAMOD developed at NATSEM. The increasingly widespread use of more powerful PCs and PC installations of MSMs will certainly help to further distribute the microsimulation idea as a tool for a broad range of microdata and policy analyses in research as in practice. The user-friendliness of menu driven PC MSMs in particular and in addition will also support teaching purposes to better understand economic and social behaviour of a society.

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