An application of consistent statistical estimation to a nonlinear macroeconomic policy model

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An application of consistent statistical estimation to a nonlinear macroeconomic policy model

by

Raphael Joseph Michalski

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CHAPTER I. INTRODUCTION

In recent years nearly every edition of the daily newspaper and every T.V. newscast has carried reports of the federal government's current economic policy -- its plans for stabilizing prices and interest rates and reducing unemployment. The socially disturbing problems of a rising rate of prices coupled with an unacceptable high rate of unemployment led to this attempt to improve one of the econometric tools available to economists who are trying to solve this price-unemployment dilemma.

The tool is the empirically estimated macroeconomic policy model. The improvement suggested and illustrated in this dissertation is a newly derived and practical statistical estimation method coupled with already well-known but not yet applied statistical techniques -- at least not yet applied to the existing large well-known macroeconomic policy models. This new estimation technique is Wayne Fuller's modified limited information maximum likelihood estimator, MLIML (Fuller 1977).

One major benefit resulting from the application of MLIML estimator coupled with already known methods of estimation is consistent estimation of the parameters of the model.

There are three F statistics that can be applied to test whether a particular structural equation is properly specified, proper-
ly identified, and subject ordinary least squares' (OLS) bias for this equation. No comparable tests have been applied to the existing well-known macroeconomic policy models, or at least such tests have not been reported. The first two tests are of great practical importance due to the fact that specification is perhaps the chief cause of a poor statistical fit for an equation with the consequence that the system as a whole performs poorly and that no easily applied rules of identification exist for nonlinear systems.

More specifically, this dissertation applies economic and statistical theory to (1) specify realistically the structural equations and identities of the medium size nonlinear macroeconomic model of the U.S. economy, (2) select a relevant and reliable sample of data, (3) estimate the parameters of the model with MLIML which, together with other appropriate statistical methods, yield consistent estimates as well as the first two $F$-tests helpful in specifying the structural equations and deciding whether they are empirically identified, (4) apply the Gauss-Seidel numerical analysis algorithm to solve the nonlinear system to equations to see whether the system converges and, if it converges rather than explodes, how well it tracks the historical paths of key economic time series over the period 1969.III - 1971.II, and (5) predict ex-post the historical paths of all endogenous variables over the four quarters of 1975.III - 1976.II.
Originally, this dissertation was to include the application of a Conjugate Gradient Optimal Control algorithm to a policy-making objective functional restricted by the estimated system of equations. This would have led to optimal paths over time of one or more control or instrumental variables needed to lead selected target variables to follow their ideal or desired paths called for in the objective functional.

In particular, unborrowed reserves at member banks plus currency was to be the practical monetary control variable. Federal government expenditures on goods and services and the Federal income tax liability were the fiscal control variables. While optimal control will not be applied in this dissertation, these three exogenous variables will be changed from their historical values in order to shock the model over the period of the 1969-1970 recession using the Gauss-Seidel algorithm. The resulting multiplier analysis will indicate how the historical paths of selected target variables would have been affected had government authorities chosen to implement alternative stabilization policies.

The original intent to use optimal control must be kept in mind in order to understand the restricted size (30 endogenous, 37 exogenous variables), shortened lags (with the one exception of expected inflation, no lag is longer than 5 quarters), and in general, simply structured behavioral relations in an effort to reduce the high computer costs of the iterative conjugate gradient method.
A main objective, economically speaking, in developing the thirteen structural equations of this model was to build in strong, yet realistic, financial-real sector interaction. The word "financial" here is used to include not only the monetary sector but other important financial institutions and instruments that occur in our economy. This objective immediately distinguishes the theoretical orientation of the model from the so-called monetarist approach of the St. Louis Federal Reserve Model (Andersen and Jordan, 1968). The specification of the latter rests on the modern quantity theory of money. The model consists in a single reduced-form equation in which quarter-to-quarter changes in GNP are regressed on quarter-to-quarter changes in the money stock and in measures of fiscal actions: high employment budget surplus, high employment expenditures, and high employment receipts. While the financial-real linkage is certainly strong in the St. Louis Model, it is restricted to the influence of the change in money stock and neglects the complex and more realistic financial-real linkage found in most current well-known models whose specifications depend more on the portfolio approach developed primarily by a neo-Keynesian, James Tobin (1956, 1958, 1965, 1969). According to portfolio theory, changes in the money stock do affect decisions to purchase or sell real goods and services. However, money is only one financial asset among many. The
financial sector of portfolio theory includes the money market, commercial banks, the capital market, savings and loans and other financial intermediaries in addition to the stock of money. As a result, the monetary transmission mechanism is complex and indirect via changes across a broad spectrum of interest rates and rates of return, each with different risk-return characteristics. This dissertation follows both modern Keynesians and monetarists in recognizing three channels of monetary policy: the cost-of-capital effect; the wealth effect; and the credit rationing effect (deLeeuw and Gramlich 1969, Spencer 1974, Brunner and Meltzer 1972).

Now the first paragraph of this introduction argued that there is a need for stabilization policy, if only to speed up the inherent long run process of adjustment necessary for price stability and full employment. Franco Modigliani devoted his Presidential Address at the eighty-seventh meeting of the American Economic Association arguing not only that current instability needs a stabilization policy, but that improved stability since 1937 in the U.S. indicates that Keynesian-type policy can work and, hence, ought to be used (1976).

This dissertation, however, makes no attempt to solve current disputes in macroeconomic theory. Nor is it an attempt to build a more realistic macromodel of the U.S. economy than some of the models already existing, although hopefully it could be used for stabilization purposes should federal government officials decide to do so. Rather, this dissertation is primarily an attempt to build a moderate-size
macro model with hitherto unused statistical techniques that easily could be used to help specify the structure and to consistently estimate the parameters of much larger and more sophisticated models and, thereby, theoretically at least, improve their performance in stabilization-policy experiments.
CHAPTER II. THE MACROECONOMIC MODEL

Lawrence Klein and Gary Fromm reported recently on a NBER/NSF seminar in which the proprietors of the most influential models of the U.S. economy met and compared results (1976). The models represented were: The Bureau of Economic Analysis Model (BEA or OBE), The Data Resources Inc. Model (DRI), the Fair Model, The Federal Reserve Bank of St. Louis Model (FRB, St. Louis), the M.I.T.-Pennsylvania-S.S.R.C. Model (MPS), the Wharton Mark III Model, the Stanford University Model (H-C Annual), the Wharton Anticipations Model, and the Cornell University Model (Liu-Hwa Monthly).

They characterized their models according to:

(1) time frame:
   annual
   quarterly
   monthly

(2) scale:
   very large (more than 200 equations)
   large
   medium
   small (10-49 equations)

(3) disaggregation:
   high
   medium (16-20 sectors)
   limited (2-6 sectors)
   none

A fifth category could have been added, viz., linear or nonlinear in the variables.
Thus, the Anderson-Jordan St. Louis Model described above in Chapter I is linear, quarterly, very small, has no disaggregation and no endogenous financial-real interaction, i.e., no feedback from the endogenous financial variables of the model to the real endogenous variables and vice-versa. On the other hand, the 1975 version of the MPS Model is nonlinear, quarterly, large (200 equations), medium in disaggregation (20 sectors), and has the strongest endogenous financial-real interaction of all the models participating. Moreover, in the NBER/NSF Seminar, the MPS Model was found to track real GNP for the first four quarters from initial values better than any model except the Wharton Anticipation version and Fair's small model. Over the long run, i.e., more than eight quarters, it outperforms Fair's model but is surpassed by the St. Louis and DRI Models. With respect to real consumption, investment in plant and equipment, inventory investment, residential construction, unemployment, the short term interest rate and money supply (M1), it ranks second or third over eight quarters, depending on the variable. It ranks first in long-term interest rate, corporate profits and man-hours demanded, but last in prices and wages. Only the DRI and Brookings Models have a better general record over eight quarters. Unfortunately, there were no results present at this seminar by the MPS authors for the post-sample prediction analysis, but Frank de Leeuw and Edward Gramlich reported on a mixed within-and post-sample prediction with an earlier version of the MPS for the six quarters of 1965.III - 1966.IV (1968). The root mean square error for GNP was 3.9442. None
of the other models in the seminar could match this, but they, of course, reported pure ex-post predictions. Finally, in an exhaustive analysis of business cycle turning point incidence, Zarnowitz, Boschan, Moore, and Su (1972) found that the MPS Model predicted turning points better and, in general, had lower mean absolute error of relative change to mean absolute actual relative change ratios than the OBE and Wharton Models.

According to Howrey, Klein and McCarthy (1974), the ability of a model to track turning points might be more important for policy purposes than the average error over the entire sample period. One reason for the MPS's ability to track turning points and predict well is the use of anticipations data such as an expected rate of change of price variable, housing starts, and orders for producers durables. Impressive as the empirical evidence is, pointing to the relatively good simulation and predictive properties of the MPS Model, the realistic and sound theoretical structure underlying the MPS Model is equally impressive and important for policy purposes. One of the chief architects of the MPS Model, Albert Ando, explains why in a recent article (1974):

"We have tried to show how some misleading conclusions have been presented in the literature previously because some authors analyzed stabilization questions using partial models which ignore some important aspects of macroeconomic systems. Such models may enable us to obtain clean cut analytical results, but at the expense of losing any correspondence to the real economy. While it gives us less aesthetic satisfaction to work with a complex model and to conclude that many important conclusions depend on numerical estimates of parameters, in the analysis of economic stabilization, there is no alternative but to accept this conclusion and to engage in the hard and unglamorous task of obtaining best estimates for numerical values of those critical parameters."
The MPS Model is unique in that roughly half of its behavioral equations are concerned with fiscal and financial variables. It concentrates on the structure of financial markets, especially the monetary transmission mechanism whereby a change in money influences the effective demand for real goods and services and thereby the level of income, prices, wages, and employment, as well as the mechanism whereby real output feeds back to the financial sector. More than any other existing model, the MPS Model incorporates the realistic macroeconomic portfolio theory discussed in Chapter I. This theory considers money as an asset substitutable for existing real assets as well as financial assets and provides a sound explanation for the interrelation of asset yields or prices, output prices and interest rates. Whereas the Wharton, Michigan, OBE, and Brookings Models find that monetary forces are relatively unimportant in influencing total demand - in sharp contrast to the historical evidence pointed to by monetarists - the MPS Model, following portfolio theory, deliberately focuses on the same general channels of the monetary transmission process recognized by leading monetarists: substitution or cost of capital effects affecting single and multiple family housing, plant and equipment, and investment in consumer durable goods via changes in prices of financial assets and real assets; wealth effects affecting first household net worth and consumption via changes in real cash balances and equity values; and then credit rationing effects in the housing market. All of these make the MPS Model capable of explaining better than other existing models.
the effects of changes in monetary as well as fiscal stabilization policy instruments on the economy.

Thus, for both theoretical and empirical reasons, the model of this dissertation (called the RJM Model) is patterned roughly after the MPS Model. Unlike the MINNIE-MPS, a collapsed version (63 equations) of the MPS Model (Battenberg, Enzler, and Havenner 1975), none of the structural relations of RJM are simply taken in their exact form from the MPS Model. All attempt to express the theoretical content of the corresponding equations in the MPS Model, but in every instance the lag structure, the nonlinearity and/or the variables used to specify the equation are either shortened or simplified or replaced or deleted.

In many instances, the difference is radical. The two crucial differences are that, on the one hand, the parameters of the RJM Model are estimated by a superior method, statistically speaking, while, on the other hand, the RJM Model is much more highly aggregated. The former difference is treated in detail in Chapter III. It should enhance the performance of RJM. The latter difference should impede the performance of RJM, but not greatly, at least for the short-run, as evidenced by the relatively-good short-run performance of the small Fair Model. Thus, for example, RJM includes only one price variable, PGNP, the GNP deflator, while MPS includes 15 or 20. This implies that any application of theory involving relative prices, as in consumer durables and other investment expenditures and in the dynamic adjustments of the net worth identity, are precluded for the RJM Model. Likewise, it has only one
short-term and one long-term interest rate in contrast to a variety of each in the MPS Model. Yet, like the MINNIE-MPS, the intent is to preserve the basic features of the larger model—especially the short-run dynamic response to policy instruments. RJM is quarterly, nonlinear in the variables, strong in endogenous financial–real interaction, (originally 38 equations of which 19 were structural, but finally 30 equations of which 13 are structural), and medium in disaggregation (9 sectors, following somewhat the MPS method of defining a sector but collapsing 3 MPS sectors into one "financial" sector).

The Consumption Sector

Operationally, consumption is defined as

\[ \text{CON} = \text{ECN} + \text{YCD} + \text{WCD} \]  

(2.1)

where ECN is the consumer expenditure on non-durable consumption goods and consumer services, YCD is the net yield on the stock of consumers durables, and WCD is the depreciation of the stock of consumer durables. Thus, specifically

\[ \text{WCD}_t = .225 (0.25 \text{ECD}_t + \text{KCD}_{t-1}) \]  

(2.2)

\[ \text{YCD}_t = .0379 (0.125 \text{ECD}_t + \text{KCD}_{t-1}) \]  

(2.3)

where \( \text{KCD}_{t-1} \) is the initial stock of consumer durables, .225 in (2.2) is the annual rate of depreciation; \( 1/4 \) or .25 multiplies ECD, expenditures on consumer durables, since ECD is the quarterly flow at an annual rate and hence needs to be converted into quarterly rates.
In (2.3) .0379 is an estimate of the average yield rate for consumer durables\(^1\) and .125 is arrived at by the same reasoning as for .25 in (2.2) plus the assumption that ECD occurs evenly over the quarter and, therefore, on the average, the yield rate should be roughly one-half of the yield rate of the initial stock. But one-half of .25 is .125.

\[ YCD + WCD \text{ may be interpreted as "consumption" of durables and} \]

\[ YCD_t + WCD_t = \{(.225 \times .25) + (.0379 \times .125)\} ECD_t + (.225 + .0379)RCD_{t-1} \]  

where "\(*\)" is the symbol for multiplication. Hence, CON, ECN, and ECD are related by accounting identities, so that only two of these variables can be independently and simultaneously determined. Since the Life-Cycle Theory of consumption behavior stresses CON as the basic behavioral concept to be explained in the long run, the two structural equations of this sector are the consumption function, CON, a flow of services, and the expenditures on consumer durables equations, ECD. The consumption function is the backbone of any macroeconometric model because consumption is such a large portion of GNP. For this model the consumption function is an adaptation of the MPS equation which, in turn, is based on the Life-Cycle hypothesis of saving developed by Modigliani, Brumberg and Ando (1963).

\(^1\)The MPS authors use the average 1958 corporate bond rate, RCB = .0379, as their proxy for the average yield on consumer durables.
For their purposes, consumption is the sum of the consumption of nondurables and the services of both nondurables and durables. Hence, the separate equation for expenditures on durables. Starting with the individual consumer's utility function, this theory assumes that the consumer maximizes his utility, \( U = U(\text{CON}_t, \text{CON}_{t+1}, \ldots) \), subject to the resources available to him, i.e., subject to the sum of his current and discounted future earnings over his lifetime and his net worth or the value of his assets at the beginning of the period, \( A_{t-1} \):

\[
\sum_{i=t}^{L} \frac{C_i}{(1+r)^{i-t}} = A_{t-1} + \sum_{i=t+1}^{N} \frac{Y_i}{(1+r)^{i-t}}
\]

where \( N \) = earning periods left.

Since they assume that optimal consumption over time follows the same pattern year after year, so that \( C^*_{t+1} = k_{t} C^*_t \) all \( t \), an individual's optimized consumption function can be derived by substituting optimal consumption into (2.5) and solving for desired consumption in period \( t \):

\[
C^*_t = g_{t} (A_{t-1} + Y_t + \sum_{i=t+1}^{N} \frac{Y_i^e}{(1+r)^{i-t}})
\]

\[
= g_{t} A_{t-1} + g_{t} Y_t + g_{t} (N-t) Y_t^e
\]

where \( Y_t^e = \frac{1}{N-t} \sum_{i=t+1}^{N} \frac{Y_i^e}{(1+r)^{i-t}} \).

The aggregate consumption function is not simply a sum of the community's individual consumption functions, since each age group has a different earning span and a different current net worth. Under at
At least five assumptions, they conclude that the parameters of the aggregate consumption function depend on current nonproperty income, expected future nonproperty income, the over-all rate of growth of income, which in turn depends on the population growth and productivity growth, and the rate of return on assets.

Although this theory calls for some concept of nonproperty or labor income, in this empirical model the MPS builders settle for a distributed lag of disposable income or total income after taxes. The shape of this lag was determined empirically by the use of a 2nd degree polynomial. A similar method will be treated in the next chapter. The net worth identity, $VN$, defined by (2.56) below, attempts to accurately reflect the ability of consumers to command future consumption, i.e., to reflect the market value of consumers' physical and financial assets less the value of debts. One of the consumer's assets are common stocks in corporations, whose value usually fluctuates suddenly in the short run. If there are substantial transaction costs and brokers' fees, consumers may look to the long run instead of adjusting their portfolios immediately, even when they believe assets are temporarily under or over-valued by a rise or fall in stock market prices. Hence, a short distributed lag of past net worth in addition to the current value is relevant to the consumption function. Finally, since consumption-per-capita more closely approximates the aggregate version of the individual's consumption function, both sides of the equation are divided by population, $N$. The original equation estimated in the RJM Model
closely resembles the MPS equation with the exception of shorter lags and the use of the GNP deflator, \( \text{PGNP} \), instead of the more appropriate \( \text{PCON} \), and is expressed by

\[
\left( \frac{\text{CON}}{N} \right)_t = a + \sum_{i=0}^{4} b_i \left( \frac{\text{YD}}{N} \right)_{t-i} + \sum_{i=0}^{4} c_i \frac{\text{VCNS}}{(.01 \times \text{PGNP} \times N)_{t-i}} + U_t
\]

The second structural equation of the consumption sector is that of expenditures on consumer durables, \( \text{ECD} \). This choice was made in the MPS Model rather than \( \text{ECN} \) because the determination of \( \text{ECD} \) is theoretically different from the determination of \( \text{CON} \). The purchase of consumer durables amounts to an investment decision, while the behavior determining \( \text{ECN} \) is broadly similar to that determining \( \text{CON} \).

The formulation of the demand for consumer durables is a simple form of the standard stock-flow adjustment model of investment:

\[
\left( \frac{\text{ECD}}{N} \right)_t = k \left( \frac{\text{CON}}{N} \right)_t (b_1 + b_2 \frac{P_t}{N}) + a - \frac{\text{KCD}_{t-1}}{N_t}
\]

where \( k \) = the speed of adjustment, \( P \) = some relative price variable measuring the cost of holding a unit of durables in terms of other consumption goods, \( \left( \frac{\text{CON}}{N} \right)_t (b_1 + b_2 \frac{P_t}{N}) + a \) approximates the desired level of stock, since durables are assumed to be superior goods so that their stock should rise if \( \frac{\text{CON}}{N} \) does, and \( \text{KCD}_{t-1} \) = actual stock of durables at the beginning of the period \( t \).
The MPS Model uses

$$p_t = \sum_{i=0}^{5} v_i \left( \frac{PCD}{PCON} \right) t-i \cdot (2.9a)$$

where RCB is the corporate bond rate, PCD is the consumer durables price deflator, PCON is the consumption price deflator, and $v_i$ are weights to be estimated. Net addition to the stock of consumer durables, \(ECD - (YCD + WCD)\), is part of saving by consumers. Since the life-cycle hypothesis allows that this form of saving might arise from transitory income, current disposable income per capita is added to this equation.

Finally, two expectation variables are added, viz, housing starts and expected inflation. Housing starts for single family units are a proven indicator of durables investment consequent to the investment decision to buy a new house. Starts represent a discernable step in the process of residential construction and with that construction comes furnishings and appliances.

They added a proxy for expected inflation, EINFL, defined for the RJM Model in (2.37), below. Apparently after 1966-67, the expected rate of change of prices began to affect interest rate expectation so that the "real" long-term interest rate then became:

$$r_t = RCB_t - EINFL_t \quad (2.9b)$$

Finally, after encountering considerable difficulty with multicollinearity and heteroskedasticity, the MPS equation was divided on both sides by \(\frac{CON}{N}\) to give a variable nonlinear in the endogenous variables,
To avoid unnecessary nonlinearities and, in keeping with RJM's need to aggregate and simplify where possible without losing the essential theoretical orientation of MPS, the RJM Model diverges considerably from the MPS Model and looks to the equations used in the Wharton (McCarthy 1972) and Brookings Models (Fromm, Klein, and Schink 1972). The last two mentioned used lagged dependent variables for both durables and nondurables as a partial adjustment mechanism. In addition to relative prices, the Wharton Mark III relies upon a liquidity variable and unemployment to explain expenditures on durables.

The RJM Model adopts the lagged dependent variable approach of the Wharton and Brookings Models. A distributed lag of the "real" corporate bond rate, $RCB-EINFL$, serves as a proxy for the expected rental price of durables or the opportunity cost of holding durables.

Because housing starts is an endogenous variable in the MPS Model but not in RJM and because federally subsidized housing starts ($ZHS$) is an exogenous variable in MPS, its distributed lag is included in RJM along with the lagged stock of durables and the lagged dependent variable to give the expenditures on consumers durables equation:

$$ ECD_t = a_0 + a_1 \left( \frac{YD}{N} \right)_t + \sum_{i=0}^{4} b_i (RCB - EINFL)_{t-i} + \sum_{i=1}^{4} c_i ZHS_{t-i} + d \left( \frac{KCD}{N} \right)_{t-1} + e ECD_{t-1} \quad (2.10) $$

Given the definition of $WCD_t$ in (2.2), the stock of consumer durables is defined as:
\[ K_{t} = .25(E_{t} - W_{t}) + K_{t-1} \]  

(2.11)

where .25 or 1/4 is again used to give quarterly rates.

The consumption sector is closed by the national income accounts definition of total personal consumption expenditure:

\[ EPCE_{t} = ECN_{t} + ECD_{t} = CON_{t} - WCD_{t} - YCD_{t} \]  

(2.12)

\[ + ECD_{t} = CON_{t} + ECD_{t} - .0379 \left\{ \frac{ECD_{t}}{8.0} + KCD_{t-1} \right\} \]

\[ - \{ .05625 ECD_{t} + .225KCD_{t-1} \} \]

Given these equations, it follows that monetary policy can affect consumer demand via all three channels: The cost of capital (rental cost of durables), the wealth effect, and the credit rationing effect. Government expenditures and taxation policies have a decisive impact on consumers through their effects on disposable income and inflation.

