THE DRI MODEL OF THE U.S. ECONOMY

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by Otto Eckstein

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PREFACE

This volume provides an account of the 800-equation Data Resources Model of the U.S. Economy. The model has been used for the last 13 years to forecast the U.S. economy and to analyze various policy proposals. It has also been available as a simulation tool to government agencies and private organizations to develop their own forecasts and policy analyses.

The initial DRI model was developed between 1968 and 1972, but it was rebuilt and substantially elaborated after the OPEC oil shock of 1974. The behavior of the economy changed considerably in the mid-1970s and various aspects of supply and finance needed to be represented more explicitly. The present volume describes the model as it has existed over the last half-dozen years.

The model is reestimated each year, after the national income account revisions become available in July. These reestimates reflect the forecasting and simulation experience of that year, as well as any structural changes that can be identified. The annual revision process has greatly complicated the production of this book because the model is continuously evolving. In general, the book describes the model used in 1981, although some of the simulation exercises were run earlier with model versions of the late 1970s.

This volume contains only a sketchy overview of the 200-equation financial sector of the model. This feature of the model, which is certainly among its most important innovations, will be presented fully in an accompanying volume by Allen Sinai.

The three opening chapters of the book have been published elsewhere in preliminary form. Chapter 1 appeared as an appendix in my book, *The Great Recession*; Chapter 2 was published in the volume, *Large-Scale Macro-Econometric Models,* J. Kmenta and J.B. Ramsey, editors. Chapter 3 appeared in my book, *Core Inflation.*

The DRI model was developed before the rise of the rational expectations school and is a structural model. While Chapter 2 contains some material which deals with the rational expectations issues, a fuller treatment will have to await future publications. The basic rationale for continuing to use structural models in the face of the rational expectations criticism is this: changes in policy regime seem to have been among the minor sources of structural change of the economy and of forecasting error in the actual

historical record. The principal obstacles to structural constancy and forecast accuracy seem to lie in the exogenous shocks of wars and OPEC, and in the unpredictability of the exogenous monetary policy variables. The central assumption of the rational expectations school, that the forecasts on which businesses and households make their decisions are free of bias and that markets clear instantaneously, so far do not seem to be confirmed by the historical record. Also, the basic theory underlying spending decisions in the DRI model emphasizes not only expected values, but also their variance, assuming decision-makers to be risk-averse; this is inconsistent with the stronger versions of the rational expectations viewpoint. But there are important lessons to be learned from the exciting recent works of this school. DRI is conducting various experiments based on the new approach, including forecasts using the monetarist, reduced-form versions of rational expectations models as well as adaptations of the large-scale structural model which substitute observable market expectations for some of the most important structural equations. It remains to be seen whether these experiments will lead to improved forecasts.

The presentation of empirical equations presents an expositional problem. Should the nearly incomprehensible mnemonics of the model be presented or should simpler expressions be substituted? Because this book is to be read in conjunction with the actual use of the model, the elaborate mnemonics are shown. Also, the full printout of test statistics is shown. To make this material more readable, each exhibit is self-contained even at the expense of repetition, with all variables defined verbally in each table.

The book does not contain all 800 equations of the model. To present them all would make the book enormous and indigestible, and in any event, the equations are reestimated every year. But the important equations are shown and, in the case of the more detailed sectors of the economy, each type of equation is illustrated by example.

* * *

An 800-equation model, reestimated each year, clearly requires a sizable team effort, and many members of DRI's National Forecasting Group have contributed ideas and equations over the years. But a few individuals can be singled out for the importance of their contributions to the effort.

Allen Sinai developed the financial sector, including the elaborate modeling of the flows-of-funds for household and corporations. He also contributed ideas on various final demand equations, particularly in the use of financial variables to integrate the real and financial systems. This work was

particularly significant in the case of the equations for investment, where interest costs in relation to cash flow and a comprehensive, multiple-source measure of the cost of capital were introduced. Comprehensive measures of net worth play a role in some of the consumer equations, and the housing equations contain a detailed treatment of the impact of mortgage supplies. These variables heighten the sensitivity of the real sector to financial fluctuations.

Over these 14 years, I have worked with an exceptionally capable series of young economists concentrating on the annual respecifications of the model. Christopher Probyn, who held this post over the last two years, developed model Version 1981C, which is most heavily represented in this volume. Among his predecessors who made major contributions to the model are Edward L. Green, the first to hold this position, Andrea Kusko, Richard Hokenson and Frank Cooper.

