CHAPTER 1
MODELING FOR RETIREMENT POLICY ANALYSIS

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CHAPTER 1

MODELING FOR RETIREMENT POLICY ANALYSIS

I. BACKGROUND

Future retirement income adequacy and security is receiving increasing attention from policy-makers and the media. Concern is frequently expressed about the long term viability of both the Social Security and the Medicare trust funds, about the adequacy and coverage of private pensions, and about the adequacy of individual savings for retirement. Moreover, efforts to reduce federal deficits have significant implications for public retirement security programs, including Social Security, Supplemental Security Income (SSI), Medicare, Medicaid, and for the tax treatment of private pensions. The age of eligibility for the normal Social Security retirement benefit is scheduled to begin to increase in the year 2000, which will affect both Social Security costs and employer pensions. Proposals for tax reform may affect private pensions and individual retirement saving. Changes in the health care market and in health care finance policies and programs will affect employer costs and benefit programs. Changes in the demographic structure of the population and in the structure of the economy -- including trends in productivity, real wages of various skill and occupational groups, the industrial structure, and the globalization of markets for labor, capital, and products -- will change the environment and conditions within which public and private retirement security programs operate.

Actuaries can and should play a major role in future debates on national pension policy. Actuaries can assist policy-makers and the public to understand the implications of proposed policy and legislative changes for the ability of employers and public programs to provide adequate and secure retirement income and other welfare benefits and the cost of those benefits. To inform its members about the nature and capabilities of analytical tools which are available for retirement policy research and to enhance its ability to contribute to the policy process, the Society of Actuaries is conducting a comprehensive review of the relevant data bases and sources and models which could be used to analyze and project the U.S. retirement income system.

II. RETIREMENT INCOME MODELING

Social scientists and policy makers use models to contribute to analysis of public policy issues. Actuaries use models to assist their clients to develop and maintain employee benefit plans and to inform the public about the affects of changes in policy and in economic and demographic conditions on employee benefits plans.

A model is a representation of a phenomenon, process, or system. A model can be used to identify and illustrate the key features and relationships of a system or other physical or social phenomenon, to simulate the behavior of a system or phenomenon under alternative conditions, and to project its behavior or status in the future. Many types of empirical models have been used to address retirement and retirement income issues. These include models of the U.S. population, the macro economy, various retirement income systems, individual pension plan sponsors, and the behavior of individuals and families.

III. MODELING APPROACHES

Models can be classified according to several aspects -- including subject matter, objective, structure, degree of aggregation, time horizon, and basic approach.

Four major frameworks, or paradigms, have been used in developing models intended to be useful for projection or policy making in the social sciences: the macroeconomic or macro time series approach, the interindustry or input-output approach, the transition matrix or Markov approach, and the microanalytic simulation approach. Generally, a particular approach is most appropriate (or is typically used) for each type of subject. However, some models combine more than one approach. The existing models which have been used to analyze aspects of retirement policy can be classified according to the major paradigm(s) utilized.

Attempts to implement quantitative **macroeconomic models** date back to the work of Tinbergen (1937, 1939, 1951), who developed pre-war models of the Dutch and U.S. economies. In the 1940s and 1950s Klein (1950) and Klein and Goldberger (1955) developed models of the U.S. economy based on the Keynesian model of the circular flow of income and expenditures. In the 1960s larger macroeconomic models of the U.S. economy were developed at The Brookings Institution (Duesenberry, Fromm, Klein and Kuh, 1965), The Wharton School of the University of Pennsylvania, the Federal Reserve Board, and M.I.T.; and in the 1970s at Data Resources, Inc. and other commercial economic consulting firms.

In the macroeconomic model approach major economic aggregates or sectors of the economy, such as household consumption expenditures and business investment, are basic components. Equations expressing the relationships among aggregate variables, such as consumption expenditures, aggregate household income, and interest rates, are specified and estimated by statistical analysis of aggregate annual or quarterly time series data. Macroeconomic models have been used to project the economic environment in which retirement income programs will operate, and the effects of alternative retirement income policies on the economy.

The **interindustry approach** to development of models of an economy originated with Leontief's work (1951). Industries are the basic components in these models, which focus on the flows of primary and intermediate inputs and outputs among industries. Early versions of these models emphasized the cross-section structure of the economy and were static rather than dynamic. Physical outputs of industries were assumed to be strictly proportional to physical inputs. Later versions have incorporated dynamic features and permitted variable proportions of inputs and outputs.