The multiplier mechanism relevant to this consumption sector arises from two relations: the consumption function (2.7) linking consumers' expenditures to their resources and the set of mechanisms linking consumers' resources to GNP. Although Model RJM has "watered down", somewhat, the MPS consumption sector, it still retains the essentials of portfolio theory as applied to consumption expenditure: consumers must decide to buy nondurables to consume now or to invest in durables and consume later.
The Housing Sector

A second and weightier investment decision faces consumers in the housing market. The cost of capital for housing in the MPS model is derived using relative prices, a mortgage rate, the corporate bond rate, plus various taxes and depreciation rates. Then, using this housing cost of capital and consumption per capita, elaborate equations are estimated for unsubsidized housing stocks and starts before the expenditures on residential construction equation is estimated, depending on these starts, current and lagged. However, the 10 equations of the MPS housing sector are aggregated into two in the RJM Model.

The first equation is the most eclectic in the RJM Model. It adopts elements from the MPS, Wharton Mark III, and Pindyck (1973) Models. Consumption per-capita relates the housing investment decision to permanent income and wealth via (2.7). If one expects higher income in the future or an increase in the value of his assets, as when stock-market prices have been rising steadily, he is more likely to invest in a new and more expensive home. As a proxy for the housing cost of capital, RJM employs a distributed lag of the long-term "real" corporate bond rate. Since RJM has no unsubsidized housing starts variable, but does have an exogenous subsidized starts variable, ZHS, a distributed lag of the latter is included. Finally, since the gross rental rate of housing responds to changes in the stock of housing, KH, and, in turn, influences expenditures, the lagged stock of housing is included. The RJM expenditures-on-housing equation is:
\[
EH_t = a + b \frac{CON}{N} + c KH_{t-1} + \sum_{i=2}^{4} d_i + (RCB-EINFL)_{t-1} + \sum_{i=1}^{4} f_i ZHS_{t-i} + g TIME + f EH_{t-1} + U3_t \tag{2.13}
\]

The stock of housing includes single and larger family units. The equation is a simple stock-adjustment type providing feedback from the previous period's expenditures on housing and stock:

\[
KH_t = (KH_1 + KH_5)_t = a + b EH_{t-1} + c KH_{t-1} + U4_t \tag{2.14}
\]

This closes the housing sector. It, too, is affected by monetary policy through all three channels since consumption per capita is influenced by expected income and wealth which, in turn, implies that the wealth and real balance effects are operating here, while the distributed lag of the "real" corporate bond rate serves as a channel for the cost of capital as well as the credit rationing effect. Fiscal policy also affects this sector through consumption per capita and price changes which determine price expectations. What was said about the multiplier mechanism in the consumption sector applies here as well.

**Investment in Producers Equipment**

This sector and the sector for investment in producers structures are the most complex and the most rigorously developed from the economic theory among the real sectors of the MPS Model.
This theory holds that the production of producers' physical capital depends on the comparison of the reproduction cost of the physical capital and the sales price or market value of the existing capital. The market value is determined by the capitalization of the future net income expected to be generated by the capital stock. The expected future net income is determined by the demand for output, the size of the existing stock of capital, and the expected wage cost. Thus, the decision to produce capital goods rests ultimately on only two pieces of information: the value of existing capital and the cost of producing capital goods.

The starting point for applications of the theory is the neoclassical model of investment behavior developed by Jorgensen (1963), extended by Jorgensen and Hall (1967) to provide a sophisticated treatment of the effects of tax policy and depreciation of investment, and applied with a rational distributed lag to estimate the lagged effect of relative prices on investment demand by Jorgensen and Stephenson (1967a, b), while rejecting the latter's empirical estimate of the lag, Bischoff (1969) supports their conclusions that relative prices, i.e., the effect of capital goods, prices, wages, output prices, the cost of capital, depreciation, and taxes, do matter in the investment decisions and, hence, policy makers can have a direct influence on these decisions. But an important policy implication of this model is that the direct effects of a one-period change in monetary or fiscal policy on investment are likely to be considerably greater in the short run than in the long run (Jorgensen 1965). The conclusion follows only for a "putty-putty"
production function on the assumption that capital is perfectly malleable so that the capital-output ratio is variable both before and after fixed capital is put in place. Bischoff developed a more realistic investment function based on the assumption of a "putty-clay" production function. The consequent investment function takes the general form:

$$I_t = k^* \Delta X^c_t$$

(2.15)

where $I_t$ denotes gross investment and $\Delta X^c_t$ denotes the gross increment to capacity which firms wish to provide for in period $t$, both for expansion and replacement, and $k^*_t$ is the optimum (cost minimizing) capital output ratio in period $t$, as determined by the prices of relevant inputs, both current and expected. He concretizes his theory in two structural equations. The first explains net new orders for producers durables by a distributed lag of the product of the optimal capital-output ratio, $k^*_t$, and output, $X_t$. The second uses orders to predict investment on equipment expenditures. The estimated lag distribution in the equations are of special interest since the time pattern of effects resulting from a change in one of the determinants of investment vitally concerns policy-makers as well as business investors. Bischoff builds in a weighted lag distribution which he attributes to Peter Tinsley (1967) in order to capture the cyclical variation of the lag between orders and shipments. Bischoff estimated $k^*_t$, the optimal capital-output ratio, but assumed that input prices would remain constant over the lifetime of newly installed equipment.
and that equipment was used until totally depreciated. Ando, Modigliani, Rasche, and Turnovsky (1974) generalized Bischoff's analysis, allowing for technical progress and for expected input and output prices to change over time due to inflation, for example. For the current choice of technology does not depend merely on the current money rate of interest in terms of output \( r_t - \text{expected output prices} \) but on the expected future "real" rate and real wages as well. A machine is not used until physically depreciated but only until the marginal cost of producing with that machine exceeds the average cost for the latest vintage of that type of machine. The currently purchased equipment is viewed as the first link of an optimal sequence of machines and minimizes the present value of expected costs and so maximize the present value of the firm.

Instead of Bischoff's CES production function, they use the following Cobb-Douglas production function:

\[
X_t = AI_t^{1-a} \left( g_t E_t \right)^a
\]

(2.16)

where:

\begin{align*}
X &\quad \text{flow of gross output} \\
I &\quad \text{"putty" content of capital equipment} \\
E &\quad \text{man-hours per unit time} \\
g &\quad \text{the rate of "Harrod Neutral" \,(embodied)\,technical progress} \\
t &\quad \text{the point in time when I is installed}
\end{align*}

The present value of costs to be minimized in producing the expected stream of output, \( X_t^e \), resulting from initial investment, \( I_0 \), is:
where:

\( T \) = service life

\( Q_0 \) = initial price of capital goods

\( w \) = the expected rate of growth of the money wage rate, \( W \)

\( d \) = rate of depreciation

\( m \) = rate of required labor as machines get older

Letting:

\( p = w - g \) = the rate of change of output prices

\( R = r - p + d \) = the real rental rate of capital

\( L = m + w - p \) = the rate of increase of labor costs

\( R^* = R - L = r - w + d - m, \)

then, from (2.17a) it follows that the present value of minimized cost per unit of initial capacity, \( X \), with respect to the capital-output and capital-labor ratios, subject to (2,16) is:

\[
\hat{C}_o(T) = \frac{C_o(X,T)}{X} = Q_o \left( \frac{I_o}{X} \right) + W_o \left( \frac{1-e^{-R^*T}}{R^*} \right)
\]

(2.17b)

where the first order minimum conditions can be solved as:

\[
\frac{I_o}{X} = A^{-1} (1-a) W_o \left( \frac{1-e^{-R^*T}}{R^*} \right) \frac{a}{Q_o}
\]

(2.18)
Substituting (2.18) and (2.19) into (2.17a) and dividing by \((r-p)\)
\[
\left(\frac{1-e^{-RT}}{R}\right)
\]
gives the unit cost of producing a constant output \(X\) over a
service life \(T\), when factor intensities are chosen optimally for that \(T\):
\[
\hat{c}_o(T) = \left\{\frac{(1-a)\left(1-e^{-RT}\right)}{R^*}\right\}^\frac{a-1}{a} \frac{Q_0}{A(r-p)a}
\]
\[
(2.20)
\]
Assuming that the price of output will rise at the rate \(p\), i.e.,
\[
P_o(t) = P_{oe}e^{pt},
\]
the present value of revenue per unit is:
\[
\int_0^t P_o(t)e^{-rt}dt = \int_0^t e^{-(r-p)t}dt = \frac{P_o}{r-p}
\]
Assuming that output price, \(Q\), is set by applying an oligopolistic
markup, \(M\), determined by entry preventing considerations, to the minimum
cost achievable, the present value of revenue per unit is \(Mc_o(T)\).
Equating the two expressions and solving for \(P_o\) gives the initial price
of output in terms of its ultimate determinants:
\[
P_o = \frac{1}{a} \left(\frac{M}{A}\right)^{1/a} \left\{\frac{(1-a)\left(1-e^{-RT}\right)}{R^*}\right\}^\frac{(a-1)}{a} \frac{Q_0}{W_o}
\]
\[
(2.21)
\]
Since they assume \(P_o = \frac{Q_o}{q_o}\), i.e., that the price of capital \(Q\), increases
at a rate of \(q\), proportional to the price of output \(P\), we
can substitute for \( P_o \) in (2.21) to get \( Q_o \), which can, in turn, be substituted into (2.18) to give, after allowing taxes to enter, the optimal capital-output ratio:

\[
\hat{k}_o = \left( \frac{1}{\lambda} \right) = \left( \frac{1-a}{M} \right) \left( \frac{1-e^{-(r-p+d)T}}{r-p+d} \right) \frac{P_o}{Q_o} \tag{2.22}
\]

where:

\( u = \) rate of direct taxation of business income

\( k = \) rate of tax credit on business investment

\( z' = \) rate of tax credit that can be deducted from original cost to obtain the depreciation base,

where \( T \) is optimal life-span of a machine, found by minimizing (2.20). They found that since \( a \), the elasticity of output with respect to labor in the U.S., is approximately 0.7, that \( T \) is in the neighborhood of 15 years \( \pm \) 2 years and is a decreasing function of the real rate of interest, but not very sensitive to changes in the real rate. Hence they approximate the numerator of the second term of (2.22) by a constant estimated from the data. Hence, \( \frac{(1-a)D}{M} \) is a constant.

Following the financial theory of Modigliani-Miller (1958, 1963) and Bischoff (1969), the MPS authors approximate the cost of capital or required real rate of return, RPS, as a function of dividend yields and of corporate bond yields, given that UDC and UTC are exogenous:
\[
\text{RPS} \sim (1.0 - \text{UDC} \times \text{UTC})\{-1.833 + 0.02635 \\
(\text{RCB} - \text{EINFL}) + 0.7258 \text{RDP}\}
\]

where

\[
\begin{align*}
\text{UDC} & = \text{the desired proportion of debt to corporate capital} \\
& \text{or desired leverage} \\
\text{UTC} & = \text{marginal rate of corporate income tax} \\
\text{RDP} & = \text{the dividend-price ratio,}
\end{align*}
\]

where the coefficients are estimated from a nonlinear form of the producers orders equation (MPS 1975) using a Gauss-Newton-Hartley nonlinear estimation technique and where the term in brackets measures the market capitalization rate of an unlevered stream of income. Since the range of the data base is some years later for RJM than that for MPS estimation, these estimated coefficients are at best only approximately correct for the RJM Model. Nevertheless, the RJM Model uses RPS exactly as it is expressed above in (2.23). On the other hand, since only one price variable is retained in RJM, viz., PGNP, since the difference between the price of output P, and the price of capital, Q, is about one percent on the average over the span of the data set, and since the constant \( \frac{(1-a)D}{M} \) allows an arbitrariness such that the MPS Manual itself defines the optimal capital-output, VPD, as the "Equilibrium Ratio of Producers Durables to Output, Multiplied by a Constant" (MPS 1975), RJM defines this important variable still essentially following (2.22) and the MPS manual, as:
where

\[ VPD_i = a_i \sigma \left( \frac{P}{e_i} \right) \sigma \]  

(2.24)

\[
\begin{align*}
\text{where} \\
 a_i & = \text{the relative share in output due to input } i \\
 P & = \text{price of output} \\
e_i & = \text{rental price of input } i \\
\sigma & = \text{elasticity of substitution of output for input} \\
\end{align*}
\]

(In the durable equipment, Bischoff found \( \sigma \) approximately equal to one.)

\[
\frac{.1 \times \text{Price of Output Per Unit}}{\text{Current Dollar Rent Per Unit of Producers Durables}}
\]

\[
= .1 \times \frac{\text{PGNP}_t}{\text{PGNP}_t} \times (\text{VWPD} + .01 \times \text{RPD})_t \times (1.0 - \text{UTC} \times \text{VWPD} - \text{ZLING})_t \times \text{TCPD}_t \times \left\{ \frac{1.0 - \text{TCPD} (1.0 - \text{ZLING})}{1.0 - \text{UTC}} \right\}
\]

\[
\text{where}
\]

\[
\text{VWPD} = \text{present value of depreciation allowance of producers durables}
\]

\[
= (1.0 - \text{WAPD})_t \times 1.0 - e^{-\text{RPD}_t \times .01 \times \text{SLPD}_t}
\]

\[
= 2.0 \times \text{WAPD}_t \times 1.0 - \left\{ \frac{1.0 - e^{-\text{RPD}_t \times .01 \times \text{SLPD}_t}}{\text{RPD}_t + .01 \times \text{SLPD}_t} \right\}
\]

\[
\text{where}
\]

\[
\text{RDP} = \text{dividend-price ratio}
\]

\[
\text{TCPD} = \text{rate of tax credit on producers durables}
\]

\[
\text{UDC} = 0.2 = \text{desired ratio of debt to capital}
\]
SLPD = service life of producers durables for tax purposes

UWPD = .16 = rate of depreciation of producers durables

ZLING = dummy variables for long amendment on depreciation basis

WAPD = proportion of new equipment depreciated using accelerated depreciation methods

Since the Wharton Anticipations Model reported a notable improvement using the U.S. Bureau of Economic Analysis' survey variable on businessmen's plant and equipment investment anticipations, RJM includes this variable, labelled EPDS (Adams and Duggal 1974). Then, collapsing the MPS orders and expenditures equations into one, the RJM expenditure on producers durable equipment is:

$$\text{EPD}_t = a + \sum_{i=0}^{4} b_i (\text{VPD} \times \text{XB})_{t-i} + \sum_{i=0}^{4} c_i \text{EPDS}_{t-i} + U_{5t}$$

where

$$\text{XB} = \text{gross private domestic business product}$$

The Producers' Structures Sector

In this sector again, the MPS model follows the theory of Bischoff (1967) who is again extending the work of Jorgensen (1963, 1965). Bischoff allows, as in the equipment sector, nonunitary price elasticity of demand for structures, nonneutral technical change, and a nonlinear
estimation of the cost-of-capital parameters. He also uses a new but less complex estimation of the lag structures, since construction demand acts "as if" factor proportions are variable both before and after buildings are put into place. In other words, a "putty-putty" production function is assumed. Part of the reason for this difference between plants and equipment investment can be explained by the difference in physical attributes - structures are not generally built to be manned by a fixed amount and quality of labor as machines are. But, in addition, a producer can more readily sell a structure and reinvest at the new optimal capital-output ratio than he can sell a specialized machine.

The RJM Model incorporates the MPS expenditures on producers structures equation, after shortening the lags and adding the BEA anticipations variable

\[ \text{EPS}_t = \sum_{i=0}^{4} b_i (\text{VPS}_t \times \text{XB}_{t-i}) + \sum_{i=0}^{4} c_i \text{EPDS}_{t-i} + d\text{KPS}_{t-l} + U_t \]  

(2.26)

The definition of the equilibrium ratio or optimal capital to output ratio, VPS, is derived similarly to VPD in (2.24) above, using Gauss-Hartley nonlinear estimation of the parameters in (2.26):

\[ \text{VPS}_t = \frac{1 \times \text{PGNP}^{.45}}{\text{RTPS}_t} e^{-0.00295 (\text{ESTOP}_t - 16.5)} \]  

(2.27)

where

\[ \text{ESTOP} = \begin{cases} \text{Time, if time} \leq 43, \\ 43, \text{if time} > 43 \end{cases} \]
32

16 = the 1958.1I quarter in the order of observations for RJM
43 = the 1965.I quarter in the order of observations for RJM

\[ RTPS_t = \text{current dollar rent per unit of procedures structures} \]

\[ = 0.1 \times \text{PGNP}_t \times (0.01 \times \text{RPS} + \text{UWPS}) \times (1.0 - UTC \times \text{VWPS} - ZLING \times \text{TCPS})_t \times \frac{1.0 - \text{TCPS} \times (1.0 - ZLING)}{1.0 - UTC_t} \]

\[ \text{VWPS}_t = \text{present value of depreciation allowance of producers' structures} \]

\[ = (1.0 - \text{WAPS}) \times \left\{ \frac{1.0 - e^{-\text{RPS} \times 0.01 \times \text{SLPS}}}{\text{RPS} \times 0.01 \times \text{SLPS}} \right\} + 2.0 \times \text{WAPS}_t \times \left\{ \frac{1.0 - e^{-\text{RPS}_t \times 0.01 \times \text{SLPS}_t}}{\text{RPS}_t \times 0.01 \times \text{SLPS}_t} \right\} \]

\[ \text{RPS} = (1.0 - \text{UDC} \times \text{UTC}) \times (-1.8330 + 0.02635 \text{RCB} + 0.7258 \text{RDP}) \]
\[ \text{RDP} = \text{dividend-price ratio} \]
\[ \text{UTC} = \text{marginal rate of corp. income tax} \]
\[ \text{TCPS} = 0 = \text{rate of tax credit of producers' structures} \]
\[ \text{SLPS} = \text{service life on producers' structures for tax purposes} \]
\[ \text{UDC} = 0.02 = \text{desired ratio of debt to capital} \]
\[ \text{UWPS} = 0.06 = \text{depreciation rate for producers' structures} \]
\[ \text{WAPS} = \text{proportion of new structures depreciated using accelerated depreciation method} = 0.534 \]
\[ \text{ZLING} = \text{dummy vbl. for long amendment on depreciation basis.} \]
The difference in the form of VPS from that of VPD is only apparent. While a detailed derivation is unavailable, Bischoff writes that the exponent \(0.45\) is the estimated steady-state ratio of net structures to output when VPS is approximately 3.0 and the steady state construction share of GNP is about 3 percent. In other words, the elasticity of substitution, \(\sigma\), is 0.45. The \(\exp(-0.00295 (\text{ESTOP} - 16.5))\) term represents structure-augmenting technical progress with estimated trend term, -0.00294, and (ESTOP-16.5) representing time. In the VPD definition the trend term was approximately zero and so the \(\exp\) term is one.

The stock of producers structures identity is based on the chosen rate of asymptotic delay, \(\text{UPWS} = 0.06\), in order to make the stock of structures conform approximately to the figures from the OBE capital goods study published in the February, 1967, *Survey of Current Business*. The .25 coefficient of \(\text{EPS}_t\) in the following identity is necessary since \(\text{EPS}_t\) is the quarterly flow at an annual rate. Thus, the stock of producers structures identity is:

\[
\text{KPS}_t = 0.25 \text{EPS}_t + (1.0 - 0.25 \text{UWPS}_t) \times \text{KPS}_{t-1} \tag{2.28}
\]

\[
= 0.25 \text{EPS}_t + 0.985 \text{KPS}_{t-1}
\]

where

\[
\text{UWPS} = 0.06 = \text{rate of depreciation of producers structures.}
\]
The Inventory Sector

Since the MPS Model estimates the stock of inventory, $K_I$, using a stock adjustment mechanism to a desired inventory sales ratio that involves three explanatory variables not in RJM, viz., new orders for producers durables, new orders for military defense goods, and man-hours idle due to major strikes, the RJM Model, after several attempts to estimate an inventory-level equation, turns eclectic again. Instead of estimating the stock of inventory, the change in the stock of inventory is estimated. Inventory investment is simply the difference between inflow and outflow (or deliveries). Since an important factor is the behavior of work-in-process inventories, a distributed lag of changes in industrial output was used in an attempt to capture this buildup or inflow of inventory on the assumption that changes in output are synchronous with changes in final sales. Changes in final sales, in turn, imply deletions in finished-product inventories which signal a change in production activity to replenish the stock of inventory. At least this seems reasonable for consumption goods, if not for investment goods where output may change without any immediate repercussions in sales or deliveries.

Changes in total consumer expenditures capture the outflow of inventories. Finally, the lagged change in stock was added to give:

$$ (K_I_t - K_I_{t-1}) = a + \sum_{i=0}^{1} b_i (EPCE_{t-i} - EPCE_{t-i-1}) + d(K_I_{t-1} - K_I_{t-2}) + U7_t $$

$$ + \sum_{i=0}^{3} c_i (XB_{t-i} - XB_{t-i-1}) $$

$$ + \sum_{i=0}^{1} d_i (K_I_{t-1} - K_I_{t-2}) + U7_t $$
Summation of Demand Components Sector

This sector consists of the following two national income identities.

The first is the gross national product identity:

\[ X_{\text{GNP}}^t = \text{EPCE}_t + \text{EH}_t + \text{EPD}_t + \text{EPS}_t + (K_1^t - K_{t-1}^t) + (\text{EEX}_t - \text{EIM}_t) + \text{EGF}_t + \text{EGS}_t + \text{EIF}_t \]  \hspace{1cm} (2.30)

where:

- \( \text{EEX} \) = exports
- \( \text{EIM} \) = imports
- \( \text{EGF} \) = federal government expenditures on goods and services
- \( \text{EGS} \) = state-local government expenditures

NB: For simulation in Chapter IV, let \( (\text{EEX} - \text{EIM}) = \text{EXIM} \) and let \( (\text{EGS} + \text{EIF}) = \text{ESF} \).