Douglas Rice and Robin Siegel developed much of the energy sector, and Rice also made a particularly significant contribution in developing the algorithm which brings the income and expenditure sides into consistency. The equations for exports and imports were initially developed by Christopher Gutry and developed further by Brigitte Sellekaerts. The equations for production, applying time series analysis to input/output estimates, were developed by V. Sundararajan, and developed in later versions by Peter Jones, Edward Green, David Gigante and Michael Cebry. Lester Thurow and Samuel Rea produced the equations for the age-sex-race breakdowns of unemployment, and James Connor developed the industry employment equations.

Important contributions to the consumer sector were made by Edward Green and Gina Rogers. The housing sector has benefitted from the work of Robert Gough and from the earlier versions developed by Eric Herr and Donna Petlock Rubin. Sara Johnson improved the state and local government sector, the wage-price block and the equations for exports and imports. The model simulation program was developed by Robert Lacey, and the initial version of the model was programmed by Rosann Cahn. Terry Glomski and Roberta Gerson contributed to the development of the financial sector. Martin Feldstein developed an initial set of financial equations.

This book has benefitted from a close editorial reading by Allen Sinai. Responsibility for any errors and omissions remains mine, however. The manuscript was produced by Lyn Hadden and she saw the book through the entire publication process.

Otto Eckstein
November 1982
Lexington, Massachusetts

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

THE DRI MODEL: HISTORICAL PERSPECTIVE AND AN OVERVIEW

1. Introduction

The Data Resources Quarterly Model of the U.S. Economy (the DRI model) is an 800-equation structure. The model depicts the decision processes of businesses, households, financial institutions and governments, and shows how they interact to produce the economy's broad movements. It is a vehicle for formalizing the existing state of knowledge about the economy's functioning and for processing the information contained in historical and current data. The model is used for forecasting the U.S. economy both short and long term, for policy analysis of a variety of government actions, and for driving the microeconomic models of specific industries, companies, products, costs and other variables of particular importance to private and public agencies.

This volume is an account of the DRI model structure and the characteristics it portrays for the behavior of the actual U.S. economy. It describes the structure in the versions used in the period 1978-81. While many of its essentials have been retained over much of its thirteen-year history of use, changing ideas and data have produced a continuing evolution of its structure.

2. Historical Perspective: The First Generation

Econometric models for advanced industrial economies have gone through three generations. The first generation began with Tinbergen's pre-war models of the Dutch and U.S. economies.[1] After the hiatus of World War II,

[1]Jan Tinbergen, *Selected Papers* (Amsterdam: North-Holland Publishing Co., 1959), pp. 36-84, and *Business Cycles in the United States of America: 1919-1932* (Geneva: League of Nations, 1939).

when even the U.S. economy was controlled and planned, Lawrence Klein began the American tradition of model building.[2] The early Klein models of the late 1940s and 1950s were very much in the Keynesian tradition, modeling the circular flow of income and expenditure. The principal equations explained the major components of final demand including consumption, fixed investment, inventories and housing. Government demands and exports were exogenous. The income side accounted for the gross national product in terms of the total wage bill, taxes, profits, and the other components of national income. The models were typically expressed in real terms, with the price-wage mechanisms superimposed in nearly recursive fashion and in highly aggregated terms.

Other investigators built models with some significant variations. Colin Clark[3] developed a quarterly business-cycle model in the late 1940s which emphasized the inventories mechanism as the principal source of short-run variation, basing it on sales expectations and cash balances. Duesenberry, Eckstein and Fromm[4] built a simulation model designed to analyze anti-recession policies in more detail, including the use of decision rules for particular instruments and stochastic simulation experiments. The OBE (later BEA)[5] and Michigan models[6] were based on the earlier work of Klein.

By today's standards, the first-generation models were small, beginning with Klein's original twelve-equation model and expanding to thirty-two equations in the Michigan model. Dynamic structures were much simpler, and the equations were limited to the larger aggregates of the national income accounts because of computational constraints.