Interindustry models have been used to investigate the effects of changes in input costs, such as changes in the costs of employee benefits, on products prices and sales, and the effects of changes in final demand for products on employment in various industries and occupations.

Demographers have used the **transition matrix approach** to model the growth and composition of populations. Stone (1961, 1966, 1971) and Land (1975, 1979) have extended the approach to other social and economic processes. A transition matrix is a rectangular array of transition probabilities which, when applied to an array representing the state (or distribution) of a population at one point in time (i.e. the composition of the population by age and sex or the distribution of workers by industry), produces an array representing the state of the population one period later. The transition matrix approach is associated with models that characterize the population by grouping individuals into cells with specified combinations of socioeconomic attributes, although the other modeling approaches are also applied to cell-based models.

A life table uses a transition matrix approach to model a hypothetical population. Elements of transition matrix models are used by the Office of the Actuary of the Social Security Administration to project the U.S. population and the future status of the Social Security trust funds.

The basic features of **microanalytic simulation** modeling were conceived by Orcutt (1956, 1960) and first implemented by Orcutt, Greenberger, Korbel and Rivlin (1961). In microanalytic simulation models the basic components are individual micro units, such as individual persons, families, enterprises, agencies, or metropolitan areas. A microanalytic simulation model contains one or more populations of such individual units. These are often samples selected to be representative of a larger universe. Microanalytic simulation models are based on cross-section survey data. A typical microanalytic simulation model is composed of sets of equations, prevalence and incidence rates, and transition probabilities which are applied to each individual in the population to simulate the state and behavior of the individual as a function of its characteristics and other micro and macro variables and parameters. After the state or behavior of each individual unit is characterized, the levels of aggregate variables for the population can be estimated by aggregating over the (properly weighted) individual units. A key difference between the microanalytic simulation approach and the three other approaches is that a microanalytic simulation model depicts the condition or behavior of individual units, whereas the other three approaches depict the condition or behavior of groups, cells, or aggregates.

IV. ACTUARIAL MODELS

Actuaries use models and modeling techniques to analyze and evaluate programs and systems which depend on events and conditions that pertain to the members of a defined population, which can be represented probabilistically, and which often occur over periods of time, such as retirement plans, disability insurance plans, and health care plans. An actuarial model projects the expected timing and amount of payments to and contributions for a defined population of individuals in a specific system. Typical systems are life, health, and disability insurance, employee benefits, or social insurance programs. The projected benefit for an individual at a specific point is based on the probability that the individual will receive the benefit and the expected amount of the benefit. The probabilities are determined by reviewing past experience of the specific population or similar populations, coupled with consideration of changes in environment that might affect the probabilities. The expected amounts of benefits and contributions are based on the entitlement rules of the system. The projections include an estimate of other factors, such as future salaries, if the entitlements depend on those factors.

Most actuarial models also include analysis of the financial status of the system. These compare the potential income, including any current fund, to potential benefits to determine if the financing is sound. The financial analysis usually incorporates discount rates to recognize the time value of money. The discount rates are also based on past experience, adjusted for expected changes in the environment.

Results of the model can be displayed at a single point in time or over several time periods. Results can show the projected number of participants and beneficiaries and the projected contributions and benefits, as well as the total contributions and benefits. The model can be either stochastic or deterministic, with results expressed as single values, a range of values, or expected values with measures of confidence.

Actuarial models often use methodologies which are similar to the transition matrix approach described earlier. Some actuarial models are similar to microanalytic simulation models, to the degree that they depict the condition of individuals.

Actuarial models usually represent the condition or outcomes for a system or program by projecting future outcomes and relationships based on observed past relationships, assumptions based on observed patterns, and program rules. Economic models, on the other hand, generally are based on theories about behavior, usually derived from economic theory. In an economic model, based on an underlying theory, functional relationships may be specified and estimated using empirical data. Statistical techniques and model simulations can be used to test the validity and usefulness of the underlying theories.