The second is the gross private domestic business product identity:

\[ X_{\text{B}}^t = X_{\text{GNP}}^t - \{ \text{EGFL} + \text{EGSL} + \text{YRW} + \text{YH} \} \]  \hspace{1cm} (2.31)

where:

- \( \text{EGFL} \) = compensation of federal government employees
- \( \text{EGSL} \) = compensation of state-local government employees
- \( \text{YRW} \) = income originating in the rest of the world
- \( \text{YH} \) = household product

NB: for simulation, let \( \{ \text{EGFL} + \ldots \} = \text{EPSWH} \)
The Labor Sector

The MPS Model estimates a man-hours demanded in non-farm business equation, LMHT, that is derived from the aggregate "putty-clay" production function from which producers' durable equipment investment is derived. However, taking the natural log of equation (2.10) above, does not immediately give equation (2.32), below. This is how Ando and Modigliani (1969) explain their equations:

"It follows directly from our postulates that, given the history of past investment, there is a well-defined direct labor requirement for any given level of output at any moment of time. In addition, however, there are indirect labor requirements to maintain the physical and managerial organization of the economy, which are more a function of the size of the productive capacity than of actual output. Since we cannot separate these two types of labor in our data, our employment function relates total man-hours to output, capacity, and the productivity trend. In order to incorporate the short-run dynamics associated with this process, we add to our equation the rate of change of output to reflect higher productivity of overtime hours and the unemployment rate to reflect labor hoarding."

The RJM Model, after attempting to estimate simpler equations, settled on an equation, which does not include the strike dummy variable, but otherwise is identical to MPS equation as follows:
\[
\ln \left( \frac{\text{LMHT}}{\text{XB}} \right)_t = a + b \left\{ \ln \left( \frac{\text{XB}}{\text{XBC}} \right)_t + \ln \left( 2.5 - \frac{\text{XB}}{\text{XBC}} \right)_t \right\} + c \ln \left( 1.0 - 0.01 \times \text{ULU} \right)_t + d \ln \left( \frac{\text{XB}_t}{\text{XB}_{t-1}} \right) + e (0.01 \times \text{TIME}) + f D1 + g D2 + U8_t
\]

where:

\text{XB} = \text{gross private domestic business product} \\
\text{XBC} = \text{productivity capacity for business output} \\
\text{ULU} = \text{unemployment rate of total labor force} \\
D1 = \begin{cases} 1, \text{ for 1969.I} \\ 0, \text{ otherwise} \end{cases} \\
D2 = \begin{cases} 1, \text{ TIME } \geq 1969.II \\ 0, \text{ otherwise} \end{cases}

The supply of labor (LF + LA), is exogenous in RJM, unlike the MPS Model. Total civilian employment is an identity depending on man-hours, viz.:

\[
\text{LE}_t = \left( \frac{\text{LMHT}}{\text{LH}} \right)_t + (\text{LES} + \text{LEF} + \text{LEO})_t
\]

where:

\text{LMHT} = \text{total man hours (nonfarm business) demanded} \\
\text{LH} = \text{total hours per man} \\
\text{LES} = \text{state-local employment} \\
\text{LEF} = \text{federal government employment} \\
\text{LEO} = \text{employment, difference between household and payroll surveys}
Total unemployment then decides unemployment through the unemployment rate identity (of total labor force in \%):

\[
ULU_t = 100 \times \left( \frac{LF - LE}{LF + LA} \right) = 100 \times \frac{LH*LF - LH*LE}{LH*LF + LH*LA}
\]  

(2.34)

where:

\( LF + LA \) = Total employment including armed forces
\( LE \) = Total Civilian Employment
\( LF \) = Civilian Labor Force

The Wage and Price Sector

In their equation explaining the rate of change of the wage rate, the MPS authors follow in the tradition of Phillips (1958) and modern search and disequilibrium theory (Phelps 1970). Even though this is perhaps the most controversial area of modern macroeconomics, the structure of the MPS wage-price model is relatively simple. Excess demand for labor drives the rate of change of money wages through a Phillips curve mechanism. Thus, rather than excess demand for goods and services with accompanying strong interaction between current prices and current wages being the dominant force determining prices and wages, the rate of change of money wages is found to depend primarily upon both the employed and unemployed searching the market for their best opportunities as well as upon employers trying to maintain manpower at optimal levels in the face of quits and recruiting problems. The Phillips curve mechanism also allows for the influence
of past changes in the cost of living, the unemployment rate, the rate of change of the unemployment rate, the rate of change of the minimum wage rate, and a complex variable measuring the rate of change of the OASI compensation rate.

The RJM Model doesn't list the latter two variables but does add a lagged rate of change of money wages, thus allowing past values of the other explanatory variables to influence the current wage rate because of the Koyck distributed lag—to be discussed in Chapter IV. Unlike the MPS model, RJM doesn't set the coefficient of expected inflation arbitrarily equal to one, which begs the questions of whether or not the expected first derivative of the Phillips curve with respect to expected inflation is unity. A unitary coefficient, as in the MPS equation, implies that, in the long-run at least, the rate of change of money wage keeps up exactly with the expected rate of change of the cost of living.

The simple Phillips-like wage equation finally adapted into the RJM Model is:

\[
\frac{PL_t - PL_{t-1}}{PL_{t-1}} * 400 = a + b \text{EINFL}_{t-1} + c \frac{1}{ULU_t} + d(\frac{PL_{t-1} - PL_{t-2}}{PL_{t-2}} * 400) + U9_t
\]

(2.35)

where \( PL = \) the employee compensation rate in nonfarm private domestic business and where the reciprocal of unemployment is used to capture the assumed nonlinear shape of the Phillips curve: a rectangular hyperbola.
In the MPS Model, a basic price equation for private business output is estimated. All other price indices are related to it or to the wage level by identities. Theoretically, this price level is obtained by applying an oligopolistic price markup to minimum average cost of output. This cost consists primarily of unit labor costs, i.e., the average wage rate times an appropriate measure of productivity, viz., man-hours per unit of output. Actual prices approach the equilibrium level gradually, so a lagged dependent variable is added, plus price variables for raw materials. Finally, the markup is assumed to be a function of the rate of capacity utilization, so as a capacity variable, they include the ratio of unfilled orders to shipments.

Because the latter variables are not in the data set of the RJM Model and since the complex MPS price level equation is in natural logs and requires renormalization after estimation, a rather different and somewhat eclectic equation for the rate of change of the GNP price deflator is used instead, following Pindyck (1976), but substituting a capacity utilization variable, XBC-XB, as a proxy for Pindyck's excess demand variable. The equation finally used in RJM is:

\[
\begin{align*}
\frac{\text{PGNP}_t - \text{PGNP}_{t-1}}{\text{PGNP}_{t-1}} &= a + b \left\{ \frac{\text{PL}_t - \text{PL}_{t-1}}{\text{PL}_{t-1}} \right\} \\
&+ \frac{\text{PL}_{t-1} - \text{PL}_{t-2}}{\text{PL}_{t-2}} + \sum_{i=0}^{1} e_{i} (XBC - XB)_{t-1} + \frac{\text{YD}_{t-3} - \text{YD}_{t-4}}{\text{YD}_{t-4}} \\
&+ e \left( \frac{\text{PGNP}_{t-2} - \text{PGNP}_{t-3}}{\text{PGNP}_{t-3}} \right) + U_{10_t}
\end{align*}
\]
where:

\[ YD = \text{disposable income} \]

\[ XBC-XB = \text{capacity production less production} \]

\[ PL = \text{the average compensation rate in nonfarm private domestic business}. \]

The final equation in this sector is a distributed lag of past price changes to approximate expected inflation. This variable was developed by Franco Modigliani and Robert J. Shiller in a paper relating the rational expectation hypothesis to the term structure of interest rates (1973). Theoretically, the expected rate of change of prices at time \( t \) is taken to be an infinite weighted average of actual past rates of change with the weights geometrically declining and summing to unity, on the grounds that if the rate of change of prices had been at some constant level, say \( \bar{P}_t \), over a sufficiently long time, then the expected rate of change should also be \( \bar{P}_t \). The lag length of eighteen used in the MPS model and the weights are arbitrarily transplanted from their estimation in reference to the term structure equation to a variety of equations in the MPS model. A set of "threshold" weights, due to Ando, Modigliani, Rasche, and Turnovsky (1974), are added, viz.:

\[
w = \frac{1}{12} \sum_{i=0}^{12} D_i
\]

where

\[
D_i = \begin{cases} 
0, & \text{if } \frac{PXB_{t-1} - PXB_{t-i-1}}{PXB_{t-i-1}} < \text{small constant} \\
1, & \text{otherwise}
\end{cases}
\]
The MPS builders assumed that this is similar to a situation in which all decision makers adjust only partially. They employ the weights, $W_i$, to make this concept operational. Moreover, they compared the EINFL time series with the series constructed by Mr. J. A. Livingston of the Philadelphia Bulletin from his semi-annual survey of Business Economists — the only continuous time series available for 1950-1969 related to the short term price expectations of business decision makers. For the period before 1960, the two series are totally different. They begin to resemble each other from 1960 to 1966. After 1966, EINFL closely matches the Livingston series.

Although the MPS authors use appropriate price variables for the different equations, the RJM Model uses only PGNP. Also, the RJM variable for EINFL has a non-zero value starting only in 1968.I, and reduces the lag length to 10 quarters to accommodate the size of the Gauss-Seidel simulation program. In the RJM Model, the expected rate of change of prices is:

$$\text{EINFL} = \begin{cases} 
0, & \text{1954.II} - 1967.IV \\
\frac{400 \sum_{i=0}^{9} (.87)^i}{\sum_{i=0}^{9} (.87)^i} \frac{\text{PGNP}_{t-i} - \text{PGNP}_{t-i-1}}{\text{PGNP}_{t-i-1}} & \text{1968.I} - \text{1990.III} \\
\frac{9 \sum_{i=0}^{10} \frac{1}{10} QZ_i}{\sum_{i=0}^{10} \frac{1}{10} QZ_i} & \text{1990.III} - \text{2000.III} 
\end{cases}$$

(2.37)
where:

\[
QZ_i = \begin{cases} 
1, & \text{if } \frac{\text{PGNP}_{t-1} - \text{PGNP}_{t-i-1}}{\text{PGNP}_{t-i-1}} > 0.00375, \\
0, & \text{otherwise.}
\end{cases}
\]

The equations of this sector constitute a channel linking the real and financial sectors, supplying feedback to the real, especially. Thus, increases in real output and/or capacity fuel prices and wages, which fuel price expectations, Changes in these three variables, in turn, will spur or depress investment enthusiasm in the real sector; create capital gains or losses by the net worth identity, which, in turn, influences consumption; influence the long term rate, RCB, and free reserves, MFR$; and feed back on prices themselves. This sector, then, plays a crucial role both because it contains a key target variable for monetary and fiscal policy, viz., prices, but also because it contains a vital channel for these policies.

The Financial Sector

The MPS model has an elaborate financial sector consisting of dozens of structural equations and identities which makes it truly unique among macro-models.

The main link between the financial and real sectors is provided by three long-term yields: the corporate bond rate (RCB), the stock yield, approximated by the dividend price ratio (RPD), and the mortgage rate (MR).
Originally, the RJM Model was to incorporate structural equations for two of these long term rates, viz., RCB and RPD, in addition to the equations for monetary variables actually incorporated, dividends, commercial loans, currency in the hands of the public, corporate profits before taxes, and total time deposits at member banks. Because of the unexpected high cost in money and time of estimating equations with acceptable statistical and theoretical properties, especially for these highly volatile financial variables, and because these variables, while important, are less important than the monetary variables whose equations were estimated, it was decided to exogenize them—a step which admittedly reduces the capability of the RJM Model to simulate as realistically or as accurately the diffuse and intricate financial-real linkage of the U.S. economy as explained by modern portfolio theory. However, it must be pointed out that even in the MPS model the stock yield is explained (not too successfully) by a distributed lag of the corporate bond yield (RCB), the rate of change of the price level, and the rate of change of real dividends (used to approximate expected capital gains), while the mortgage rate is also tied basically to the corporate bond rate.

Thus, the RJM financial sector is reduced to a monetary sector that is further simplified in that only one short-term interest rate, the treasury bill rate (RTB), and one long term rate, the corporate bond rate (RCB), is retained. Nevertheless, its structural equations for member bank free reserves (FMR$) and identities for unborrowed reserves (MRU$) and the money supply (M1$) provide the basic MPS linkage to
the real sector via RTB and RCB. In fact, since RCB is estimated by a distributed lag of the commercial paper rate which, in turn, is estimated by a distributed lag of RTB, the ultimate linkage depends on RTB, the short-term rate. Ando and Modigliani write that the money market plays a central role in the MPS model since it provides the mechanism through which the real sector feeds back on the financial markets, thereby contributing to the determination of market yields. And the yield determined by the equilibrium between the demand and supply in the money market is the short term rate (1969).

In the terms of portfolio theory, the supply of money depends crucially upon the behavior of commercial banks as they adjust their portfolio of earning assets to changing circumstances, such as changes in unborrowed reserves and the demand for commercial loans. The quantity of money demanded adjusts gradually, arising from a lack of timing between receipts and payments plus the transactions costs involved in exchanging money for short-term assets whose yield is taken to be the short-term rate, RTB. According to Modigliani, Rasche, and Cooper (1970), this rate determines the ratio of money demand to transactions or the Cambridge k. Theoretically, the money demand equation is a function of the short-term interest rate and GNP. Assuming that the elasticity of money with respect to GNP is one, we get:

\[ M^*_t = k(RTB_t)GNP_t \]  \hspace{1cm} (2.38)

where \( \frac{\partial M^*_t}{\partial RTB_t} < 0 \), since RTB is the opportunity cost of holding money, and GNP is a broad measure of the flow of transactions. But the public
needs time to react to the change in RTB in adjusting to optimal cash balances. So an adjustment mechanism is built in giving in terms of natural logs,

\[ \ln M_t = \gamma(\ln M^*_t - \ln M_{t-1}) + \ln M_{t-1} \quad (2.39) \]

After substituting \( M^*_t \) of (2.38) in (2.39), it follows that

\[ \ln M_t = \gamma(\ln k(\text{RTB}) + \ln \text{GNP}_t) + (1-\gamma)\ln M_{t-1} \quad (2.40) \]

The demand for demand deposits by the non-bank public is first estimated in the MPS Model and then renormalized to make the short-term or treasury bill rate the dependent variable. Subtracting \( \ln \text{GNP}_t \) from both sides of (2.40) and assuming \( \ln k(\text{RTB}) \) to be a linear-in-natural-logs function of RTB, say, \( a + b \ln \text{RTB}_t \), the demand for money becomes:

\[ \ln \left( \frac{M_t}{\text{GNP}_t} \right) = \gamma a + \gamma b(\ln \text{RTB}_t) + (1-\gamma)\ln \left( \frac{M_{t-1}}{\text{GNP}_t} \right) \quad (2.41) \]

In order to better estimate the demand for money by the average citizen, the MPS Model also includes several other short-term rates in this equation, viz., the rate on time deposits, the savings and loan rate, the ratio of current to lagged federal reserve discount rate, \( ZDR^A \). To capture real income effects and to cover the case where the elasticity of money with respect to GNP is not equal to one, real income per capita, \( \text{GNP}/N \), is added. Since the RJM Model has only one short rate, RTB, the exogenous ceiling on time deposits variable, ZCT, was used instead of the rate on time deposits. The demand for demand deposits equation in RJM is:
\[
\ln\left(\frac{M^D}{XGNP^S}\right)_t = a + b \ln R_{TB_t} + c \ln\left(\frac{XGNP^S}{N}\right)_t \\
+ d \ln ZCT + e \ln\left(\frac{\ln ZDRA}{ZDRA_{t-1}}\right) + g \ln\left(\frac{M^D_{t-1}}{XGNP^S_t}\right) + U_{11_t}
\]  
(2.42)

where:

- \( M^D \) = demand deposits adjusted at all commercial banks
- \( XGNP^S \) = gross national product in nominal terms
- \( N \) = population

A term structure of interest rates equation determines the long-term rate, \( R_{CB_t} \), in the MPS model. Franco Modigliani and Robert J. Shiller developed the theoretical model upon which the empirical equation is based (1973). They generalize the "Preferred Habitat" version of the Expectation Theory in which the term structure of interest rates for the U.S. is explained remarkably well by a model expressing expected future rates as a linear function of past rates. Modigliani and Shiller add a distributed lag of past changes in prices to give the effect of expectations of future changes in the price level on the long-term bond rate.

The term structure of interest rates is based on the fact that the market yields of debt securities differing only in time to maturity when graphed in the yield-maturity plane display a discrete but nearly smooth yield curve. Various theories have been developed to explain the slope of this yield curve. One, the widely held Expectation Theory, claims that the curve's shape results primarily from investor expectations about future interest rates. Assuming always that the investor
intends to maximize his rate of return, he will choose that investment in bonds whose future yields he expects to be the highest in the market. Precisely because different investors have different expectations about future rates, the market yields of bonds with different maturities differ. More specifically, the theory explains how current market yields of bonds of long maturities depend ultimately on an average of current and future one-year rates that are expected to prevail in the intervening periods. Hence, the shape of the yield curve varies with changes in expectations.

The "Preferred Habitat" version adds a risk premium to the yield perhaps inaccurately predicted by the simple Expectation Theory and also a premium to bridge any imbalance between borrowers and lenders bargaining in a particular preferred habitat of n-periods.

But in an economy subject to considerable price fluctuations, it is reasonable to assume that financial investors will base their decision on expectations concerning the "real" short-term rate, i.e.,
\[
i_t = RTB_t - \pi_t,
\]
where \( RTB \) is the short-term money rate and
\[
\pi_t = \frac{p_t - p_{t-1}}{p_{t-1}}
\]
the rate of change of prices. Modigliani and Shiller take the view that expectations of the real rate are based exclusively on the past history of the real rate. The short-term money rates expected at time \( t \) to prevail \( n \) periods later, \( (t+n)^{RTB^e}_t \), is reasonably thought of as the sum of an expected real rate and an expected rate of change of prices for the period, since prices as well as the "real" rate may be expected to continue to change in the future with
\[
(t + n)^{RTB^e}_t = (t + n)^e_t + (t + n)^p_t, \quad n = 1, 2, \ldots
\]  
(2.43a)
Their term structure equation for the current long-term rate then reduces to a sum of an expected real rate and an expected rate of change of prices for that period, or substituting $RTB_t - P_t$ for $i_t$, since $i_t$ is not observable,

$$RCB_t = \sum_{i=0}^{\infty} W_i RTB_{t-i} + \sum_{i=0}^{\infty} V_i 400 \frac{P_{t-1} - P_{t-i-1}}{P_{t-i-1}} + K$$

(2.43b)

where $P$ = the price level, and $W_i$ and $V_i$ are identical weighting structures, and $K$ is a liquidity premium.

For their empirical equation, however, they use a finite lag of 18 periods to approximate the infinite lag. They also add a moving standard deviation of the short term rate as a reasonable measure of the uncertainty about the future course of interest rates. In the RJM model the latter variable is not included and the lag length is reduced to five on the grounds that RJM is a short term model and collinearity will be greatly reduced. Moreover, the expected inflation variable, $EINFL$, is itself a ten-period lagged rate of change of prices, defined above in (2.37).

The RJM term structure equation for the corporate bond rate is:

$$RCB_t = a + \sum_{i=0}^{4} b_i RTB_{t-i} + \sum_{i=0}^{4} c_i EINFL_{t-i} + U_{12t}$$

(2.44)
The money supply concept used in the MPS model is that called ML: the sum of currency and demand deposits. Accordingly, the RJM Model adds the identity:

\[ ML_t = MC_t + MD_t \]  

(2.45)

where

- \( MC_t \) = currency outside banks, and
- \( MD_t \) = demand deposits adjusted at all commercial banks.

It follows that an equation for each of these determinants is needed to explain the supply of money. But in RJM currency outside banks is taken as exogenous. Even in the MPS model, \( MC_t \) is entirely controlled by the demand for currency outside banks. Hence, to explain the total supply of money, one must explain the stock of demand deposits. Moreover, in the U.S., approximately 75 percent of total commercial bank deposits are created by member banks of the Federal Reserve System, so that, at least in the short run, the behavior of their deposits controls approximately the total.

Hence, in MPS and RJM, the following identity relates demand deposits adjusted at all commercial banks to deposits at member banks only:

\[ MD_t = ((JMSA \cdot MD_S \cdot JMSB) - (JMSA \cdot MG_F))_t \]  

(2.46)
where:

\[ \text{JMSA} = \text{seasonal adjustment factor for MD\$} \]
\[ \text{JMSB} = \text{blow-up factor to convert MDS\$ to MD\$} \]
\[ \text{MGF\$} = \text{U.S. Government deposits at all commercial banks} \]
\[ \text{MDS\$} = \text{net demand deposits subject to reserves at all member banks} \]

The net demand deposits subject to reserves at all member banks identity is given by:

\[ \text{MDS\$}_t = \left( \frac{\text{MRU\$} - \text{MFR\$} - (\text{ZRT} \times \text{MTM\$})}{\text{ZRD}} \right)_t \] (2.47)

where:

\[ \text{MRU\$} = \text{unborrowed reserves at all member banks} \]
\[ \text{MFR\$} = \text{free reserves at all member banks} \]
\[ \text{MTM\$} = \text{total time deposits at all member banks} \]
\[ \text{ZRT} = \text{reserve requirements against time deposits at all member banks} \]
\[ \text{ZRD} = \text{reserve requirements against net demand deposits at all member banks} \]

But the stock of demand deposits at member banks, as at commercial banks, depends on the interactions of public demand (perhaps increasing supply by making deposits), the portfolio decisions of commercial banks (who may decide to earn profit by buying Treasury Bills with their free or excess reserves, thus increasing the size of the money multiplier), and also by the Central Bank. The latter can
increase or decrease supply by a variety of controls. The RJM model retains five basic instruments of monetary policy, viz., open market operations via the exogenous member bank unborrowed reserves plus currency (ZMR$), the federal reserve discount rate (ZDRA), the reserve requirement on demand deposits (ZRD), the reserve requirement on time deposits (ZRT), and the ceiling rate on time deposits (ZCT).

According to the authors of the MPS model, the stock of demand deposits depends especially on the behavior of commercial loans. Since commercial borrowers are so important as potential sources of deposits and other business, banks will tend to accommodate their demands. But to accommodate these demands, banks must rearrange their portfolios, perhaps by selling treasury bills. But these counteractions take time. In the short run, total earning assets can be expected to rise along with demand deposits to accommodate them, a combination which may draw down excess or free reserves and even require short-run borrowing.