3. The Second Generation

The second generation of macroeconometric models began in the early 1960s with the development of the large-scale Brookings model,[7] and continued

[2]Lawrence R. Klein, *Economic Fluctuations in the United States: 1921-1944*, Cowles Commission Monograph No. 11 (New York: Wiley, 1950); and Lawrence R. Klein and Arthur S. Goldberger, *An Econometric Model of the United States, 1929-1952* (Amsterdam: North-Holland Publishing Co., 1955).

[3]Colin Clark, "A System of Equations Explaining the United States Trade Cycle, 1921-1944," *Econometrica* (June 1949), pp. 93-124.

[4]James S. Duesenberry, Otto Eckstein and Gary Fromm, "A Simulation of the U.S. Economy in Recession," *Econometrica* (October 1960), pp. 749-809.

[5]Maurice Liebenberg, Albert A. Hirsch and Joel Popkin, "A Quarterly Econometric Model of the United States: A Progress Report," *Survey of Current Business* (May 1966), pp. 13-39.

[6]Daniel B. Suits, "Forecasting and Analysis with an Econometric Model," *American Economic Review* (March 1962), pp. 104-132.

[7]James S. Duesenberry, Gary Fromm, Lawrence R. Klein and Edwin Kuh, eds., *The Brookings Quarterly Econometric Model of the United States* (Chicago: Rand McNally, 1965).

with the early versions of the Wharton[8] and the Federal Reserve-MIT[9] (now MPS) models. The Data Resources models up to 1974 also fall in this general category. Each represented a sizable team effort spanning several years, and consequently contained considerably more disaggregated and elaborate equations for the final demands, incomes, labor markets, and wages and prices. The Brookings and Fed-MIT models were primarily testing grounds for new theories and the technology of larger-scale model building. The Wharton model went beyond the earlier pioneer forecasting of the Michigan model and earlier Klein models, to provide the first intensive quarterly forecasting effort aimed at replacing previous informal methods. The DRI model was part of the development of the first national economic information system and was primarily designed for forecasting and policy analysis.[10]

These models were larger than their antecedents. The initial version of the Brookings model contained 150 equations, the 1976 Wharton model about 200 equations. The original Fed-MIT model had sixty-six equations, but the later version (MPS) grew to 175 equations. Early versions of the DRI model (e.g., 1971) had about 300 equations. The increased size was due to the desire to model the economic processes more fully as inputs to institutional decision making. Faster computers and better programs allowed the more efficient development of equations and made solutions of larger models practical.

The principal advances sprang out of the general econometric work of the field as a whole. The Brookings model project energized many scholars to make their results usable in the large-model context. The Almon and Koyck methods for estimating distributed lags made more precise dynamic structures possible. Jorgenson's neoclassical theory of investment had become available. The lifetime consumption theories of Modigliani, Ando and Brumberg opened up new possibilities for the consumer sector. The wage and price equations developed by Phillips, Lipsey, Eckstein, Wilson, Fromm, Perry, Schultze and others allowed better—if still inadequate—wage-price sectors. And, particularly in the MPS model, the Jorgenson technique of defining synthetic time series variables derived from profit-maximization

[8]Michael K. Evans and Lawrence R. Klein, *The Wharton Econometric Forecasting Model* (Philadelphia: Economic Research Unit, University of Pennsylvania, 1967).

[9]Frank De Leeuw and Edward M. Gramlich, "The Federal Reserve-MIT Model," *Federal Reserve Bulletin* (June 1969), pp. 11-40; and Albert Ando, Franco Modigliani and Robert Rasche, "Equations and Definitions of Variables for the FRB-MIT-PENN Econometric Model, November 1969," in *Econometric Models of Cyclical Behavior*, Bert Hickman, ed. (Cambridge, Mass.: National Bureau of Economic Research, 1972), pp. 543-598.

[10]Otto Eckstein, *The Data Resources Econometric Forecasting System, A Preliminary Account* (Lexington, Mass.: Data Resources, Inc., April 1970); also "The Organization and Retrieval of Economic Knowledge," Kiel Symposium of the International Economic Association, July 1975, and "Information Processing and Econometric Model Forecasting," Paper presented to the Ottawa Meeting of the Econometric Society, June 1977.

assumptions was carried over into other demand equations: rental price concepts were defined for housing and the consumption of durable goods as a means of introducing neoclassical relative price effects and overcoming the attendant difficulty of multicollinearity.