V. MODELS REVIEWED IN THIS REPORT

Models have been developed to represent particular aspects or components of the retirement income system, or the entire system. In addition, models which have been developed for other purposes provide information relevant to, or can be used to analyze retirement issues. Population projection models provide inputs needed for aggregative projection and analysis of retirement income from various sources. Macroeconomic forecasting models have been used to project the economic environment within which retirement systems will operate, including labor market conditions, interest rates, and inflation, as well as to estimate the effects of alternative pension and social policies on the economy. Dynamic microsimulation models have been used to simulate earnings and job histories that can be used in turn to simulate pension and social security accruals and benefits and other retirement income.

The models reviewed in this report are the following, classified primarily according to the subject being modeled. Although there is frequently a correspondence between the subject and the modeling approach, several models draw on more than one approach.

<u>Population/demographic projection models and systems (transition matrix)</u>

U.S. Census Bureau population projection system
Social Security Administration Office of the Actuary population projection methodologies
Capital Research Associates population model

<u>Macroeconomic Models</u>

Jorgenson macroeconomic growth model
Data Resources Inc/McGraw-Hill quarterly macroeconomic model
WEFA Group macroeconomic model
University of Washington St. Louis (Lawrence Meyer) macroeconomic model

<u>Interindustry (Input-Output) Models</u>

U.S. Department of Commerce, Bureau of Economic Analysis Input-Output tables
INFORUM Model
Regional Economic Models, Inc (REMI) models

<u>Social Security System Models (transition matrix/macro)</u>

Social Security Administration Office of the Actuary OASDI projection methodology
American Association of Retired Persons (AARP) Social Security Solvency and Individual Return (SIR) Model
Brookings Social Security Model (Aaron-Bosworth-Burtless)
Social Security Stochastic Simulation Model (SSASIM) (model developed for 1994-95 Social Security Advisory Council by Martin Holmer, now sponsored by EBRI)
Macroeconomic-Demographic Model (MDM) (National Institute on Aging/Capital Research Associates)
Gokahale Model (Federal Reserve Bank of Cleveland)

Pension and Retirement Income System Models (transition matrix/macro)

Schieber and Shoven Pension Funding Model (Wyatt Company/Stanford)
Actuarial consulting firms pension models
Macroeconomic-Demographic Model (NIA/CRA)
Pension Insurance Management System (PIMS) (Pension Benefit Guarantee Corporation stochastic microsimulation model of firms)

Intergenerational / Computable General Equilibrium Models (transition matrix/macro)

Auerbach-Kotlikoff Model
Imrohorogiu-Huang-Sargent Model

Microsimulation Models of Household and Family Demographic and Socioeconomic Behavior

Static

TRIM (Transfer Income Model) (Urban Institute)
MATH Model (Micro Analysis of Transfers to Households) (Mathematica Policy Research)
HITSM (Household Income and Tax Simulation Model) (Lewin Group, formerly ICF)
U.S. Treasury Individual Income Tax Simulation Model (OTA Model)

Dynamic

CORSIM (Steve Caldwell, Cornell University)
DYNASIM2 (Dynamic Simulation of Income Model) (Urban Institute)
PRISM (Pension and Retirement Income Simulation Model) (Lewin Group, formerly ICF)
Wolf Model for Simulating Life Histories of the Elderly (Urban Institute, under development)
DYNACAN - Canadian model (Canada Office of Supervisor of Financial Institutions)
PIMS (Pension Insurance Management System) (PBGC microsimulation model of firms)

Health Care Models

Aggregative or Cell-Based (transition matrix/macro)

HCFA Office of the Actuary National Health Expenditures Projection methodology
Macroeconomic-Demographic Model (NIA/CRA)

Microsimulation

Agency for Health Care Policy Research (AHCPR) Health Simulation Model (AHSIM)
HCFA Special Policy Analysis Model (SPAM)

Congressional Budget Office (CBO) modeling methodologies
Lewin Health Benefits Simulation Model (HBSM)
Price-Waterhouse models
Peat-Marwick models
Economic Policy Institute model
TRIM Health Expenditures Model
DYNASIM2 Disability and Long Term Care Model

VI. OTHER MODEL DISTINCTIONS

In addition to this classification by subject and approach, two other distinctions are relevant -- conceptual models versus simulation models, and structural models versus reduced form models.