Now free reserves at member banks are defined as:

\[ \text{MFR} = \text{unborrowed reserves} - \text{required reserves} \quad (2.48) \]

\[ = \text{MD}_t (1 - \text{ZRD}_t) + \text{MTM}_t (1 - \text{ZRT}_t) - \text{MCL}_t - I_t + CA_t \]

where:

\[ \text{MTM} = \text{total time deposits at member banks} \]

\[ \text{MCL} = \text{commercial and industrial loans at member banks} \]

\[ I_t = \text{bank investments in earning assets} \]

and:

\[ \text{CA} = \text{bank capital assets}. \]
Moreover, aggregating assets and liabilities of a standardized bank balance sheet, they derive an accounting identity relating changes in demand deposits to changes in investments:

\[ \Delta \text{MD} = \Delta \text{MRU} + \Delta \text{MCL} + \Delta \text{I} - \Delta \text{MTM} - \Delta \text{CA} \]  \hspace{1cm} (2.49)

Since CA is given and MDS, MTM and MCL are only anticipations and, hence, random variables not fully in control of the bank, the problem of the bank is to choose the most profitable level of its investment portfolio level, I, and to that choice there corresponds an uncertain outcome in terms of free reserves. After first developing a rigorous mathematical model for a bank's optimal expected profits as a function of expected MFR$ and I, then approximating anticipations by using the "static" expectation hypothesis \((E(Z_t) = Z_{t-1})\), and finally aggregating, they derive the member banks' aggregate demand for investment as:

\[
\Delta \text{I} = n_D (1-ZRD) \Delta \text{MD} + n_T (1-ZRT) \Delta \text{MTM} \\
- n_{CL} \Delta \text{MCL} - n_F \Delta \text{MFR} + \text{CA} \hspace{1cm} (2.50)
\]

where the \(n_i\) are coefficients measuring the extent to which the portfolio responds to errors in expectations.

Solving (2.49) and (2.50) simultaneously gives the money supply as:

\[
\text{MDS} = \frac{1}{(1-n_D^D) + ZRD \times n_D} \{ \Delta \text{MRU} + (1-n_{CL}) \Delta \text{MCL} \\
- (1-n_T^T + ZRT \times n_T) \Delta \text{MTM} - n_F \Delta \text{MFR} \} \hspace{1cm} (2.51)
\]
Finally, unborrowed reserves is defined by the identity:

\[ MRU_s^t = ZMS_s^t - MC_s^t \]

(2.52)

where:

\[ MC_s^t \] = currency outside banks and

\[ ZMS_s^t \] = unborrowed reserves at member banks plus currency outside the banks.

Note that \( ZMS_s^t \) is the key monetary policy control variable insofar as Federal Reserve open market operations decide its size and it then affects the stock of money through (2.52), (2.47), (2.46), and (2.45).

Before (2.51) can be expressed as an empirically estimable equation, \( MFR_s^t \) must be so expressed in terms of the appropriate interest rates for investments, \( I \), viz., \( RTB \) (the rate on earning assets), for negative free reserves or borrowing, viz., \( ZDR \) (the federal reserve discount rate), and a savings or time deposit rate. Modigliani, Rasche, and Cooper (1970), instead of using \( MD_s^t \) as the independent variable, do an elaborate theoretical analysis based on numerous simplifying assumptions to arrive at an empirical relation for free reserves. It has no time deposit rate and it is based on the assumption than banks strive to achieve a desired ratio of free reserves to deposits in the long run rather than simply a desired level of free reserves. Hence, this ratio becomes the dependent variable. The RJM Model simplifies the MPS equation somewhat and adds expected inflation as an explanatory variable. The result is the behavioral equation contributing most to money supply, viz., the free reserves of member banks:
The equations of this monetary sector constitute the source and the first steps of the financial-real sector linkage. Equations (2.42), (2.43), (2.46), (2.47), (2.52) and (2.53) are all crucial channels of monetary policy. A change in a policy control variable leads directly to changes in RTB, which lead directly to changes in RGB. Changes in RTB and RGB lead directly to changes in investments in consumer durables, housing, plant and equipment; indirectly, via portfolio adjustment and the wealth effect, to changes in the consumption of nondurables; and also indirectly, via investment, to changes in wages, prices and unemployment.

The Wealth and Income Sector

Theoretically, the MPS definition of net worth of consumers represents the market value of all assets of consumers less their liabilities. This includes both physical and financial assets owned by consumers. The greater bulk of financial assets owned consists of total corporate shares or equities, although consumer durables, housing and
personal disposable income net of nondurable consumption are all relevant, in addition to a number of items summed in a residue variable, VGS. The MPS authors define the change in wealth first in general as:

\[ VCNS_t - VCNS_{t-1} = \sum_{i=1}^{n} p_i^t (A_i^t - A_i^{t-1}) + \sum_{i=1}^{n} A_i^{t-1} (p_i^{t-1} - p_i^t) \]

\[ + \sum_{j=1}^{m} Q_j^t (D_j^t - D_j^{t-1}) - \sum_{j=1}^{m} D_j^{t-1} (Q_j^t - Q_j^{t-1}) \]  

Personal savings during period t is approximately:

\[ S_t = \sum_{i=1}^{n} p_i^t (A_i^t - A_i^{t-1}) - \sum_{j=1}^{m} Q_j^t (D_j^t - D_j^{t-1}) \]

where:

\( p_i^t \) and \( Q_j^t \) = average prices per period t,

\( A_i^t \) = asset i in period t, and

\( D_j^t \) = debt j in period t.

But \( \sum_{i=1}^{m} D_i^{t-1} (Q_i^t - Q_i^{t-1}) \) can be closely approximated by zero under most circumstances, since debts of consumers are almost entirely contracted in money terms and not negotiable.

The term \( \sum_{i=1}^{n} A_i^{t-1} (p_i^{t-1} - p_i^t) \) represents the capital gains on all assets by consumers. Although savings deposits, life insurance reserves, pension funds, etc., are fixed in money terms and, hence, have no capital gains, long term corporate bonds and government bonds do change in value as the market rate of interest changes, thereby generating capital gains or losses. However, the MPS model retains only capital gains or losses for equity shares and the major physical assets mentioned earlier. Land is not treated explicitly because of the extreme complications involved in capital gains.
If the total value of equity at the beginning of the period is approximated by the average during the period, viz., by:

\[
\frac{1}{2} \left\{ \frac{YDVS}{RDP \times .01} t + \frac{YDVS}{RDP \times .01} t-1 \right\}
\]

then the capital gains on this equity can be approximated by:

\[
\frac{1}{2} \left\{ \frac{YDVS}{RDP \times .01} t - \frac{YDVS}{RDP \times .01} t-2 \right\}
\]

The change in net worth is then defined as:

\[
VCN^t_s - VCN^t-1_s = \frac{1}{.02} \left\{ \frac{YDVS}{RDP} t - \frac{YDVS}{RDP} t-2 \right\} + \frac{1}{2} \left\{ \frac{PCD^t - PCD^{t-2}}{100} \right\} KCD^t-2 + \frac{1}{2} \left\{ \frac{PKH^t - PKH^{t-2}}{100} \right\} (KH1 + KH2)^t-2 + (YD$ - .01 \times PCON) x CON)^t-1 + VG^t_s
\]

To justify the identity, however, the MPS model makers found it necessary to multiply the right hand side by .001. Moving $VCN^t_s$ to the right hand side then defines consumer net worth. Unfortunately, the RJM Model does not list the three different price variables, so it uses PGNP as a proxy in all three cases. This distorts the identity slightly, and in simulations over specific intervals, this identity had to be adjusted. At any rate, the RJM new worth identity is (in trillions):

\[
VCN^t_s = VCN^t_s - .05 \left\{ \frac{YDVS}{RDP} t - \frac{YDVS}{RDP} t-2 \right\} + .001 (YD$ - .01 \times PGNP \times CON)^t-1
\]

(2.56)
\[ + .000005 (PGNP_t - PGNP_{t-2}) KCD_{t-2} \]
\[ + .000005 (PGNP_t - PGNP_{t-2}) KH_{t-2} \]
\[ + .001 VG$_{t-1} \]

where:

\[ YDV$ = \text{corporate dividends} \]
\[ RDP = \text{dividend-price ratio} \]
\[ VG$ = \text{residual in net worth identity} \]
\[ YD$ = \text{disposable income} \]

Although no attempt will be made here to delineate them, personal income is expressed as the sum of various types of income in the identity (in nominal terms):

\[ YP$ = YNI$ - YCP$ + YDV$ - TO$ - TU$ - TSC$ - TOSI$ + GB$ + GSP$ + GFP$ + GSI$ + GFI$ + YRC$ \]
\[ + YBT$ - YLAD$ = (XGNP \times PGNP \times .01)_t \]
\[ - \{WCCA$ + TIBF$ + TIBS$ + TSS$ + YBT$ - GFG$ + TO$ \]
\[ + TSC$ - GYT$ + YPC$ - YDV$ \}_t \]

where:

\[ YNI$ = \text{national income} \]
\[ YPC$ = \text{corporate profits and inventory valuation adjustment} \]
\[ YDV$ = \text{corporate dividends} \]
\[ TO$ = \text{OASI contributions (Social Security)} \]
\[ TU$ = \text{unemployment insurance contributions} \]
\[ TSC$ = \text{state and local soc. insurance} \]
TOSI$ = contribution to soc. insurance other than above
GB$ = unemployment insurance benefits
GSP$ = state and local transfer payments
GFP$ = federal transfer payments
GSI$ = state-local interest payments
GFI$ = federal interest payments
YRC$ = interest paid by consumers
YBT$ = business transfer payments
YLAD$ = wage accruals less disbursements
WCCA$ = capital consumption allowance
GFG$ = federal subsidies less surpluses of federal enterprise
TIBF$ = federal indirect business taxes
TSS$ = current surplus of state-local enterprises
GYT$ = other items of YP$
TIBS$ = state and local indirect business taxes

Note that this identity provides a loop or a feedback from the real back to the real sector by way of gross national product, XGNP, and prices, PGNP, since personal income feeds disposable personal income, YD$, which, in turn, directly influences expenditures on consumer durables, ECD, which is an element in the XGNP identity.

Finally, disposable personal income, in nominal terms, is defined as:
\[ YD_t = (YD_t \ast 0.01 \ast PGNP_t) = YPS_t - TPF_t \]  
\[ = (TEGF_t + TPS_t + YRC_t) + \{ (0.01 \ast RCB_t) \ast (0.01 \ast PGNP)_t \} \]  
\[ \ast (KCD_{t-1} + 0.125 \ast ECD_t) \]

where:

- \( TEGF_t \) = federal estate and gift taxes
- \( TPS_t \) = state and local personal income tax and non-tax payments
- \( YRC_t \) = interest paid by consumers
- \( TPF_t \) = federal income tax liability
  \[ = 0.01 \ast UTPF \ast YTF_t \]

where:

- \( UTPF \) = effective income tax rate
- \( YTF_t \) = taxable income for federal income tax purposes
  \[ = YPS_t (1 - e^{QYTF_t}) \]

where:

- \( QYTF_t = \delta + \beta \ln\left(\frac{YPS_t}{N_t}\right) + \gamma \ln TEX_t + \delta QYTF_{t-1} + U_t \)

where:

- \( TEX \) = per capita exemption for federal income tax purposes.

Note that the federal income tax liability, \( TPF_t \), is endogenous to the MPS model which uses the effective tax rate, \( UTPF \), as an exogenous fiscal policy variable. In the RJM Model, however, \( TPF_t \) is exogenized and is used itself as a fiscal control variable.
An Exports-Imports Sector, originally planned, was dropped for reasons of economy.

Conclusion

The RJM Model is now completely specified with 17 identities and 13 behavioral equations that constitute a relatively tight system incorporating the kind of real-financial sector linkage called for by modern portfolio theory. Each equation and identity has been carefully developed following current and sound economic theory, usually that developed by the authors of the MPS model. The next chapters are devoted to the estimation of the behavioral equations and simulation experiments on the system as a whole under various policy strategies.
CHAPTER III. THE ECONOMETRICS

Lawrence Klein, E. Philip Howrey and Michael D. McCarthy, all of the Wharton School of Finance and creators of the famous Wharton Forecasting Model, recently wrote about testing the predictive performance of Econometric Models. In particular, they criticized a study of Ronald Cooper (1972) which concludes that simple autoregressive time series processes seem to perform at least as well from the viewpoint of squared error considerations as structural policy models, such as the Wharton and MPS models.

Klein, et al., concluded that "the estimation procedure employed by Cooper does not, in general, yield consistent estimates of the parameters in nonlinear models. This certainly detracts from the predictive error tests that (Cooper) performed with the re-estimated models. However, it should be noted that there is no guarantee that the small-sample mean squared prediction errors would have been smaller had a consistent estimator been used instead of the inconsistent estimator. Indeed, the original model (such as the Wharton and MPS) were frequently estimated by inconsistent methods and the inappropriate estimators used in the original models may have led to an acceptance of erroneous structural hypotheses." (Klein, Howrey, and McCarthy 1974)

This quotation by Klein, et al., provides one of the basic motives for this dissertation. None of the well-known nonlinear macromodels, large or small, uses statistical techniques that yield consistent estimates of the parameters of the model. Fair (1971) uses an
estimator that gives consistent estimates for linear systems, but, despite some nonlinear equations in his model, he makes no attempt to use estimation techniques that correct for the bias resulting from these nonlinearities. For reasons that will be given later, a prime motive of this dissertation is consistent estimation of the parameters of Model RJM.

Secondly, only Fair corrects all equations for autocorrelation and none of the model builders attempt to correct for the contemporaneous correlation that almost certainly exists between some of the structural equations.

Thirdly, (and this is perhaps the most original contribution of this dissertation) no macro model of any kind has heretofore been estimated using Wayne A. Fuller's Modified Limited Information Maximum Likelihood Estimator (MLMLE) nor employed two of his three derived F statistics to ascertain empirically the degree of specification and identification of each estimated equation (Fuller 1977).

Consistency and Efficiency

In order to understand why consistent and efficient estimation techniques are important in developing a macroeconomic policy model, it is necessary to define a consistent and efficient estimator. One starts with the definition of an estimate or more precisely, a point estimate, \( \hat{b} \), of \( b_0 \), the true value of a parameter, \( b \). Following Wilks (1962), let \(( Y_1, \ldots, Y_n)\) be an \( n \)-dimensional random variable from a cumulative distribution function \( F(Y_1, \ldots, Y_n; b) \), where \( b \) is a one-dimensional real
parameter with parameter space $\Omega$. Let $\hat{b}$ be a function of $(Y_1, \ldots, Y_n)$ and itself a random variable. If the observed value of $\hat{b}$ corresponding to an observed value of $(Y_1, \ldots, Y_n)$ is used for $b_o$, the true value of $b$, then the random value of $b$ is called a point estimate or estimator for $b_o$, which is presumed unknown.

If, when $b = b_o$, $E(\hat{b}) = b_o$, then $\hat{b}$ is called an unbiased estimator for $b_o$. If an estimator $b$ converges in probability to $b_o$ as $n \to \infty$, it is called a consistent estimator for $b_o$. Finally, if $b$ is an unbiased estimator for $b_o$ having finite variance, and no other unbiased estimator has a smaller variance, then $b$ is called an efficient estimator for $b_o$.

The property of consistency relates to the distribution of an estimator as the sample size approaches infinity. In general, if the distribution of an estimator tends to some specific distribution, as the sample size increases, then such a distribution is called the asymptotic distribution of the estimator. Unfortunately, the asymptotic properties of an estimator are not always the same as its finite sample properties. Hence, even though it may be proved theoretically that an estimator, $\hat{b}$, is consistent, i.e.:

$$\text{plim } \hat{b} = b_o$$

or:

$$\lim_{n \to \infty} P(b_o - \varepsilon \leq \hat{b} \leq b_o + \varepsilon) = 1$$

where $\varepsilon$ is any arbitrarily small number, $\hat{b}$ may not approximate $b_o$ closely when $n$ is small. If both bias and variance decrease, i.e., if
\[ \lim_{n \to \infty} \{ \text{sum of bias}^2 \text{ and variance of } \hat{b} \} = \lim_{n \to \infty} \{ \text{Mean Square Error} (\hat{b}) \} = \lim_{n \to \infty} \{ (\hat{b} - b)^2 \} = 0, \text{ then } \hat{b} \text{ is consistent.} \]

But for small samples, an estimate that is asymptotically consistent may not be efficient. It is this conclusion that allows asymptotically consistent estimates, such as those arrived at in estimating the Model RJM using Fuller's MLIML algorithm, to be improved upon by going a step further: re-estimating the Model using Zellner and Theil's Three Stage Least Squares (3SLS) technique (Zellner and Theil 1962). 3SLS corrects for the contemporaneous correlation of the errors of various behavioral relations in a model. It is an application of Aitken's Generalized Least Squares to a system of equations. The specific technique used in RJM is an adaptation and extension of the techniques for dynamic models developed by Fuller and Wang (1975). The result is a reduction in the variance of the estimates.

Now, for economic policy purposes, as Klein and his colleagues noted (1974), there is no guarantee that in small samples consistent estimates of the parameters of a macro model will result in better tracking and predicting, i.e., smaller prediction errors. Fortunately, a practical method exists for investigating whether the asymptotic properties of an estimator hold in small samples. It is called the Monte Carlo Method. It consists in generating a large number of different sized random samples which are then used to estimate known parameters of a model by the estimation technique being investigated.

To fully appreciate what difference consistent and efficient estimation can mean to macroeconomic policy making, consider the

In the first place, all the macro models are simultaneous systems of equations, with the exception of the Anderson-Jordan model. This means that to obtain consistent estimates, the models which are simultaneous systems require either one of the many single equation methods developed for systems but applied seriatim (e.g., Two Stage Least Squares (2SLS) or Fuller's MLIML) or complete system methods which are applied to the system as a whole (e.g., 3SLS). But, with the exception of Ray Fair's small (nine equations) model, all of the models mentioned used Ordinary Least Squares (OLS) to estimate most of their structural equations. Rarely do the model makers use 2SLS or a similar instrumental variable technique that would eliminate so-called "simultaneous bias" and produce consistent estimates. Consider the following example taken from Johnston (1972) who applies OLS to a simple Keynesian macro model:

\[ C_t = a + bY_t + u_t \]  \hspace{1cm} (3.1)
\[ Y_t = C_t + Z_t \]  \hspace{1cm} (3.2)

where \( Z_t \) is exogenous expenditure, independent of \( u_t \), and \( (E(u'u')) = \sigma^2 I \), where \( u = (u_t, u_{t+1}, \ldots, u_{t+n}) \).
Substituting (3.1) into (3.2) gives:

\[ y_t = a + b y_t + z_t + u_t = \frac{a}{1-b} + \frac{1}{1-b} z_t + \frac{u_t}{1-b} \]  

(3.3)

showing that \( y_t \) is correlated with \( u_t \), so that:

\[ E(y_t) = \frac{a}{1-b} + \frac{1}{1-b} z_t \]  

(3.4)

but

\[ E(u_t (y_t - E(y_t))) = \frac{1}{1-b} E(u_t^2) \neq 0 \]  

(3.5)

As a result of this correlation, applying OLS to equation (3.1) to solve for \( b \) gives the estimator:

\[ \hat{b} = b \frac{1}{n} \sum_{t=1}^{n} (z_t - \bar{z})^2 \]  

(3.6)

\[ + (1+b) \frac{1}{n} \sum_{t=1}^{n} \frac{(z_t - \bar{z})(u_t - \bar{u}) + \frac{1}{n} \sum_{t=1}^{n} (u_t - \bar{u})^2}{\frac{1}{n} \sum_{t=1}^{n} (z_t - \bar{z})^2 + \frac{1}{n} \sum_{t=1}^{n} (z_t - \bar{z})(u_t - \bar{u}) + \frac{1}{n} \sum_{t=1}^{n} (u_t - \bar{u})^2} \]

which, by the assumption above, implies:

\[ \text{plim} \, \hat{b} = b \frac{\text{SUMZ} + \sigma^2}{\text{SUMZ} + \sigma^2} \]  

(3.7)

\[ = \hat{b} + (1-b) \frac{\sigma^2}{1 + \sigma^2 \text{SUMZ}^{-1}} \]

where:

\( \text{SUMZ} \) is a positive constant
The second term is the simultaneous bias. In this case, since the marginal propensity to consume is less than one, i.e., \( b < 1 \), the bias is positive. In general, the bias could be negative or positive and is of unknown magnitude. In general, methods such as 2SLS purge the explanatory variable, \( Y_t \), in (3.1) from the association with the residual \( u_t \). First a reduced form equation is estimated by OLS:

\[
\hat{Y}_t = \hat{P}_1 + \hat{P}_2 Z_t = (Z' Z)^{-1} Z' Y
\]

(3.9)

where \( Y_t = P_1 + P_2 Z_t + e_t \).

Then, substituting (3.9) into (3.1) gives:

\[
C_t = a + b\hat{Y}_t + (u_t + be_t)
\]

(3.10)

where \( b \) can now be estimated consistently by applying OLS again since, in matrix notation:

\[
b = (W' W)^{-1} W' Y
\]

(3.11)

\[
= (W' W)^{-1} W' (Zb + u + be)
\]

where:

\( W = (Y, Z) \)

Then \( \text{plim} \hat{b} = b \) if all elements of \( Z \) are fixed. If the residuals of these equations are autocorrelated and the equation contains lagged endogenous variables, then \( \hat{b} \) is not consistent, i.e., \( \text{plim} \hat{b} = b + \text{bias} \).

It follows that if lagged dependent variables are coupled with autocorrelated residuals within equations, the single equation methods for systems, such as 2SLS and MLIML, are inconsistent. Klein argues that...
in dynamic multiperiod forecasting models, the last situation holds if only because the lagged endogenous variables can be assumed as predetermined only for the first period forecasts and thereafter are generated within the model (1971).

Goldberger (1962) has shown that the gain in efficiency or reduction of prediction variance associated with correction for first order autocorrelation in a single equation model is \((1 - \rho^2)\) where \(\rho\) is the correlation coefficient. It is reasonable to assume that similar results hold for nonlinear systems of equations, i.e., the higher the degree of autocorrelation, the less reliable are policy simulations of dynamic systems whose equations have not been corrected for autocorrelation.

Finally, it is unrealistic to assume that different sectors of the economy are not correlated over time. Although single equation methods such as 2SLS and MLIML give consistent estimates when correction for autocorrelation in dynamic models is properly made, the estimates are still not as efficient as a full information method such as 3SLS. To eliminate the bias and inefficiency in the RJM Model due to simultaneity, autocorrelation, correlation due to lagged dependent variables, the single equation estimate MLIML is used. Then, to correct for correlation between equations, a full information estimation technique (3SLS) is applied to the system as a whole. The overall technique will be called A3SMLML.
A3SMLML is simply a generalization and adaption of the FA2SLS and A3SLS1 estimators, i.e., the limited and full information estimators of Fuller and Wang (1975). Whereas their FA2SLS is based on initial estimates from the MLIML estimator of Fuller (1977), and then 2SLS is used on the transformed data, A3SMLML uses the MLIML estimators initially to calculate the residual correlation coefficient, $\rho$, and then estimates the transformed equation again using MLIML. Finally to correct for correlation between equations, the residuals from the latter regression are used in 3SLS estimation.