Besides this general progress in macro-econometrics, the second generation of models was characterized by five major innovations: (1) the use of input-output analysis to calculate production in a time-series framework; (2) the development of financial sectors; (3) the introduction of endogenous behavioral equations for state and local government taxes and expenditures; (4) the use of explicit demographic elements, thereby blurring the previous distinctions between short- and long-run models; and (5) social indicator equations.

3.1 Input-Output Analysis

Input-output analysis was introduced into time series-oriented econometrics by Arrow and Hoffenberg,[11] who developed a technique for combining the fixed-coefficient, Leontief-matrix estimates of industry production with technologically based time trends that shift the relationships, and with systematic cyclical variables. The initial attempts to apply the technique empirically were not successful. The Brookings model[12] used a simpler approach to incorporate input-output into a full-scale econometric model, a technique which combined the fixed-coefficient estimate with an autocorrelative adjustment that automatically corrected the observed errors by extrapolation. The DRI model[13] developed the Arrow-Hoffenberg technique by modeling the trend and cycle influences on production coefficients more elaborately and by correcting for other limitations of the available input-output tables. The current DRI model uses an eighty-four-industry, input-output matrix to calculate the Leontief estimates of production, which are then aggregated and applied in fifty-six quarterly industry production equations.

[11]Kenneth J. Arrow and Marvin Hoffenberg, *A Time Series Analysis of Interindustry Demands* (Amsterdam: North-Holland Publishing Co., 1959).

[12]Franklin M. Fisher, Lawrence R. Klein and Y. Shinkai, "Price and Output Aggregation in the Brookings Econometric Model," in *The Brookings Quarterly Econometric Model of the United States*, eds. J. S. Duesenberry et al. (Chicago: Rand McNally, 1965), pp. 653-679; and Gary Fromm and Lawrence R. Klein, "Solutions of the Complete System," in *The Brookings Model: Some Further Results*, eds. J. S. Duesenberry et al. (Chicago: Rand McNally, 1969), pp. 362-422.

[13]V. Sundararajan, "A Flexible Coefficient Bridge Model: Trend-Cycle Adjustments in Input-Output Analysis," (unpublished, 1971).

3.2 Financial Sectors

The introduction of financial sectors into large-scale models must be credited to Frank De Leeuw, who did the initial work for the Brookings model.[14] This financial sector consisted of nineteen equations for the demand and supply of money, time deposits of commercial banks, U.S. Government securities, household and business debt, savings accounts, and several interest rates. The short-term, 90-day Treasury bill rate was estimated from the relationships among loan demands, commercial bank deposits and the bank reserves provided by monetary policy. The resultant short-term rate then became the principal device for estimating the long-term interest rate through the long-established term-structure theory, modified by the supply of government securities. Interest rates were determinants for several kinds of spending including investment through the cost of capital, housing principally through the relationship between short- and long-term interest rates, and public construction for schools through the long-term rate.

The Federal Reserve-MIT (MPS) model substantially expanded the financial sector, integrating it increasingly with the real sectors. In particular, it added a model of the mortgage market which showed how major financial intermediaries allocated savings inflows to mortgages. The model also strengthened the importance of other financial effects in some spending equations. The mortgage market conditions became prime determinants of housing activity.[15] The stock market became a prime mover of household wealth which, in turn, was a determinant of consumer spending.

The early DRI models modified this approach by assuming a two-sector capital market. The long-term interest rate was determined independently of the short rates, principally from inflation expectations and the supply of liquidity provided by monetary policy in relation to the level of aggregate economic activity.[16] Later editions of the model contained expanded financial sectors of this type, adding twenty-four interest rates, with particularly elaborate modeling of the mortgage market and the behavior of the various financial intermediaries.[17]

[14]Frank De Leeuw, "A Model of Financial Behavior," in *The Brookings Quarterly Econometric Model*, eds. J.S. Duesenberry et al., pp. 465-530.

[15]Edward M. Gramlich and Dwight M. Jaffee, eds., *Savings Deposits, Mortgages and Housing* (Lexington, Mass.: D.C. Heath & Co., 1972).

[16]Martin S. Feldstein and Otto Eckstein, "The Fundamental Determinants of the Interest Rate," *Review of Economics and Statistics* (November 1970), pp. 363-375.

[17]Otto Eckstein, Edward W. Green, and Allen Sinai, "The Data Resources Model: Uses, Structure and Analysis of the U.S. Economy," *International Economic Review* (October 1974), pp. 595-615.