A **conceptual model** refers to a theory about some aspect of behavior. This is the common use of the word "model" by social scientists in theoretical discussions. For example, discussions of the effects of pensions and social security on saving often refer to the "life cycle model" of consumption and saving. This is the theory or hypothesis that an individual's consumption in each period of his life is determined by what he expects his income to be over his whole life, not just what it is in that period. This life cycle hypothesis or "model" could provide the theoretical basis for the determination of savings in an empirical model of household economic behavior or a model of the national economy (as it is in several of the large macroeconomic forecasting models and in the Macroeconomic-Demographic Model of the U.S. Retirement Income System).

A **simulation model** is a mathematical specification of a system that depicts quantitatively how the system behaves.[1] It is usually a set of equations, with estimated coefficients and parameters, that depict the relationships among the variables represented in the model. The equations can be solved for values of the variables determined within the model (the endogenous variables) given the values of other variables determined outside the model (the exogenous variables) and the parameters. Such a simulation model is usually based upon several conceptual models.

The development of high-speed computers has permitted the construction of elaborate simulation models with many equations and variables, whose solution requires thousands of calculations. **Computer models** have become so common that, to many, "modeling analysis" often

[1] In some applications a simulation model could be a physical representation of a larger or more complex physical entity or of a physical-social system, such as a traffic control system or a production process. Physical models are rarely used to simulate social or economic systems, although physical models are sometimes used as pedagogical devices to illustrate the functioning of a market or of the national economy.

connotes the development and use of such a computer model. Almost all the models discussed in this report are computer based models.

Simulation can be used for research--to test the usefulness or validity of hypothesis or theories embodied in the model. The model can be simulated over a historic period and the predicted values of model variables can be compared to actual values to assess the validity of the theory behind the model.

Simulation can be used for policy analysis. Alternative policies can be simulated to predict how the system would behave if those policies had been implemented and to estimate their effects. Simulation models have been used to evaluate alternative fiscal and monetary policies and alternative social security benefit rules.

Simulation models can be used for forecasting the future values of the variables determined by the model (endogenous variables) if the values of variables determined outside the model (exogenous variables) can be forecast. Forecasting may be facilitated by the development of a **dynamic model**. In a dynamic model some of the current period endogenous variables are determined by lagged (past) values of endogenous variables. Previous period solutions of the model determine the values of the lagged endogenous variables, which then determine the current period values for some variables. Those variables then determine the values of other current period variables. The model is solved one period at a time to trace the behavior of the system through time. This is the structure of the major macroeconomic forecasting models, economic growth models, and dynamic microsimulation models, as well as the population projection models used by the U.S. Census Bureau and the Social Security Office of the Actuary.

Another useful distinction is between structural and reduced form models. The equations of a **structural model** depict what the model builder believes are basic causal relationships. A structural model often depicts the interactions among several endogenous variables of the model. To understand the underlying determinants of a system's behavior, one needs a structural model. Often the equations of a structural model can be solved to provide an expression for each endogenous variable in terms of exogenous variables only. These equations are called the **reduced form** of the model. A reduced form does not depict the actual causal relationships of the system. However, a set of reduced form equations can be used to predict how the endogenous variables respond to the exogenous variables.[2]

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[2] Structural form and reduced form can be illustrated by a very simple model of national income determination. Consumption (C) is a function of the level of national income (Y) in the current period:

$$C = a + bY$$

National income is simply the sum of consumption expenditures and government expenditures (G):

$$Y = C + G$$

Government expenditures are exogenous, i.e. determined outside this system. C and Y are endogenous.

While a reduced form model may provide predictions that are as good as the structural model, it is useful only as long as the structure of the system remains unchanged. If one wants to use a model to analyze or predict the effects of a policy that will change the structure of the system, a structural model must be used.

This simple two equation system is a *structural model*. The equations can be solved simultaneously for C and Y, if G and the parameters a and b are known. But, C and Y can also be expressed in terms of G directly:

$$C = (a/(1-b)) + (b/(1-b))G$$

$$Y = (a/(1-b)) + (1/(1-b))G$$

These two expressions are the *reduced form* of this model. Given G, they can be solved to predict C and Y. But they do not show the process by which C and Y are determined. The expressions in parenthesis represent a "black box" through which G "determines" C and Y. Nevertheless, they will provide predictions that are as good as the structural form equations, as long as the structure does not change.