To understand each stage of Fuller's MLIML estimator and the F-tests, we summarize his development (Fuller 1977).

Let the entire system be expressed as:

$$YB + Xr = U$$

where $Y$ is the $NXq$ matrix of all endogenous variables, current and lagged, $X$ is an $NXm$ matrix of all exogenous variables, and $U$ is the $NXq$ matrix of residuals with assumed error structure:

$$U = U^{-1}R + E$$

where the residuals, $E$, are assumed to be independently distributed random variables with zero mean, covariance matrix

$$\Sigma = \{\sigma_{ij}\}$$

and

$$E(UX) = 0$$
Then a structural equation can be expressed as:

\[ Y = Y_2 \beta_2 + X_1 Y + U \]  

(3.14)

and the reduced form as:

\[ (y:Y_2) = X_1 (\delta_1: \delta_2) + X_2 (\pi_1: \pi_2) + \varepsilon \]  

(3.15)

where \( \varepsilon \) are assumed to have the same error structure as \( U \) in (3.12), the rank of \( \pi_2 \) is \( g \),

- \( y \) = the dependent variable of the structural equation,
- \( Y_2 \) = the NXg matrix of all other endogenous variables, current and lagged as well as lagged \( y \),
- \( X_1 \) = theNXk_1 matrix of observations on the exogenous variables in the equation, current and lagged,

and:

- \( X_2 \) = theNXk_2 matrix of observations on the exogenous variables, current and lagged, in the system yet not in the equation.

Using OLS estimate the reduced form coefficients as:

\[
\begin{pmatrix}
\hat{\delta} \\
\hat{\pi}
\end{pmatrix} = (X'X)^{-1} X'Y
\]  

(3.16)

where:

- \( X = (X_1: X_2) \)

and:

- \( Y = (y:Y_2) \)
Fuller assumes that the sequence of matrices $X_N$ is such that

$$X_N'X_N$$

is nonsingular for all $N > k_1 + k_2$ and

$$\lim_{N \to \infty} \frac{1}{k_2} (X_N'X_N)^{-1} = A$$  \hspace{1cm} (3.17)

where

$A$ is nonsingular, $X_1'X_2 = 0$,

$$\frac{1}{N} (X_2'X_2) = I, \lim_{N \to \infty} \frac{1}{N} \pi_2'\pi_2 = \lim_{N \to \infty} M_{22} = \tilde{M}_{22},$$

$\tilde{M}_{22}$ is nonsingular.

He defines the estimators:

$$\hat{M} = \frac{1}{k_2} \begin{pmatrix} \hat{\beta}_1' \hat{\beta}_2 \\ \hat{\beta}_2' \hat{\beta}_1 \end{pmatrix} = \begin{pmatrix} \hat{M}_{11} & \hat{M}_{12} \\ \hat{M}_{21} & \hat{M}_{22} \end{pmatrix}$$  \hspace{1cm} (3.18)

$$S = \frac{1}{N(N-k_1-k_2)} \hat{\epsilon}'\hat{\epsilon} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}$$  \hspace{1cm} (3.19)

Now from (3.12) it follows that:

$$Y = -X\Gamma B^{-1} + UB^{-1} = X\Lambda + V$$  \hspace{1cm} (3.20)

But then $\Lambda = (\hat{\delta}_\pi) = -\Gamma B^{-1}$, by (3.16) and so:

$$\begin{bmatrix} \hat{\delta} \\ \pi \end{bmatrix} = \begin{pmatrix} \delta_1' & \delta_2' \\ \pi_1' & \pi_2' \end{pmatrix} \beta = -\Gamma$$  \hspace{1cm} (3.21)

Hence,

$$\delta_1 + \delta_2 \beta_2 = -\gamma$$  \hspace{1cm} (3.22)
The limited information maximum likelihood estimator is given by

\[ \beta_{\text{LIML}} = \left( \hat{M}_{22} - \hat{\lambda}S_{22} \right)^{-1} \left( \hat{M}_{21} - \hat{\lambda}S_{21} \right) \]  

(3.25)

where \( \hat{\lambda} \) is the smallest root of \( |\hat{M} - \hat{\lambda}S| = 0 \), and Fuller's modified limited information maximum likelihood estimator, MLIML, is given by

\[ \hat{\beta}_{\text{MLIML}} = \left( \hat{M}_{22} - \left( \hat{\lambda} - \frac{\alpha}{k_2} \right)S_{22} \right)^{-1} \left( \hat{M}_{21} - \left( \hat{\lambda} - \frac{\alpha}{k_2} \right)S_{21} \right) \]  

(3.26)

where \( \alpha > 0 \) is a fixed real number and \( \hat{\lambda} \) is the smallest root of \( |\hat{M}_{22} - \lambda S_{22}| = 0 \). Fuller's modification consists in modifying Theil's "k-class" estimators and is itself a member of that class. Fuller shows that \( \alpha \) should always be chosen \( \geq 1 \). Fuller shows that setting \( \alpha = 4 \) yields estimators whose mean square error to \( O(t^{-2}) \) is uniformly smaller than that associated with any smaller \( \alpha \). The MLIML estimator is also more efficient than the "fixed" k-class estimators.

On the other hand, setting \( \alpha = 1 \), as was done in estimating the RJM Model, reduces the bias of MLIML estimates and keeps them consistent, but does not yield the lowest variance of estimate. Setting \( \alpha = 1 \) is desirable when using Fuller's derived F-tests to test empirically for specification and identification.

\[ \pi_1 + \pi_2 \beta_2 = 0 \]  

(3.23)

Equation (3.24) was deleted because it was incorrectly inserted here.
The computational form of the MLIML estimator is

\[
\begin{pmatrix}
Y_2'Y_2 - (\lambda^* - \frac{\alpha}{N-k_2-k_1} w_{22}) Y_2'X_1 \\
X_1'Y_2 \\
Y_1'Y_2 - (\lambda^* - \frac{\alpha}{N-k_2-k_1} w_{21}) X_1'
\end{pmatrix}
\begin{pmatrix}
X_1'X_1 \\
X_1'Y_2 \\
X_1'
\end{pmatrix}
\]

where \( \lambda^* \) is the smallest root of:

\[
|B - \lambda W| = 0
\]  

(3.28)

and is related to the root, \( \hat{\lambda} \), of (3.26) by:

\[
\lambda^* = 1 + k_2 (N-k_2-k_1)^{-1} \hat{\lambda}
\]

and where:

\[
W = \begin{pmatrix}
w_{11} & w_{12} \\
w_{21} & w_{22}
\end{pmatrix} = Y'(I-X(X'X)^{-1}X')Y
\]

(3.29)

\[
B = Y'(I-X_1(X_1'X_1)^{-1}X_1')Y
\]

(3.30)

The test of specification or of overidentifying restrictions is

\[
F_1 = F(k_2-g, N-k_2-k_1) = (\lambda^* - 1)(\frac{N-k_2-k_1}{k_2-g})
\]

(3.31)

assuming \( n-g > 0 \). The null hypothesis is rejected for large \( F \).

The second \( F \) tests the hypothesis that the equation is identified. The null hypothesis is \( H_0 \): the rank of \( M_{22} \) is less than \( g \), where \( g \) = the number of endogenous variables for which coefficients are to be estimated.
The test is given by:

$$F_2 = F(k_2-g+1, N-k_2-k_1) = (f_\alpha - 1) \frac{N-k_2-k_1}{k_2-g+1}$$  \hspace{1cm} (3.32)

where \( f_\alpha \) is the smallest root of:

$$|B_{22} - f W_{22}| = 0$$  \hspace{1cm} (3.33)

A large \( F \) suggests that the rank of \( M_{22} \) is \( g \), and hence, that the equation is identified. A small two-equation sample model due to Fuller illustrates the use of this second \( F \). Consider:

\[\begin{align*}
(1) & \quad Y_1 = \beta Y_2 + u_1 \\
(2) & \quad Y_2 = \gamma X_1 + u_2
\end{align*}\]

If \( \gamma = 0 \), then \( E(X_1 Y_2) = 0 \). Hence, the denominator of \( B \) is estimating the zero. Hence, equation (1) is not identified, even though it satisfies the usual order condition for identification. It does not satisfy the rank condition.

$$F_2 = \frac{\sum Y_2^2 - \sum (Y_2 - \hat{\gamma} X_1)^2}{\sum (Y_2 - \hat{\gamma} X_1)^2} \cdot \frac{\sum (X_1 Y_2)^2}{\sum (Y_2 - \hat{\gamma} X_1)^2} = \frac{\gamma^2 \sum (X_1 Y_2)^2}{\sum u_2^2 / N-1}$$  \hspace{1cm} (3.34)

which is the usual F-test for the null hypothesis \( H_0: \gamma = 0 \). Thus, the null hypothesis is rejected for large \( F \), i.e., a large \( F \) indicates
that the system is identified. Likewise, if $\gamma$ is small then (3.33) gives

$$\left| \left( y_2'y_2 \right) - \hat{f}(\hat{u}_2'\hat{u}_2) \right| = \left| y_2'y_2 - \hat{f}(y_2'y_2 - \gamma^2 x_1'x_1) \right|. \quad (3.35)$$

This implies that $\hat{f}$ is small which, in turn, implies that $F_2$ is small. But a small $F_2$ implies that equation (1) is not empirically identified.

Fuller derives a third $F$-test of the hypothesis that the OLS estimates for this equation are unbiased, but the computer software used for estimating RJM did not provide the necessary output to construct this test. The practical importance of tests $F_1$ and $F_2$ cannot be over-emphasized as will become more evident later in discussing the problems of specification and of identification.

Since the model RJM is a dynamic system of equations, the errors are assumed to be autocorrelated. Thus, following Fuller and Wang (1975), we rewrite (3.15) as:

$$Xb + X_\Gamma + Y_{-s}C_s = U, \ s=1, 2, 3, 4 \quad \quad (3.36)$$

where $Y$ is an $NXq$ matrix of current endogenous variables, $X$ is an $NXM$ matrix of current and lagged exogenous variables, each $Y_{-s}$ is an $NXq$ matrix of structural disturbances, and $B, \Gamma,$ and $C_s$ are matrices of corresponding structural coefficients.

The error structure of the model is assumed to be
\[ U = U_{-1} R + E \]  
\[ (3.37) \]

where \( U_{-1} \) is an \( NXq \) matrix of \( U \) lagged one period and \( R = \text{diag}(\rho_1, \rho_2, \ldots, \rho_q) \), where \( |\rho_i| < 1 \) for \( i = 1, 2, \ldots, q \). It is assumed that the vectors \( E_t = (e_{t1}, e_{t2}, \ldots, e_{tq}) \), \( t = 1, 2, \ldots, N \), are independently distributed as multivariate normal random variables with a zero mean vector and a nonsingular covariance matrix, \( \Sigma = (\sigma_{ij}) \). The reduced form of the model is:

\[ Y = XFB^{-1} - Y_{-1}C_{-1} + Y_{-1}RB^{-1} + EB^{-1}, \]
\[ = XFB^{-1} - Y_{-1}C_{-1} + Y_{-1}RB^{-1} \]
\[ + X_{-1}\Gamma B^{-1} + Y_{-1}C_{-1} \]
\[ = -XFB^{-1} - Y_{-1}(C_{-1} - BR)B^{-1} + X_{-1}\Gamma B^{-1} + Y_{-1}C_{-1} \]
\[ = (R^{-1})B^{-1} + EB^{-1} \]
\[ = X\pi + Y_{-1}\pi_2 + X_{-1}\pi_3 + Y_{-1}s - 1 \]
\[ = F\pi + V \]

where

\[ s = 1, \ldots, 4 \]

and where

\[ V = EB^{-1}, F = \{X, Y_{-1}, X_{-s-1}, Y_{-s-1}\}, Y_{-s-1} \]

is the matrix of endogenous lagged two or more periods, and \( \pi \) is partitioned to conform to the partition of \( F \).
The $i$th structural equation of model (3.36) may be written as:

$$Y_i = Z_i \delta_i + u_i, \quad i = 1, 2, \ldots, q$$

(3.39)

where

$$Z_i = (Y_i, X_i, y_{i-1}, i)$$

$$\delta_i = (B_i', \Gamma_i', C_i')$$

$Y_i$ the $i$th $N \times 1$ column of $Y$, $y_{i-1}$, is the lagged $y_i$ of the left hand side, and $u_i$, the $i$th column of $U$, is assumed to satisfy:

$$u_{it} = \rho_i u_{it-1} + E_i$$

(3.40)

where $E_i$ is the $i$th column of $E$ in (3.37). In matrix notation the complete model becomes:

$$y = Z + u$$

(3.41)

where:

$$y' = (Y_1', Y_2', \ldots, Y_q')$$

$$Z = \text{block diag} (Z_1, Z_2, \ldots, Z_q)$$

$$\delta' = (\delta'_1, \delta'_2, \ldots, \delta'_q)$$

and:

$$u = (u_1', u_2', \ldots, u_q')$$
The resulting $\delta_i = (B_{i1}', \Gamma_i', \hat{C}_{si}' \hat{s}_{i}', \hat{C}_{si}' \hat{s}_{i}')$ are used in step three to calculate estimated residuals $u_{ti} = y_i - Z_i \delta_i$, which, in turn, are used to calculate the autocorrelation coefficients by:

$$\hat{\beta}_i = \frac{\sum_{t=1}^{N} \hat{u}_{ti} \hat{u}_{t-1, i}}{\sum_{t=1}^{N} \hat{u}_{t-1, i}^2} \quad (3.42)$$

The estimated autocorrelation coefficient, $\hat{\rho}_i$, is then used to construct a transformation, $\hat{T}_i$, as follows:

$$\hat{T}_i = \begin{bmatrix} (1-\hat{\rho}_i^2)^{1/2} & 0 & 0 & \cdots & 0 & 0 & 0 \\ -\hat{\rho}_i & 1 & 0 & \cdots & 0 & 0 & 0 \\ 0 & -\hat{\rho}_i & 1 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & (1-\hat{\rho}_i^2)^{1/2} & 0 & 0 \\ 0 & 0 & 0 & \cdots & -\hat{\rho}_i & 1 & 0 \\ 0 & 0 & 0 & \cdots & -\hat{\rho}_i & 1 & 0 \end{bmatrix} \quad (3.43)$$

After transforming all the variables of each equation by the appropriate transformation matrix $\hat{T}_i$ of (3.43), the fourth step is to regress $\hat{T}_i y_i$ and $\hat{T}_i y_{t-s,i}$ on $\hat{T}_i x_i$, $\hat{T}_x_{i}'$, $\hat{T}_{x_{t-1}, i}'$ and $\hat{u}_{t-1, i}'$, where all the lagged residuals are treated as additional exogenous variables. Once again a smallest $\hat{\lambda}$ and estimated residual matrices, $S_{22}$ and $S_{21}$, are produced in order to be used in yet a fifth step where new AMLIML
estimates are found via (3.26), including an estimate, \( \Delta \beta_i \), corresponding to the \( \hat{u}_{t-1,i} \), which leads to the revised estimator of \( \rho_i \),

\[ \beta_i = \beta_i + \Delta \beta_i \]. If \( \Delta \rho_i \) is relatively large, then an iteration of the last two steps is called for, using \( \rho_i \) to transform the variables.

In estimating RJM, a sixth step is added, following the final steps of the method suggested by Fuller and Wang for their full information estimator, A3LSL1 (1975). After step five of the A3SMLIML procedure, the system of equations can be written in matrix form as:

\[
\hat{T}Y = \hat{H}W + \hat{\varepsilon}B + E \quad (3.44)
\]

where:

\[
\hat{T} = \text{Block diag } \hat{T}_1, \hat{T}_2, \ldots, \hat{T}_\ell
\]

\( \hat{T}_i \) is \( T_i \) defined in (3.43) evaluated at \( \rho_i = \hat{\rho}_i \)

\( H = \text{Block diag } (H_1, H_2, \ldots, H_\ell) \)

\( \hat{H}_i = \{ (1-\rho_i)^{1/2} \hat{y}_{1i}, (\hat{y}_{2i} - \hat{\rho}_i \hat{y}_{1i})', \ldots, (\hat{y}_{Ni} - \hat{\rho}_i \hat{y}_{N-1,i})' \} \)

\( W = (w_1, w_2, \ldots, w_\ell)' \)

\[ w_i = (B_i', \Gamma_i', C_i', \Delta \rho_i) = (\hat{\theta}_i', \Delta \rho_i) \]

\( \Delta \rho_i = \rho_i - \hat{\rho}_i \)

\( y \) is defined in (3.41)

\( \varepsilon = \text{Block diag } (\bar{\varepsilon}_1, \bar{\varepsilon}_2, \ldots, \bar{\varepsilon}_\ell) \)

\( \hat{\varepsilon}_i = Y_i - \hat{Y}_i \)

where \( \ell = q \)
Nonlinearity

Macro model builders are faced with two additional problems: small-sample sizes and nonlinearities. And the latter compounds the former.

The small-sample problem arises theoretically, from the fact, as seen above, that favorable asymptotic theory does not necessarily hold for a finite number of observations. Practically speaking, the small-sample problem is a degree-of-freedom problem, since each observation in a sample provides the estimation technique with another degree of freedom. Unfortunately, for large systems such as the 200-equation MPS Model, the first step of the A3SMLML estimation technique outlined above is impossible because the number of explanatory variables is greater than the number of observations in the sample.

Kloek and Mennes (1960) first suggested a feasible remedy and Klein (1969) applied it to a version of the Klein-Goldberger Model. This remedy consists in reducing a large set of exogenous variables to a relatively small set of principal components. However, a new problem arises, viz., the choice of the principal components, for at least \( g \) principal components are needed to identify the equation.

Let \( Z \) take the place of \( X \) in (3.12), where:

\[
Z = (X^1, F) \tag{3.45}
\]
and \( F \) is the matrix of principal components. Then substituting for \( X_2 \) in (3.27), the MLIML estimator based on principal components is:

\[
\begin{pmatrix}
\beta \\
\gamma
\end{pmatrix}_{PCMLML} = \begin{pmatrix}
Y_2'Y_2 - (\lambda^{**} - \frac{\alpha}{n-k_2-k_1})W^*_{22} Y_2'X_1 \\
X_1'Y_2 \\
X_1'X_1
\end{pmatrix}
\]

(3.46)

\[
\begin{pmatrix}
Y_2'y - (\lambda^{**} - \frac{\alpha}{N-k_2-k_1}) W^*_{21} \\
X_1'y
\end{pmatrix}
\]

where \( \lambda^{**} \) is derived from \( \lambda \), the smallest root of \( |B - \lambda W^*| = 0 \), and

\[ W^* = Y'(I - ZZ'^{-1}Z')Y \]

However, \( g \), the number of jointly dependent or "other" endogenous variables in an equation varies across equations. To cover all cases in RJM, only five principal components were selected since the largest number of current "other" endogenous variables in any one structural equation of RJM was less than five and since the first five \( P_1 \) accounted for more than 90 percent of the variation (the \( \lambda_1 \)) of the 37 original exogenous variables (the \( X_1 \)).

Fortunately, since the principal components themselves are orthogonal by construction, and hence not linearly related, the use of \( F \) in place of \( X_2 \) helps to reduce the problem of multicollinearity.
In RJM, besides the five $p_i$ used to represent the current 37 exogenous variables, $X_t$, 3 $p_i$ are constructed from the original 37 exogenous lagged once to represent the $X_{t-1}$, 3 $p_i$ construction from the original 37 lagged twice represent the $X_{t-2}$, and a single $p_i$ constructed from the original $X_{t-3}$, ..., $X_{t-9}$ represent the $X_{t-3}$, ..., $X_{t-9}$.

It should be noted at this point that this use of principal components would seem to satisfy Theorem 3 of Brundy and Jorgenson (1974) concerning the necessary and sufficient conditions for the use of principal components in a linear model in the first stage of 2SLS such that the 2SLS estimator reduces to an instrumental variables estimator and hence a consistent estimator. By their Theorems 4 and 5, however, using principal components such that 2SLS reduces to an instrumental variable estimator makes the 2SLS estimator inefficient. Hence, it may be that this same use of principal components in a nonlinear model renders MLIML estimates inefficient, even though they remain consistent.

The use of principal components can overcome the small-sample problem even for relatively large systems. But the nonlinearity problem still remains. Klein points out that principal components can be of help in estimating nonlinear systems as well.

Identification depends on specification, i.e., various kinds of restrictions must be placed on parameters of equations, such as setting the coefficients equal to zero. Specification depends on sound economic theory and on any prior knowledge of the system that is available to the econometrician.
Only if the model is properly specified and satisfies the rules of identification can a unique structure be estimated for the general model. But the practical identification of nonlinear systems is easier said than done. Franklin Fisher (1966) uses a simple model to illustrate the identification rules for both linear and nonlinear systems. Let the general form of the model be:

\[ A \mathbf{q}(\mathbf{x}) = \mathbf{u} \quad (3.47) \]

where \( A \) is an \( M \times N^0 \) matrix of structural parameters to be estimated.

Let \( Y = f(Z, \mathbf{u}) \) be the subvector of \( X \) consisting of \( M \) endogenous variables and \( Z \) the subvector of \( N^0 - M \) exogenous variables. Assume that the elements of \( \mathbf{q}(\mathbf{x}) \) are linearly independent and the elements of \( \mathbf{u} \) are distributed independently of the elements of \( Z \).

If \( \mathbf{q}(\mathbf{x}) = X \), we have the linear case.

Consider prior linear restrictions on the first equation of (3.47), viz.:

\[ A_1 \mathbf{\phi} = 0 \quad (3.48) \]

where \( \mathbf{\phi} \) is a matrix of constants, each column of \( \mathbf{\phi} \) being a restriction on the coefficients of the first equation. In this case, the necessary order condition for identifiability is that:

\[ \text{rank} (\mathbf{\phi}) \geq M-1 \quad (3.49) \]

since \( A_1 \) has \( N \) elements to be identified and normalization reduces this to \( N-1 \), and \( N-M \) restrictions are provided by the reduced form, i.e.,

\[ A_1(\pi) = 0, \quad \text{where} \quad \pi = \text{the reduced form coefficients of the system.} \]
A practical interpretation of this rule, when the restrictions are solely exclusion restrictions, is that the number of predetermined variables excluded from the equation must be at least as great as the number of endogenous variables included less one.

The necessary and sufficient rank condition for indentifiability is that:

$$\text{rank } (A_0) = M - 1$$  \hspace{1cm} (3.50)

In the nonlinear case, unfortunately, the transformations generating restrictions that make equations identical may be nonlinear as well as linear. Fisher derives order and rank conditions for the nonlinear case analogous to (3.49) and (3.50) for the linear case, but as Goldfeld and Quandt point out (1972), extreme care must be taken in using the order condition and there is at least the formal possibility that multiple solutions (more than one nonlinear relationship between the endogenous variables and the predetermined variables and the disturbances) exist and, hence, a selection rule must be applied to assure identification. But little is known about such selection rules. In summary, while identification of nonlinear systems can be done, practically speaking it would be a tedious job for even medium size systems.

Fuller's two F-tests, (3.31) and (3.32), were used as basic practical criteria in deciding whether the estimated equations of Model RJM were correctly specified and identified. A priori, the only slightly nonlinear equations of RJM satisfied the linear order conditions for
identification. The first stage consisted in regressing each endogenous variable in the structural equation on 29 orthogonal principal components plus any exogenous variable that appears in the structural equation. (Appendix B has the program and the final estimation run which illustrates the technique.) Unfortunately, the question still to be answered is whether Fuller's MLIML estimate produces consistent estimates when the system is nonlinear in the variables.

Klein et al. (1974) has shown that a system nonlinear in the variables cannot be consistently estimated by a version of 2SLS called Repeated Reduced Form (RR). Consider the nonlinear system in matrix notation:

\[ Y = F(Y,X) + XB + E \]  

(3.51)

where \( F = F(Y,X) \) is a nonlinear function. In economics this might arise in the case of production functions, the use of natural logarithms, capacity ceilings or depreciation floors, non-negativities, but especially from the fact that the behavioral equations are in real terms—they depend on relative prices and deflated variables; while the basic identities depend on nominal terms— they must be in current price involving sums and differences of products between price quantity variables. As long as the endogenous variables to be explained are in constant dollar terms this situation makes for nonlinearities.

In the first stage of RR, estimates of \( F \) are formed which are then used in the second stage to give the estimates for the \( i \)th equation:
\[
\begin{pmatrix}
\hat{\alpha}_1 \\
\hat{\beta}_1
\end{pmatrix}
= \begin{pmatrix}
\hat{F}'_i F'_i X'_i & \hat{F}'_i Y_i \\
X'_i F'_i Y_i & X'_i Y_i
\end{pmatrix}^{-1}
\begin{pmatrix}
\hat{F}'_i Y_i \\
X'_i Y_i
\end{pmatrix}
\]

(3.52)

\[
* \begin{pmatrix}
N^{-1} F'_i e_i + N^{-1} F'_i e_i \\
N^{-1} X'_i e_i + N^{-1} X'_i e_i
\end{pmatrix}^{-1}
\]

(3.52 cont.)

where \( e_i \) is the error from the reduced form regression. Since realistically:

\[
\lim_{N \to \infty} N^{-1} \hat{F}'_i e_i \neq 0
\]

and:

\[
\lim_{N \to \infty} N^{-1} X'_i e_i \neq 0
\]

this method yields inconsistent estimates. However, Howrey, Klein and McCarthy (1972) immediately show that an instrumental variable formulation avoids this difficulty, given the usual instrumental variable assumptions, viz., \( E(X'_t e_{t+s}) = 0 = E(\hat{F}'_t e_{t+s}) \), all \( s \) and \( t \). However, difficulties for the instrumental technique also arise in the first stage unless the instruments are carefully chosen.
Eisenpress and Greenstadt originally dismissed the application of 2SLS and similar single-equation system techniques to nonlinear systems on the grounds that it required the "probably poor assumption" that the residuals of the structural equation are involved in an additive form (1966). Chernoff and Rubin had previously linearized a nonlinear system, applied the LIML estimator, and then showed that its desirable asymptotic properties still held (1953). Goldfeld and Quandt (1972) modifications of FIML, 2SLS and DLS (Direct Least Squares) estimators which they considered sufficient to retain desirable asymptotic properties when used on nonlinear systems even without linearization (1968). They found that the 2SLS technique, using both linear and quadratic polynomials of the exogenous variables in the system as instruments, outperformed the FIML and DLS as far as estimating structural parameters, but FIML provided a closer correspondence between the root mean square error of estimate and the mean asymptotic standard deviation. Moreover, there is no rule for the optimal degree for polynomial in the first stage. They found that the appropriate degree seemed to vary from model to model and there is a marked difference in the estimates depending on the degree chosen.

Kelejian (1971) demonstrated that econometric models whose structural equations are linear in the parameters, but contain regressors which are nonlinear functions of endogenous and predetermined variables can be consistently estimated by the 2SLS procedure. Contra Eisenpress and Greenstadt he also shows that the consistency of 2SLS estimates does not depend on the condition that the reduced form
equations be linear in the structural disturbances. Furthermore, he shows that if the functional forms of the reduced form equations are not known, and therefore approximated by polynomials, the polynomials must be of the same degree if the 2SLS estimates are to be consistent.

Kelejian considers the systems expressed in (3.51) where the $i$th equation $F_i = (f_1^i, f_2^i, \ldots, f_k^i)$ and $f_j^i = f_j^i(Y,X)$. He assumes $E(E_{i|x}) = 0$, $E(E_{i1}^2 | X_i) = \sigma_i^2$, all $i$, $E(E_{ti} E_{is}) = 0$, all $t \neq s$, and the sample moments of $X$ and $E$ converge in probability to the population moments. He claims that 2SLS estimates will be consistent if $k_i$ instruments can be found for the regressor functions $f_j^i$. Following the definition of instrumental variables, these instruments, $\theta_i = (\theta_1, \theta_2, \ldots, \theta_{k_i})$, must, for large samples, be uncorrelated with $E_i$, correlated with the nonlinear functions $f_j^i$, while their elements are linearly independent of $X_i$.

Kelejian then shows that these $k_i$ instruments can be obtained by regressing each $f_j^i$ on the elements of a polynomial in $X$. Since the expectation of one variable conditioned on a set of others is, generally, a function of the others, he gets:

$$f_j^i = h_j^i + V_j^i, \quad j=1, 2, \ldots, k_i$$

(3.53)

where

$$h_j^i = h_j^i(x), \quad E(V_j^i|X) = 0$$
Earlier Kelejian showed that if equation i is identified subject to zero restrictions, then all \( h_j^i \) are linearly independent of \( X_1 \). It follows that the \( k_j^i \) are perfect instruments to be used for \( f_j^i \) in 2SLS. The problem is to estimate the \( h_j^i \), since they are unknown. He does it by regressing with OLS each known \( f_j^i \) on a polynomial of degree d in \( X \), say \( P_j^i = P_j^i(X) \), and then estimating:

\[
\hat{P}_j^i = \hat{f}_{oj} + \hat{f}_{lj} X_1 + \ldots + \hat{f}_{nj} X_n + \ldots
\]

\[
+ \hat{\pi}_{lj} X_1^2 + \ldots + \hat{\pi}_{nj} X_2^2 + \ldots + \hat{\pi}_{ng} X_n^d
\]

where the \( X_q, q = 1, \ldots, n \), are the elements of \( X \). Let \( M = (X_1 \ldots X_m, X_1^2, \ldots, X_n^2, \ldots, X_n^d) \). Then \( P_j^i = M_i \pi_j^i \) and the instruments we need are the estimates:

\[
\hat{P}_j^i = M_i \hat{\pi}_j^i, j=1, 2, \ldots, k_i
\]

where

\[
\hat{\pi} = (M'M)^{-1} M' f_j^i
\]

and

\[
\operatorname{Plim}_{N \to \infty} \hat{\pi}_j^i = \pi_j^i
\]

Hence, the 2SLS estimates for nonlinear systems are consistent, but only if all the polynomials are of the same degree since only then will all of the instruments be orthogonal to each estimated residual.
Following the good results of the experiments of Goldfeld and Quandt (1972), who apply Kelejian's method, the 37 original exogenous variables in RJM were squared, principal components were calculated and the first ten ranked according to highest variance explained were picked to join the previous 19 principal components as the basic set of instrumental variables in the first stage of Fuller's MLIML estimation procedure.

Note that although Kelejian's proof is for 2SLS, he also shows that the consistency of 2SLS does not depend upon the condition that the reduced form equations be linear, additive functions of the structural disturbance terms. Since Fuller's MLIML estimator depends on instrumental variables in its first stage and it is a k-class estimator as is 2SLS, Kelejian's arguments for consistency apply as well to MLIML and, hence, to A3SMLML estimates.

However, even if it is the case that MLIML remains consistent for nonlinear systems using some polynomial of exogenous variables in the first stage, there is so far only the limited empirical evidence of Goldfeld and Quandt that the linear and quadratic polynomial, $P^i_j$, chosen for estimating the first stage of RJM is of sufficiently large degree to approximate the nonlinear function $f^i_j$ in each equation $i$ of the model. Kelejian notes that clearly some degree, $d$, exists so that the approximation is good enough (he doesn't note it, but this is because of Weierstrass' Theorem), he assumes that the approximation improves as $d$ increases. But Klein (1969) found a lack of monotonicity in this regard.
Conclusion

While the estimator $A_3SMLML$ used to estimate the Model RJM is not necessarily fully efficient, there is some empirical evidence that it performs well when a linear and quadratic polynomial is used as an instrumental variable. For that reason it has been applied to estimate the RJM Model. The technique is practical and could be applied to much larger systems, including the MPS Model.
CHAPTER IV. ESTIMATION

In this chapter the statistical and economic properties of the 13 structural equations are analyzed.

Before estimating the individual equations, a few remarks are made concerning the data used in estimation, the computer software and hardware used for the estimations, the A3SMLML estimator, and several types of distributed lags which were built into the equations.

The quarterly data set was obtained from Helen Farr, Economist, Division of Research and Statistics, Board of Governors of the Federal Reserve System. It is 1972 based data, i.e., all variables are deflated according to price indices which are equal to 100 in the first quarter of 1972. Since the 1972-based data set was first released in the summer of 1976, RJM is one of the first, if not the first, macromodel to be estimated using the new data. The MPS data set lists 388 endogenous and 138 exogenous variables. The original RJM Model (RJM1) uses 30 endogenous variables and 37 exogenous variables for estimation purposes. The final version of RJM (RJM3) uses two more exogenous variables in one equation, but these are dummy variables composed of zeros and ones.

Some of the variables in the MPS data are not seasonably adjusted and some are, while a few variables are listed as "seasonal adjustment factors," such as JMSA, seasonal adjustment factor of MD$, used in the demand deposit identity (2.46). In several structural equations the MPS Model uses seasonal dummies to estimate any seasonal influences.
None are used in RJM, since it is a short-run model in which the level of aggregation is very high and the specification of the equations is relatively simple. Fair (1971) points out that, especially in the case of large-scale structural models, a considerable amount of information about the short-run fluctuation of various economic variables is lost when the data are seasonally adjusted.

There are aggregation problems, even with a large model such as the MPS. One example is the assumption in Chapter II of a single aggregate Cobb-Douglas production function with assumed smooth substitutability between capital and labor. From it was derived, ultimately, the optimal (aggregate) capital-output ratio defined by (2.24). Fisher (1969) has shown that the conditions under which aggregate capital and labor must be organized to achieve maximum total output from these factors are so stringent, both technologically and socially, that an exact representation is out of the question. Nevertheless, whatever it is that is working behind the scenes, there is something in the U.S. economy that allows a single aggregate Cobb-Douglas production function to predict approximately the correct picture of labor's share (75 percent) of U.S. output. Fisher concludes that aggregate data and functions of that data sometimes can and do give adequate approximations for policy and forecasting models as long as things keep on moving pretty much together (e.g., as long as there is not a great deal of movement in the appropriate relative variables of a production function or as long as individual marginal propensities to consume are about
equal or as long as the distribution of income remains relatively fixed). In the long run, these elements will change, but for short run models, they usually won't change much and, hence, aggregation poses less of a problem. Nevertheless, because RJM is only one-seventh the size of the MPS Model, it follows that RJM should suffer somewhat in performance from the aggregation problem alone.

The data set was first punched on cards following the computer printouts received from the Federal Reserve Board. The cards were read onto a direct-access data set on a private disk leased by the Economics Department and shared by its members. Since SAS, the software package used for estimation, could not easily read data from a direct-access data set, a PLl program was written to create a sequential data set on a public pack and this, in turn, served as the input to SAS.

Since some variables, such as subsidized housing starts, ZHS, and depreciation on producers' durables, WAPD, have observations recorded only from 1954.II, and since the last four observations of the data set were not used in order to allow for an ex-post prediction, the span of the data set for all equations is 1954.II - 1975.II. In other words, there are 85 observations in the statistical sample.

Distributed Lags

Chapter II was devoted to the specification of the RJM Model. One of the most difficult problems in the specification of a model is the shape and length of various distributed lags. In other words, if the equation has the form:
then the question arises: What are the magnitudes of \( n \) and the \( w(i) \)?

It is usually assumed that the longer the lag, the greater the degree of multicollinearity. The MPS Model relies on the popular Almon Lag procedure (Almon 1965) to estimate its distributed lags of explanatory variables.

The Almon Lag procedure assumes that successive weights of a distributed lag lie on a polynomial. A theorem by Weierstrass states that a function continuous in a closed interval can be approximated over the whole interval by a polynomial of suitable degree which differs from the function by less than a given positive quantity at every point of the interval. This theorem is the basis for the Almon Lag procedure as well as for Kelejian's development of consistent nonlinear estimators in Chapter III, above. The Almon Lag is convenient, especially when theory implies a rise in the weights for a time and then a decline, as in the investment equations (2.25) and (2.26). The procedure estimates a few points on the polynomial by OLS regression and then uses Lagrangian interpolation to fill in the points of the curve between the regression estimates. The best lag length is the one that gives the best \( R^2 \).

The Almon scheme is more difficult computationally than the mathematically equivalent one developed in Tinsley (1970). Once the length of the lag, \( n \), and the degree of polynomial, \( d \), are decided upon the weights are calculated by:

\[
Y_t = \sum_{i=0}^{n-1} w(i) X_{t-i}
\]
\[ W(i) = U_0 + U_1i + U_2i^2 + \ldots + U_di^d \]  

(4.2)

Substituting into (4.1) gives:

\[ Y_t = \sum_{i=0}^{n-1} (U_0 + U_1i + U_2i^2 + \ldots + U_di^d) X_{t-i} \]  

(4.3)

Thus, for \( n = 3, d = 2 \):

\[ Y_t = U_0 X_t + (U_0 + U_1 + U_2)X_{t-1} \]

\[ + (U_0 + 2U_1 + 4U_2) X_{t-2} \]

\[ = U_0 (X_t + X_{t-1} + X_{t-2}) + U_1 (X_{t-1} + 2X_{t-2}) \]

\[ + U_2 (X_{t-1} + 4X_{t-2}) \]

(4.4)

Using OLS, the \( U_i \) can be estimated and replaced in (4.2) to calculate the weights, \( W(i) \).

In RJM a variation of this method suggested by Wayne Fuller is used that employs the capability of the software package, SAS, to linearly restrict the regression coefficients in a model. Thus, to capture the inverted-V shape of an investment function, consider the parameters of a lag of length seven, where the current value is unrestricted, but both tails of the lag are restricted to zero along a quadratic polynomial expressed by the familiar transformation matrix for linear restrictions:

\[ CB = \Gamma \]  

(4.5)
which implies:

\[ \beta = C^{-1} \Gamma \]  

\[ \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 2 & 4 \\ 1 & 3 & 9 \\ 1 & 4 & 16 \\ 1 & 5 & 25 \\ 1 & 6 & 36 \end{bmatrix} \begin{bmatrix} \gamma_0 \\ \gamma_1 \\ \gamma_2 \end{bmatrix} \]

The model assumes that \( \beta_0 = 0 \) and \( \beta_6 = 0 \). It follows that \( \beta_0 = \gamma_0 = 0 \).

Also

\[ 6\gamma_1 + 36\gamma_2 = \beta_6 = 0 \]  

(4.7)

and

\[ \gamma_1 = -6\gamma_2 \]

Therefore

\[ \beta_0 = 0 \quad \beta_1 = \gamma_1 + \gamma_2 = -5\gamma_2 \]  

(4.8)

\[ \beta_2 = 2\gamma_1 + 4\gamma_2 = -8\gamma_2 = 8/5\beta_1 = 1.6\beta_1 \]

\[ \beta_3 = 3\gamma_1 + 9\gamma_2 = -18\gamma_2 + 9\gamma_2 = -9\gamma_2 = 9/5 = 1.8\beta_1 \]

\[ \beta_4 = 8/5\beta_1 = 1.6\beta_1 \quad \beta_5 = 5/5\beta_1 = \beta_1 \quad \beta_6 = 0 \]
Similarly, when theory called for a declining weighted average of distributed lags, as in the case of lagged disposable income per capita in the consumption function (2.7), the linear restrictions were:

\[ \beta_2 = 0.8\beta_1 \]  
\[ \beta_3 = 0.6\beta_1 \]  
\[ \beta_4 = 0.4\beta_1 \]  
\[ \beta_5 = 0.2\beta_1 \]  

(4.9)

The Koyck distributed lag is used often in RJM when a partial adjustment mechanism is called for or adaptive expectations are assumed. The general Koyck form is:

\[ Y_t = \beta(1-\lambda)X_t + \lambda Y_{t-1} + (U_t - \lambda U_{t-1}) \]  
\[ = b X_t + c Y_{t-1} + e_t \]  

(4.10)

The Hardware and Software

The computer used in estimating RJM was an IBM 370/58 with 800K of fast core available to users via batch processing. A key was made available to operate the reader and printer in a remote terminal located in the Economics Department.

The software consisted of two packages: ECONPK and SAS. The former is a set of programs developed for the Economics Department at Iowa State University. Although Fuller's MLIML algorithm has been programmed by this author and is part of ECONPK, the program is limited
in size to 99 variables and only 15 per equation. For this reason, the new 1976 version of SAS was used. This statistical analysis system was developed by the SAS Institute, Inc., Raleigh, North Carolina. The exact SAS program used in the final version of the model, RJM3, is listed in Appendix B, below. In its 1976 version, SAS incorporated Fuller's MLIML estimator and allows over 1000 variables together with unlimited observations per data set. Unfortunately, while SAS was intended to handle far more variables than needed per equation in the RJM Model, the MLIML program was never debugged for systems as large as RJM. Hence, the estimation of RJM was made much more costly in time and money than necessary. Moreover, SAS does not explicitly calculate Fuller's first two F statistics and the third F statistic not at all. It calculates the k-class statistic:

\[ k = 1 - \frac{\alpha_{1-k_2}}{N-k_2} \]  

(4.11)

from which the user must carry out the rest of the calculations.

Furthermore, in calculating the t statistics for restricted distributed lags, the same t is reported for each coefficient in the lag because only one parameter is being estimated.

The principal components program in SAS does not output the principal components by observation. Such output was necessary in order to use the principal components of the 37 exogenous variables as instruments in the first stage of MLIML estimation. Therefore, a principal components program in ECONPK was employed.
Since the lagging of large numbers of variables on SAS is cumbersome, while it is relatively simple on ECONPK, all variables with lags were lagged on ECONPK, read into the sequential data set on a public pack, and then into SAS.

Since each equation had to be estimated first by MLIML, then transformed by the unique \( \hat{\rho} \) for that equation and reestimated by MLIML to get estimates corrected for autocorrelation and to get the two F statistics, and since the estimated equation might be unsatisfactory, there was no attempt to pass all 13 equations from AMLIML into 3SLS immediately for the first two models, RJM1 and RJM2.

The Model RJM1

The original model (RJM1) was specified in Chapter II. The system consists of 30 equations. The 13 structural equations were specified in (2.7), (2.10), (2.13), (2.14), (2.25), (2.26), (2.29), (2.32), (2.35), (2.36), (2.42), (2.44), and (2.53) of Chapter II. The 17 identities were specified in (2.11), (2.12), (2.24), (2.27), (2.28), (2.30), (2.31), (2.33), (2.34), (2.37), (2.45), (2.46), (2.47), (2.52), (2.56), (2.57), and (2.58).

After each estimated equation, the mean square error, the \( \hat{\rho} \) used to transform the variables, the two F-tests and an analysis of these statistics of the coefficients will be given. If the first version of the equation failed in any major respect, a second and third was estimated until an acceptable equation evolved.

The consumption function in (2.7) was first estimated as:
where the lag of VCNS, wealth, is a 2nd degree polynomial constrained to zero at the tail, the lag of YD, disposable income, is constrained to decline linearly except for the current period, and where

\[
(\text{CON})_{t} = -0.011389 + \sum_{i=0}^{4} a_i \left( \frac{\text{YD}}{N} \right)_{t-i} + \sum_{i=0}^{4} b_i \left( \frac{\text{VCNS}}{0.01*\text{PGNP}*N} \right)_{t-i} + 0.0349 U1_{t-1} (0.708)_{t-1}
\]

Thus the signs for both disposable income per capita and wealth per capita satisfy theory. The sum of the \(a_i\)'s gives a total marginal propensity to consume per capita of 0.6518, which is comparable to the MPS's 0.6630, and the t values indicate strong significance. The current marginal propensity to consume out of wealth is only \(b_0 = 24.889\),
however; far less than the MPS's 54.43. Note that the marginal propen
sity to consume out of real wealth per capita is 24.9 when VCN$ is in
trillions of dollars, but MPCW = .0249 when wealth, VCN$, is expressed
in billions of dollars. Moreover, the two F-tests are marginal. For
these reasons, three other versions were estimated.

The simple consumption function:

\[
\left( \frac{CON}{N} \right)_t = 0.01011 + 0.7697 \left( \frac{YD}{N} \right)_t \\
\text{(0.14312) (13.461)}
\]

\[+ 30.5959 \left( \frac{VCN$}{01*PCNP*N} \right)_t + 0.00846 \hat{U}_t \]

\[\text{MSE = .000467} \]

\[\hat{\rho} = 0.7880 \]

\[(-12.07)\]

was estimated. The \( F_1 = 2.1 > 1.65 = F_{56,.05} \) implies that the model is
not properly specified. Moreover, the magnitude of the marginal
propensity to consume out of wealth is only half of the MPS's estimate.

In the next version only current values were retained and the
Koyck structure introduced, giving

\[
\left( \frac{CON}{N} \right)_t = -0.021 + 0.0505 \left( \frac{YD}{N} \right)_t \\
\text{(-1.295)(1.1011)}
\]

\[+ 6.1692 \left( \frac{VCN$}{01*PCNP*N} \right)_t + 0.9263 \left( \frac{CON}{N} \right)_{t-1} \]

\[\text{MSE = 0.00016} \]

\[\hat{\rho} = -0.16 \]

\[(-1.53)\]
K1 = 1.4642 implies a small F1 and K2 = 2.9393 implies a large F2 so that the F's imply good specification and identification. The long run marginal propensity to consume out of disposable income is a reasonable 0.6847, but the small t value for this variable precluded (4.12c)

A final Koyck1 version was estimated, viz.:

\[
\frac{\text{CON}}{N} = -0.01416 + \sum_{i=0}^{4} a_i \frac{\text{YD}}{N} + \sum_{i=0}^{4} b_i \frac{\text{VCNS}}{N} + 0.9659 \frac{\text{CON}}{N} \quad (4.12d)
\]

\[
-0.0327 \quad (0.0268)
\]

\[
a_0 = 0.1194 \\ b_0 = 11.1829 \\
(2.654) \\ (3.158)
\]

\[
a_1 = -0.0328 \\ b_1 = -1.4435 \\
(-1.768) \\ (-2.762)
\]

\[
a_2 = -0.0262 \\ b_2 = -2.3095 \\
(-1.768) \\ (-2.762)
\]

\[
a_3 = -0.0197 \\ b_3 = -2.5982 \\
(-1.768) \\ (02.762)
\]

\[
a_4 = -0.0131 \\ b_4 = -2.3095 \\
(01.768) \\ (-2.762)
\]

\[\Sigma a_i = 0.029 \text{ implies that the long run marginal propensity to consume out of income } = \text{MPCY } = \frac{0.029}{1 - 0.0659} = 0.85055. \] \[\Sigma b_i = 2.524 \text{ implies that}
\]

1There was an unfortunate oversight in estimating all versions of this consumption function, viz., all of the 89 observations of the data set were used instead of only the first 85. The last four observations were to be used only for the ex-post prediction, later, in Chapter V. For the remaining equations, only 85 observations were used.
the long run marginal propensity to consume out of net worth = MPCW = 
\[ \frac{2.524}{1 - 0.0659} = 74.01, \] 
when VCN$ is in trillions of dollars, but MPCW = 0.07401 if wealth were expressed in billions.

\[ F_1 = 0.9732 \times 1.71 = F_{49.05}^{26} \]

\[ F_2 = 2.004 > 1.70 = F_{40.05}^{27} \]

\[ \text{MSE} = 0.0001198 \]

\[ \hat{\rho} = -0.0561 \]

\[ (0.53) \]

\[ \bar{\rho} = -0.0561 - 0.0327 = -0.0888 \]

The lag on wealth, VCN$, is a 2nd degree polynomial constrained to zero at the tail, while the lag on YD/N is constrained to decline linearly. However, the imposition of the Koyck structure obviously affects the weights of these lags.

Since the signs and magnitudes of the coefficients, the t values, the smallest mean square error among the versions estimated, the insig- nificance of \( \hat{\rho} \), the small \( \Delta\bar{\rho} \), and the two F's are all highly favorable to this version, it is adopted into the Model RJM1.

The expenditures on consumer durables equation proved to be one of several weak spots in the RJM Model. With hindsight, it is regrettable that the specifications of (2,10) did not follow more closely that of the MPS Model. At any rate, the estimation of (2,10) resulted in:

\[ \text{ECD}_t = -24.3812 + 20.302 \left( \frac{YD}{N} \right)_t \]

\[ (-1.978) \quad (2.107) \quad (4.13a) \]

\[ + \sum_{i=0}^{4} a_i (RCB - EINFL)_{t-i} \]
where the lagged coefficients of RCB, the corporate bond rate, are restricted by the usual 2nd degree polynomial and the coefficients of the subsidized housing starts, ZHS, are restricted linearly, and where:

\[ \sum_{i=1}^{4} b_i ZHS_{t-1} -11.464 \frac{ECD_t}{N_t} -0.0824 U2_{t-1} \]

\[ (4.641) (-0.488) \]

\[ + 0.7039 \]

\[ \text{where the lagged coefficients of RCB, the corporate bond rate, are restricted by the usual 2nd degree polynomial and the coefficients of the subsidized housing starts, ZHS, are restricted linearly, and where:} \]

\[ a_0 = -0.0337 \]
\[ a_1 = -0.1375 \]
\[ a_2 = -0.22 \]
\[ a_3 = -0.2475 \]
\[ a_4 = -0.220 \]

\[ \hat{\rho} = -0.1371 \]

\[ \text{MSE} = 6.7595 \]

\[ F_1 = 1.2747 < F_{54,.05}^2 = 1.70 \]

\[ F_2 = 1.354 < 1.68 = F_{55,.05}^2 \]

The small second F implies that the equation is not empirically identified. Moreover, the poor t's and relatively large MSE indicate a poor fit.
After further research on the corresponding MPS equation, the (4.13a) equation was run again except that per capita expenditures were used. Again, a 2nd degree polynomial was used to restrict the lagged interest rates, and linearly declining weights were imposed on lagged subsidized housing, ZHS, yielding the following:

\[
\left( \frac{ECD}{N} \right)_t = -0.0534 + 0.08724 \left( \frac{YD}{N} \right)_t \\
(-1.8287) (2.514)
\]

\[
+ \sum_{i=0}^{4} a_i (RCB - EINFL)_{t-i} + \sum_{i=1}^{4} b_i ZHS_{t-i}
\]

\[
-0.10452 \left( \frac{KCD}{N} \right)_{t-1} + 0.79543 \left( \frac{ECD}{N} \right)_{t-1} - 0.0861 \left( \frac{U2}{t-1} \right)
\]

\[
(-2.706) (7.952) (-0.618)
\]

where:

\[
a_0 = -0.00504 \quad b_1 = 0.0009 \\
(-1.413) \quad (0.41)
\]

\[
a_1 = 0.00026 \quad b_2 = 0.00073 \\
(0.472) \quad (0.782)
\]

\[
a_2 = 0.00042 \quad b_3 = 0.00058 \\
(0.472) \quad (0.782)
\]

\[
a_4 = 0.00046 \quad b_4 = 0.00044 \\
(0.472) \quad (0.782)
\]

\[
a_5 = 0.00041 \quad b_4 = 0.00044 \\
(0.472) \quad (0.782)
\]

\[
\sum_{i} a_i = 0.00349 \quad \sum_{i} b_i = 0.002622 \\
0.05 \quad 0.05
\]

\[
F_1 = 1.37 < 1.75 = F_{44,0.05}^{26}
\]

\[
F_2 = 1.7 < 1.73 = F_{44,0.05}^{27}
\]
The new $\hat{\beta} = -0.035 + 0.0861 = -0.1211$.

Even though the t's on the interest rate (RCB) and on subsidized housing (ZHS) are poor, they are also poor in the MPS Model. The magnitudes and signs are comparable. The long run marginal propensity to consume durables out of disposable income per capita is $\frac{0.08724}{1 - 0.79543} = 0.1232$. The sign, magnitude, and t value for the lagged stock of consumer durables per capita, $\left(\frac{K_{CD}}{N}\right)_{t-1}$, are all comparable to that of the MPS Model and are theoretically acceptable. Moreover, the small MSE, the insignificant $\hat{\rho}$, the small change in $\hat{\beta}$, and the favorable first F all recommend this equation. The second F is only slightly too small for proper empirical identification. This is most likely due to the two lagged variables whose t's indicate insignificance. Nevertheless, since they are theoretically important cost and expectation variables, they are retained in the RJMl Model.

The estimator of the eclectic expenditures on residential construction equation, (2.13), yielded:

$$EH_t = -0.83105 + 1.62498 \left(\frac{CON}{N}\right)_t$$

$$+ 0.00326 \left(\frac{KH}{NL}\right)_{t-1} + \sum_{i=0}^{4} a_i (RCB - EINFL)_{t-i}$$

$$+ \sum_{i=1}^{4} b_i ZHS_{t-i} + 0.67731 EH_{t-1} - 0.0189 U_3$$

$$+ 0.67731 EH_{t-1} - 0.0189 U_3$$

(4.14a)
where a second degree polynomial is used to restrict the lagged interest rate lag, RCB, while subsidized housing starts, ZHS, is restricted by linearly declining weights, and:

\[
\begin{align*}
\hat{a}_0 &= 2.1645 \\
(2.75) \\
\hat{a}_1 &= 0.1379 \\
(-1.15) \\
\hat{a}_2 &= -0.2206 \\
(-1.157) \\
\hat{a}_3 &= -0.2482 \\
(-1.157) \\
\hat{a}_4 &= -0.2206 \\
(-1.157) \\
\hat{b}_1 &= 0.3458 \\
(1.368) \\
\hat{b}_2 &= 0.40 \\
(2.527) \\
\hat{b}_3 &= 0.32 \\
(2.027) \\
\hat{b}_4 &= 0.24 \\
(2.527)
\end{align*}
\]

The signs of the lagged interest rate and subsidized housing are wrong, the mean square error is high, \( \hat{\rho} \) is high and significant indicating strong autocorrelation originally, the t on \( \frac{CON}{N} \) is insignificant, and the 2nd F indicates that this equation is not empirically identified. Hence, a second version was estimated using RTB, the short-term rate, as the cost of capital proxy and the long-term rate less the short-term (RCB-RTB) as a credit-crunch variable:
\[
EH_t = 28.0392 + 15.6586 \left( \frac{CON}{N} \right)_t^{(4.231)} \left( \frac{RTB}{4} \right)_t^{(2.299)}
- 0.1005 \; KH_{t-1} + \sum_{i=2}^{4} a_i \left( RCB-RTB \right)_{t-i}^{(-3.013)}
- 1.6840 \; RTB_t - 1.3589 \; RTB_{t-1} + 0.7831 \; RTB_{t-2}^{(-3.277)}
\sum_{i=1}^{4} b_i \; ZHS_{t-i} + 0.4511 \; \text{TIME}_t^{(-1.518)} (0.783)
+ 0.0751 \; U_3_{t-1} + 0.79545 \; EH_{t-1}^{(-0.627)} (8.141)
\]

\[
a_2 = -1.3297 \quad \quad b_1 = 0.346 \quad \quad (1.125) \quad \quad (1.121)
\]

\[
a_3 = 0.5724 \quad \quad b_2 = -0.175 \quad \quad (0.914) \quad \quad (0.829)
\]

\[
a_4 = 0.847 \quad \quad b_3 = -0.1401 \quad \quad (0.702) \quad \quad (0.829)
\]

\[
\sum_{i=2}^{4} a_i = 0.0817 \quad \sum_{i=1}^{4} b_i = -0.0743
\]

\[
F_1 = 1.1258 < 1.75 = F_{42,.05}^{26}
F_2 = 2.418 > 1.73 = F_{42,.05}^{27}
\]

\[
\text{MSE} = 2.2512
\rho = -0.26 \quad \quad (-2.484)
\]

The new \( \rho = 0.26 + 0.0751 = 0.3351 \).
In this equation the lagged short-term rate, RTB, was not constrained. In this version, the mean square error is lower and the t's for the interest rates and subsidized housing starts are improved, if not always significant. The signs are all theoretically acceptable except for the sum of subsidized housing starts; but the insignificant t's indicate that this variable is irrelevant. Both F's are favorable and not much autocorrelation seems to remain. Hence, this equation entered RJM1.

The housing stock equation (2.14) was estimated with little trouble as:

\[
KH_t = (KH_1 + KH_5)_t = 0.78924 + 0.2206 \text{EH}_{t-1}^{(0.629)} (11.97) + 0.0331 U_4^{(-0.786)} (5.738) KH_{t-1}^{t-1}
\]

\[
F_1 = 1.3423 < 1.7 = F_{28}^{.05}
\]

\[
\text{MSE} = 0.12891
\]

\[
\hat{\varphi} = 0.8471
\]

\[
(-14.693)
\]

This equation has no current endogenous on the right hand side and hence, no F2 is called for. This equation is identified as is any single equation model since the transformed lagged endogenous on the right hand side are now exogenous.

This is the only equation in RJM needing but one version, the first. All the signs are acceptable and the small and insignificant \( \Delta \hat{\varphi} \) coefficient indicates that the residuals are no longer highly correlated despite the large \( \hat{\varphi} \).
In the hope of reducing the size of the model while retaining essentially the same producers' investment sector, the producers durables and structures equations, (2.25) and (2.26), were aggregated into one variable, PDS, giving the following investment equation:

\[
PDS_t = -2.38978 + \sum_{i=0}^{4} a_i (VPD * XB)_{t-i} (-1.1882) + \sum_{i=0}^{4} b_i (VPS * XB)_{t-i} + 0.93113 PDS_{t-1} (16.3275) + 0.02909 U5_{t-1}
\]

where:

\[
a_0 = -0.0028259 (-1.96) \quad b_0 = 0.075298 (7.1294)
a_1 = 0.001114 (2.0152) \quad b_1 = -0.021971 (-4.8123)
a_2 = 0.0009583 (2.0152) \quad b_2 = -0.022
a_3 = 0.0007912 (2.0152) \quad b_3 = -0.01253 (-4.8123)
a_4 = 0.0006352 (2.0152) \quad b_4 = -0.012524 (-4.8123)
\]

\[
\frac{\sum_{i=0}^{4} a_i}{\sum_{i=0}^{4} b_i} = \frac{0.00068}{0.00972} = .000687 = \frac{.000687}{.0916} \quad \frac{\sum_{i=0}^{4} b_i}{\sum_{i=0}^{4} a_i} = \frac{0.06887}{0.93113} = .06887
\]

\[
F1 = 1.57275 < 1.65 = F_{48,.05}^{34} \\
F2 = 4.559 > 1.64 = F_{48,.05}^{35}
\]
MSE = 2.38515
\[ \hat{\rho} = 0.176582 \]
\[ (-1.6528) \]

Final \[ \hat{\beta} = .0176482 + 0.02909 = .205572 \]

and where both lags are constrained by a 2nd degree polynomial.

Although the two F's are highly favorable to this equation, as is the small change in the autocorrelation coefficient \( \Delta \hat{\rho} \), and the significant t values, the sums of the lagged coefficients, due to the unexpected negative signs, are so small relative to the coefficients in the MPS Model, that this equation seemed inadequate.

Several other attempts were made to find an aggregate version of producers investment, but the others were much worse than (4.16a). When more explanatory variables were added, such as the OBE expectations variable, EPDS, as specified in (2.25) and (2.26), and the lagged stocks of producers' durables and structures, the coefficients of the two distributed lags became even smaller and their t's became insignificant.

Hence, (4.16a) was disaggregated, but producers expectations for both plant and equipment investment, EPDS, and the lagged stock of producers durables were retained, giving expenditures on producers durables as:

\[
\text{EPD}_t = -29.7533 + \sum_{i=0}^{4} a_i (VPD \times XB)_{t-i} + \sum_{i=0}^{4} b_i \text{EPDS}_{i} + 0.312 \text{KPD}_{t-1} + 0.144 \text{US}_{5t-1} + \hat{\epsilon}_t
\]

\[ (-2.393) \]

\[ (-2.393) \]

\[ (1.92) \]
where:

$$
\begin{align*}
    a_0 &= 0.00095 \\
    (0.499) &
    b_0 = -0.63845 \\
    (-2.736) \\
    a_1 &= 0.00532 \\
    (5.91) &
    b_1 = 0.05732 \\
    (-1.5) \\
    a_2 &= 0.00458 \\
    (5.91) &
    b_2 = 0.09171 \\
    (-1.5) \\
    a_3 &= 0.00378 \\
    (5.91) &
    b_3 = -0.1032 \\
    (-1.5) \\
    a_4 &= 0.00303 \\
    (5.91) &
    b_4 = -0.09171 \\
    (-1.5)
\end{align*}
$$

But the negative signs on the expectations-for-plant-and-equipment-investment variables made this version unacceptable. Hence, a third version of expenditures on producers durables was estimated, viz., that specified in (2.25), resulting in:

$$
\begin{align*}
    \text{EPD}_t &= 8.06641 + \sum_{i=0}^{4} a_i (\text{VPD} \times \text{XB})_{t-i} \\
    (2.91) &
    + \sum_{i=0}^{4} b_i \text{EPD}_{t-i} + 0.1989 U_5 \\
    (2.673) &
    \text{EPD}_{t-1}
\end{align*}
$$

where the lagged desired capital variable, VPD \times XB, is restricted by a linearly declining weighted average, lagged expectations is restricted by a 2nd degree polynomial, and

$$
\begin{align*}
    a_0 &= 0.003940 \\
    (3.0496) &
    b_0 = -0.09658 \\
    (-0.5069) \\
    a_1 &= 0.001250 \\
    (3.487) &
    b_1 = 0.03704 \\
    (1.2126)
\end{align*}
$$
The reasonable magnitude and the positive signs on both distributed lag coefficients, the significant t values for all the desired capital coefficients, and the current expectations variables, plus the two highly favorable F tests indicate that (4.16c) is the best of the versions estimated and so it was adopted into RJML. Note that the large \( \hat{\rho} \) with a highly significant t value together with a significant t for \( \hat{U}_t^{5} \) indicates autocorrelation is still present and, ideally, the data should be transformed again using \( \hat{\beta} \) and the equation reestimated. It was not, however, due to funding and time restrictions.
Since the MPS Model retained lagged stock of producers structures in their expenditures on producers structures equation, it was also retained in RJML, as expressed in (2.26). Using linearly declining weights to restrict the lagged VPS * XB and a 2nd degreee polynomial to restrict EPDS, the estimated equation is:

\[ \text{EPS}_t = -18.2076 + \sum_{i=0}^{4} a_i (VPS * XB)_{t-i} \]

\[ + \sum_{i=0}^{4} b_i \text{EPDS}_{t-i} - 0.2434 \text{KPS}_{t-1} \]

\[ + 0.0154 U6_{t-1} \]

\[
\begin{align*}
a_0 &= 0.01017 \quad &b_0 &= -0.03601 \\
&\quad (0.658) \quad &\quad (-0.269) \\
a_1 &= 0.05487 \quad &b_1 &= 0.05443 \\
&\quad (9.494) \quad &\quad (2.111) \\
a_2 &= 0.04693 \quad &b_2 &= 0.08709 \\
&\quad (0.494) \quad &\quad (2.111) \\
a_3 &= 0.03875 \quad &b_3 &= 0.0971 \\
&\quad (0.494) \quad &\quad (2.111) \\
a_4 &= 0.03112 \quad &b_4 &= 0.0871 \\
&\quad (9.494) \quad &\quad (2.111) \\
\sum_{i=0}^{4} a_i &= 0.18184 \quad &\sum_{i=0}^{4} b_i &= 0.28971 \\
\text{MSE} &= 2.1236 \\
F_1 &= 0.6427 < 1.65 = F_{40,.05}^{35} \\
F_2 &= 1.7513 > 1.64 = F_{49,.05}^{36} 
\]
\[ \hat{\rho} = 0.8429 \]
\[ (-14.443) \]
\[ \hat{\beta} = 0.8429 + .0154 = 0.8583 \]

Everything seemed favorable to this equation and it was adopted into RJML. However, during simulation of RJML, because the endogenous variable VPS, defined in (2.27), tracked so poorly, both VPS and EPD were exogenized. Not until the third version of the model RJM was estimated was it discovered that EPS as used in (4.17a) was really
\[ \text{PDS} = \text{EPD} + \text{EPS}, \]
and so, after correcting this error, (4.17b) was estimated as follows:

\[
\begin{align*}
\text{EPS}_t &= -1.6698 + \sum_{i=0}^{4} a_i (VPS * XB)_{t-i} \\
&+ \sum_{i=0}^{4} b_i \text{EPDS}_{t-i} - 0.01682 \text{KPS}_{t-1} \\
&+ 0.0151 \hat{U6}_{t-1}
\end{align*}
\]

(4.17b)

where

\[
\begin{align*}
a_0 &= -0.01369 \\
&\quad (-1.28) \\
a_1 &= 0.02018 \\
&\quad (5.19) \\
a_2 &= 0.01735 \\
&\quad (5.19) \\
a_3 &= 0.01433 \\
&\quad (5.19) \\
a_4 &= 0.0115 \\
&\quad (0.19) \\
b_0 &= 0.017 \\
&\quad (-0.182) \\
b_1 &= 0.0169 \\
&\quad (-0.971) \\
b_2 &= 0.02718 \\
&\quad (-0.971) \\
b_3 &= 0.03058 \\
&\quad (-0.971) \\
b_4 &= -0.0272 \\
&\quad (-0.971)
\end{align*}
\]
Even though the 2 $F$'s are favorable to this equation, the negative signs and low t values for the expectation variables, EPDS, and the low t values for the lagged stock of structures, $KPS_{t-1}$, led to the estimation of another version of expenditures on producers structures, viz.:

$$
EPS_t = -3.06 + \sum_{i=0}^{4} a_i (VPS * XB)_{t-i} - 0.12832 EPDS_t - 0.02303 KPS_{t-1} + 0.0104 u_6
$$

(4.17c)

where the lagged desired capital variable, $VPS * XB$, is restricted by a linearly declining weighted average:

$$
a_0 = -0.1956
$$

(-1.596)

$$
a_1 = 0.02351
$$

(5.9)

$$
a_2 = 0.0202
$$

(5.9)

$$
a_3 = 0.0167
$$

(5.9)

$$
a_4 = 0.0134
$$

(5.9)
Again, the sign on expectations variable, EPOS, is unacceptable, but the t value indicates that this coefficient is insignificant and so the variable is irrelevant to the explanation of EPS. The sign of the coefficient for lagged stock, KPS_{t-1}, is correct, but the coefficient is unexpectedly insignificant. However, the absolute value of the t's are large for all the other coefficients and the 2nd F is larger for version (17.c) than for (17.b), so (17.c) was adopted into RJML.

Since the MPS inventory equation regresses the level of inventory stock on its explanatory variables, an attempt was made first to estimate a level of inventory stock equation using EGF, federal government expenditures on goods and services, in place of MPS's defense expenditures, and a capacity variable, (XBC-XB) as a proxy for the MPS's orders for producers durables and number of workers on strike. The following equation was estimated:

\[
K_i = -138.6544 + 0.6591 EPC_{i} + 0.6969 EPC_{i-1} - 0.17113 (XBC-XB)_{t-1} + 0.7192 (XBC-XB) - 0.13592 EGF_{t-1} - 1.98992 \text{TIME}_{t} \\
\]

\[
(4.18a) \quad (-0.959) \quad (9.64) \quad (1.745) \quad (-13.09) \quad (3.327) \quad (-0.252) \quad (-1.09)
\]
This huge mean square error and negative intercept coupled with the inexplicable greater-than-one value of the coefficient for the lagged dependent variable despite no trace of error in the data, led to another version. Omitting the lagged dependent value and simplifying equation (4.18a) gave the following version:

\[ KI_t = 6.495 - 0.40961 \text{EPCE}_t \]
\[ - 0.04342 (\text{XBC-XB}) - 0.02418 \text{EGF}_t \]
\[ + 0.1595 \text{TIME} + 0.1713 \text{U}^8_{t-1} \]

\[ \text{MSE} = 23.4 \quad F_1 = 0.0174 < 1.69 = F_{48,.05}^{33} \]
\[ \hat{\rho} = 0.5299 \quad F_2 = 0.917 < 1.7 = F_{48,.05}^{34} \]
\[ \bar{\rho} = 0.7012 \]

The low t values on the capacity variable and the government expenditures variable, the negative sign for total consumer expenditures, plus a very small F2 led to the decision to drop the capacity variable.

\[ ^2 \text{Through an oversight, F2 was not calculated} \]
and use instead a distributed lag of desired capital, VPD * XB, since this variable is used successfully in the MPS Model to explain producers orders. EGF is retained since government expenditures is one of RJM's control variables and the MPS model used defense expenditures successfully in this equation.

The equation estimated was:

\[
K_I = -28.8398 - 0.26654 \text{EPCE}_t - 0.2936 \text{EGF}_t + 0.6074 \text{EPCE}_{t-1}^4 + \sum_{i=0}^{4} a_i (\text{VPD} \times \text{XB})_{t-i} \\
+ 0.15867 \text{EGF}_{t-1} - 0.2936 \text{EGF}_t - 0.0371 \text{U8}_{t-1} + 0.9723 K_I_{t-1} - 0.0371 U8_{t-1} \\
\text{MSE} = 136.1769 \quad F_1 = 1.322 < 1.74 = F_{41,.05}^{30} \\
\hat{\rho} = 0.821 \quad F_2 = 1.23 < 1.73 = F_{41,.05}^{31} \\
\beta = 0.821 - .0371 \\
= 0.7839
\]

where lagged VPD * XB is constrained to decline linearly,

\[
a_0 = -0.05149 \quad (-11.41) \\
\]
\[
a_1 = 0.00861 \quad (3.6) \\
\]
\[
a_2 = 0.0074 \quad (3.6)
\]
\[ a_3 = 0.0061 \]  
\[ (3.6) \]

\[ a_4 = 0.0049 \]  
\[ (3.6) \]

Since the sum of the coefficients for desired capital is smaller than that of MPS's producers orders by a factor of approximately 100 and especially because of the small second F and huge mean square error, another version was estimated using inventory investment, \( K_t - K_{t-1} \), as the dependent variable, following Pindyck (1973, 1976) and the Wharton Mark III (McCarthy 1972).

Estimating investment exactly as specified in (2.29) resulted in

\[
K_t - K_{t-1} = -4.2235 \]  
\[ (-1.25) \]

\[ + 0.354 \left( EPCE_t - EPCE_{t-1} \right) \]  
\[ (-0.259) \]

\[ + -0.6625 \left( XB_{t-2} - XB_{t-1} \right) - 0.1696 \left( XB_{t-1} - XB_{t-2} \right) \]  
\[ (1.72) \]  
\[ (-1.156) \]

\[ - 0.0848 \left( XB_{t-2} - XB_{t-3} \right) - 0.0565 \left( XB_{t-3} - XB_{t-4} \right) \]  
\[ (-1.146) \]  
\[ (-1.146) \]

\[ + 1.1067 \left( K_{t-1} - K_{t-2} \right) + 0.277 \hat{\Upsilon} \]  
\[ (4.5) \]  
\[ (0.925) \]

\[
\text{MSE} = 43.7
\]

\[ \hat{\rho} = -0.1475 \]  
\[ (1.40) \]

\[ \bar{\rho} = -0.1475 + 0.277 \]

\[ = 0.1295 \]
\[ F_1 = 1.468 < 1.74 = F_{27}^{48,.05} \]

\[ F_2^3 \]

The coefficient for the lagged dependent variable is unacceptable, being greater than one. Since both \( \rho \) and the coefficient for \( \Delta \bar{y} \) are small and insignificant, it seems that the correction for autocorrelation is not required for this equation. The untransformed version is:

\[
(KI_t - KI_{t-1}) = 0.26818 - 0.83058(EPCE_t - EPCE_{t-1}) \]
\[
(0.264) \quad (-4.572) \]
\[
+ 0.2521 (EPCE_{t-1} - EPCE_{t-2}) \]
\[
(0.833) \]
\[
+ 0.60956 (XB_t - XB_{t-1}) - 0.038020 (XB_{t-1} - XB_{t-2}) \]
\[
(5.002) \quad (-0.586) \]
\[
- 0.0190078 (XB_{t-2} - XB_{t-3}) - 0.01266 (XB_{t-3} - XB_{t-4}) \]
\[
(-0.486) \quad (-0.586) \]
\[
+ 0.8911163 (KI_t - KI_{t-2}) \]

\[ \text{MSE} = 9.9613 \]
\[ F_1 = .421 < 1.73 = F_{21}^{56,.05} \]

Since this equation was estimated in the same run with version (4.18d), footnote 2 applies for \( F_2 \). In version (4.18e), the coefficient for the lagged dependent variable, \( KI_{t-1} - KI_{t-2} \), is now reasonable. The t value of the changes in total consumer expenditures, \( EPCE_t - EPCE_{t-1} \),

---

\(^3\text{Due to an oversight, } F_2 \text{ was not calculated}\)
and for the most recent changes in private business product, \( X_{B_t} - X_{B_{t-1}} \) are now significant, unlike those of version (4.18a) and the mean square error and \( F_1 \) are both considerably smaller.

Hence, (4.18e) was used in RJM, despite the low t's for the longer lags. In the man-hours demanded equation of the MPS Model, as specified in (2.32), the production capacity variable, \( X_{BC} \), is endogenous. To make it genuinely exogenous in RJM, a new variable was constructed, viz., \( X_{BC} - X_{B_o} e^{-\frac{\lambda}{4} t} \), where \( X_{B_o} \) is private business output in 1954.II.

Using the \( X_{BC} \) variable, we attempted to simplify and improve the MPS equation by using a single capacity-utilization term, \( X_{B}/X_{BC} \), in place of the complex and unexplained 2nd term of (2.32); dropping the two dummy variables, \( D_1 \) and \( D_2 \), in (2.32); using population over 16 in place of \( TIME \); using man-hours, \( LMHT \), instead of man-hours to output ratio, \( LMHT/X_{B} \); and adding lagged man-hours to the right side as a partial-adjustment mechanism. The resulting estimated equation was:

\[
\ln LMHT_t = 8.87273 - 47.6525 \ln(XB/XBC)_t \tag{4.19a} \\
- 6.13 \ln(1.0 - .01 ULU)_t - 31.2222 \ln(XB/XB_{t-1}) \\
- 0.04522 N16_t + 0.5541 U8_{t-1} \\
MSE = 1.1414 \quad F_1 = 1.446 < 1.7 = F_{28,50,.05}^{28} \\
\hat{\rho} = 0.4815 \quad F_2 = 1.61 < 1.69 = F_{29,50,.05}^{29} \\
\hat{\beta} = 0.48150 + .5541 = 1.03
\]
The small 2nd F2 and especially the inexplicable $\beta > 1.0$ signal that something is wrong with this equation. Hence, a move was made toward the exact structure of the MPS equation by estimating the man-hours per unit of output in nonfarm business equation as:

$$\ln \left( \frac{LMHT}{XB} \right)_t = -2.00657 \quad (4.19b)$$

$$\quad + 29.06375 \ln \left( \frac{XB}{XBC} \right) \quad (5.052)$$

$$\quad - 13.1962 \ln \left( 1 - .01 + ULU \right)_t \quad (-1.596)$$

$$\quad + 10.8132 \ln \left( \frac{XB}{XB_{t-1}} \right) \quad (3.356)$$

$$\quad + 1.64192 (.01 * \text{TIME}) + 0.3986 \text{UL}_t \quad (2.272) \quad (1.725) \quad t-1$$

MSE = 0.28796

$$\beta = 0.5412 \quad F_1 = 1.32 < 1.7 = F^{28}_{50,.05}$$

$$(-5.934) \quad \beta = .5412 + .3986 \quad F_2 = 1.725 > 1.69 = F^{29}_{50,.05}$$

$$= .9398$$

Considering the signs of the coefficients, one would not expect, theoretically, that as output nears capacity, a one percent increase (decrease) in the output-to-capacity ratio would cause a 29 percent increase (decrease) in the man-hours-to-output ratio. Nor does theory allow that a one percent change in the employment rate will cause the man-hours-to-output ratio to decrease by 13 percent, since the last few employees hired should, theoretically, be less skilled and hence, less productive.
While the two $F$'s and the $t$ values on all but the employment rate are favorable to this equation, the large $\Delta z$, the large positive coefficient on the output to capacity ratio, $XB/XBC$, and the incorrect signs for several key variables precluded (4.19b).

Note that this version of the equation illustrates the importance of satisfying the demands of economic theory instead of blindly following good statistics, such as the significant $t$'s and favorable $F$'s of (4.19b). After restoring the complex 2nd term of (2.32) and the two dummies, the final version estimated was:

$$
\ln\left(\frac{LMHT}{XB}\right)_t = 0.39225 - 4.88296 \ln\left(\frac{XB}{XBC}\right)_t + \ln(25 - \frac{XB}{XBC}) + 0.220 \ln(1.0 - .01*ULU)_t \\
+ 0.50378 \ln(\frac{XB}{XB}_{t-1}) - 0.696996 (.01*TIME) + 0.00124 D1_t \\
- 0.000251 D2_t - 0.07889 U8_t \\
$$

where

$$
D1 = \begin{cases} 1, & \text{for 1969.I} \\ 0, & \text{otherwise} \end{cases}
$$

$$
D2 = \begin{cases} 1, & \text{TIME \geq 1969.II} \\ 0, & \text{otherwise} \end{cases}
$$

$$
MSE = 0.000926
$$
\[ F_1 = 1.143 < 1.71 = F_{48,.05}^{28} \]
\[ F_2 = .7354 < 1.70 = F_{48,.05}^{29} \]
\[ \hat{\rho} = 0.4781 \]
\[ (-5.018) \]
\[ \bar{\rho} = 0.4781 - .07889 = 0.39921 \]

For simulation the transformed eq. is:

\[
LMHT_t = XB_t \cdot \left( \frac{e^{0.39225}}{(2.5 - \frac{XB_t}{XBC_t})^{-4.88296}} \cdot \left(1.0 - .01 \cdot ULU_t \right)^{0.22} \cdot \left( \frac{XB_t}{XB_{t-1}} \right)^{-0.50378} \cdot e^{-0.00697 \cdot \text{TIME}} \cdot e^{(.00124 D1 - 0.000250 D2 - 0.07889 U8_{t-1})} \right)
\]

This equation is very close to that of the MPS Model, with two small exceptions. The negative coefficient on the 2nd term is almost four times larger in absolute value than the magnitude of the same variable in the MPS Model and the coefficient on employment is only one-third that of the MPS Model. This last coefficient is insignificant in (4.19b), while the MPS's coefficient is highly significant. The small mean square error, small coefficient for \( \Delta \rho \), and the general closeness to the MPS equation in its properties, suggest that (4.19b) be used in RJM1. But the very small 2nd F, pointing to a lack of identification, led to the estimation of yet another version for RJM2.
Since the MPS wage rate equation does not specify a lagged dependent variable but does specify the rate of change of the unemployment rate as an explanatory variable, the first annual rate of change of wages equation estimated was:

\[
\frac{PL_t - PL_{t-1}}{PL_{t-1}} \times 400 = 4.2749 \quad (1.476)
\]

\[-0.1163 \left( \frac{ULU_t - ULU_{t-1}}{ULU_{t-1}} \right) \times 400 \quad (-1.377)
\]

\[+ 1.2893 \text{ EINFL}_t - 1.781 \left( \frac{1}{ULU_t} \right) \quad (3.0) \quad (-0.124)
\]

\[+ 0.3136 \text{ U9}_t^{1} \quad (1.013) \quad t-1
\]

\[\text{MSE} = 11.94 \quad F_1 = 0.69 < 1.63 = F_{54,.05}^{48}
\]

\[\beta^4 \quad F_2 = 0.235 < 1.62 = F_{54,.05}^{49}
\]

The extremely small F indicates almost complete lack of identification. This is reflected in the small t values for all variables but expected inflation. However, had the equation been transformed by \(\rho\), as it should have been, it might have had better properties.

Nevertheless, the extremely poor results for (4.20a) coupled with ignorance of the fact that the equation had not been transformed, led to

\[\text{Due to an oversight, the data was never transformed for this equation.}\]
a radical change in approach. Following Pindyck (1976), retaining
all three lags for the rate of unemployment and for changes is disposable
income, the level of the wage rate, PL, equation was estimated as follows:

\[
PL_t = -2.18374 + 0.14322 (YD_t - YD_{t-1}) \\
- 0.2485 (YD_{t-1} - YD_{t-2}) - 0.12425 (YD_{t-2} - YD_{t-3}) \\
0.76167 EINFL_t + 91.319 (1/ULU_t) \\
-55.233 (1/ULU_{t-1}) - 27.6165 (1/ULU_{t-2}) \\
+ 1.0163 PL_{t-1} + 0.06111 U9_t \\
\]

(4.20b)

where both the changes in disposable income and the inverted unemployment
rate are restricted by linearly declining weighted averages and where

\[
MSE = 6.228 \\
\beta = -0.0356 \\
\tilde{\beta} = 0.0255 \\
F_1 = 0.745 < 1.72 = F_{54,.05}^{20} \\
F_2 = 2.04 > 1.71 = F_{54,.05}^{21}
\]
Unfortunately, a coefficient greater than one for the lagged dependent variable is unacceptable and perhaps indicates the need of including some trend-dominated variable in this equation. No errors were found in the data or the coding of the program, so the lagged dependent variable was dropped and the equation estimated again to give:

\[ PL_t = 266.282 + 3.3143 (YD_t - YD_{t-1}) + 3.1383 (YD_{t-1} - YD_{t-2}) + 1.5692 (YD_{t-2} - YD_{t-3}) + 48.8135 EINFL_t + 1645.0266 (1/ULU_t) - 1273.51 (1/ULU_{t-1}) - 636.755 (1/ULU)_{t-2} + 0.2195 U9_{t-1} \]

\[ (5.49) (2.03) \]

\[ (1.85) \]

\[ (1.85) \]

\[ (12.67) \]

\[ (2.34) \]

\[ (-2.6) \]

\[ (2.11) \]

\[ MSE = 1706.55 \]

\[ F1 = 0.517 < 1.72 = F_{54,.05}^{21} \]

\[ p = 0.4552 \]

\[ (-4.713) \]

\[ F2 = 1.935 > 1.71 = F_{54,.05}^{22} \]

\[ \bar{p} = 0.6747 \]

The negative sign on the inverse of unemployment and especially the magnitude of the sum of coefficients plus the huge mean square error led to the abandonment of this approach and a return to a Phillips curve type equation. But the small F1 led to a specification almost the same as (4.20c) except that the annual rate of change of the wage rate is once
again the dependent variable and the rate of change of the unemployment rate is added. The result of estimation is:

\[
\frac{\text{PL}_t - \text{PL}_{t-1}}{\text{PL}_{t-1}} \times 400 = 1.4982 \quad (4.20d)
\]

\[+ 0.02317 \left( \frac{\text{YD}_t - \text{YD}_{t-1}}{\text{ULU}_t} \right) \quad (0.269)\]

\[- 0.05909 \left( \frac{\text{YD}_{t-1} - \text{YD}_{t-2}}{\text{ULU}_{t-1}} \right) - 0.02954 \left( \frac{\text{YD}_{t-2} - \text{YD}_{t-3}}{\text{ULU}_{t-2}} \right) \quad (-1.1995)\]

\[- 0.01085 \left( \frac{\text{ULU}_t - \text{ULU}_{t-1}}{\text{ULU}_{t-1}} \right) \times 400 + 0.8158 \text{EINFL}_t \quad (-0.139)\]

\[+ 35.632 \left( \frac{1}{\text{ULU}_t} \right) - 14.0079 \left( \frac{1}{\text{ULU}_{t-1}} \right) \quad (0.368)\]

\[\text{MSE} = 3.4296 \quad \beta_1 = 1.344 < 1.745 = F^{24}_{50,.05}\]

\[\hat{\beta} = 0.0347 \quad (-0.32)\]

\[\hat{\beta} = 0.00257 \quad F_2 = 1.398 < 1.74 = F^{25}_{50,.05}\]

The low t values and the small second F disqualify this equation.

In an effort to simplify (2.20d), the exact specification of (4.20a) was estimated except for the addition of the lagged dependent variable. The estimation gave:

\[
\frac{\text{PL}_t - \text{PL}_{t-1}}{\text{PL}_{t-1}} \times 400 = 1.4056 + 0.46451 \text{EINFL}_t \quad (4.20e)
\]

\[+ 0.01781 \left( \frac{\text{ULU}_t - \text{ULU}_{t-1}}{\text{ULU}_{t-1}} \right) \times 400 \quad (0.694)\]

\[+ 8.69734 \left( \frac{1}{\text{ULU}_t} \right) + 0.23975 \text{U9}_{t-1} \quad (2.064)\]

\[+ 0.27503 \left( \frac{\text{PL}_t - \text{PL}_{t-1}}{\text{PL}_{t-1}} \right) \times 400 \quad (1.92)\]
\[
\text{MSE} = 4.3557 \quad F_1 = 1.48 \quad F_2 = 1.49
\]

\[
\hat{\beta} = -0.46226
\]

\[
(4.918) \quad \frac{\hat{\beta}}{F_{55, 0.05}} = 1.75 \quad \frac{\hat{\beta}}{F_{55, 0.05}} = 1.72
\]

\[
\hat{\beta} = -0.22251
\]

Except for the magnitude of the coefficient for the third term, and the slightly small second F, this is a very promising equation. An effort to improve it was made by dropping the rate of change of the unemployment rate, \(\frac{\Delta U_L}{U_L}\), and so the exact specification of (2.35) was estimated to give:

\[
\frac{PL_t - PL_{t-1}}{PL_{t-1}} \ast 400 = 1.2391 + 0.5634 \text{EINFL}_t (1.562) (4.95)
\]

\[
+ 9.969 \left(\frac{1}{ULU_t}\right) + 0.2073 \hat{U}_9_{t-1} (2.07)
\]

\[
+ 0.2344 \left[\frac{PL_{t-1} - PL_{t-2}}{PL_{t-2}} \ast 400\right] (1.82)
\]

\[
\text{MSE} = 3.438 \quad F_1 = 1.907 \quad F_2 = 2.697
\]

\[
\hat{\beta} = -0.45 \quad > 1.74 = \frac{F_{53, 0.05}}{29} \quad > \frac{F_{53, 0.05}}{30}
\]

\[
(4.66) = 1.70
\]

\[
\hat{\beta} = -0.45 + 0.20732 = 0.2427
\]

The only disparaging property of this equation is the slightly large first F pointing to misspecification in that some variable(s) in the system not specified in this equation belongs in this equation. Despite this defect, (4.20f) became the wage equation of RJML.
Since the MPS Model estimates a basic price level equation, the first attempt in RJM1 was to estimate the price level. Distributed lags of the wage rate, PL, and capacity utilization, XBC - XB, restricted by a 2nd degree polynomial. In addition, current and lagged expected inflation joins the explanatory variables in the estimated GNP price deflator equation:

\[
\begin{align*}
\text{PGNP}_t &= 31.38114 + 0.2766 \text{ PL}_t \\
& \quad - 0.02597 \text{ PL}_{t-1} - 0.04155 \text{ PL}_{t-2} - 0.04625 \text{ PL}_{t-3} \\
& \quad - 0.04155 \text{ PL}_{t-4} - 0.00802 (\text{XBC} - \text{XB})_t \\
& \quad + 0.000512 (\text{XBC} - \text{XB})_{t-1} + 0.00082 (\text{XBC} - \text{XB})_{t-2} \\
& \quad + 0.00092 (\text{XBC} - \text{XB})_{t-3} + 0.00082 (\text{XBC} - \text{XB})_{t-4} \\
& \quad + 1.8862 \text{ EINFL}_t - 0.11332 \text{ EINFL}_{t-1} \\
& \quad + 0.106 \text{ UIO}_{t-1} \\
\text{MSE} &= 0.7365 \\
\text{F1} &= 0.904 < 1.74 = F_{30}^{40,05} \\
\text{F2} &= 0.9275 < 1.73 = F_{31}^{40,05} \\
\beta &= 0.955, \quad (-29.6) \\
\bar{\beta} &= 1.061
\end{align*}
\]
The unacceptable $\beta > 1$ and the small $F_2$ of this equation led to a simpler specification, dropping some of the lags but adding disposable income from the previous period and lagged price, giving:

\[
PGNP_t = 52.3247 + 0.2757 PL_t - 0.0311 PL_{t-1} - 0.0155 PL_{t-2} - 0.00692 (XBC - XB)_t + 1.86451 EINFL_t - 2.6024 XD_{t-1} - 0.4644 PGNP_{t-1} + 0.0735 U10_{t-1} \\
MSE = 0.6364 \quad F_1 = 1.244 < 1.68 = F_{48,.05}^{33} \quad \beta = 0.935 \quad F_2 = .864 < 1.67 = F_{48,.05}^{33} \\
\hat{\beta} = 1.009
\]  

Again, $\beta > 1$ and the low $F_2$ signal the lack of identification. But $\beta \approx 1$ seems to call for first differences, so the next attempt was to estimate an equation to explain the change in the GNP deflator and the simple estimated equation is:

\[
PGNP_t - PGNP_{t-1} = 0.3965 + 0.3194 PL_t - 0.323 PL_{t-1} + 0.0181 EINFL_t - 0.0054 U10_t \\
\text{MSE} = 0.6364 \quad F_1 = 1.244 < 1.68 = F_{48,.05}^{33} \quad \beta = 0.935 \quad F_2 = .864 < 1.67 = F_{48,.05}^{33} \\
\hat{\beta} = 1.009
\]
The large $F_1$ signals that some other variable(s) in the system should be specified in this equation. Moreover, the sum of the coefficients for wages, PL, is negative when a priori it is expected to be positive, and expected inflation is insignificant. This led to the dropping of expected inflation and estimation of the rate of change of price as explained by the rates of change of the wage rate and disposable income, thus:

\[
\frac{\text{PGNP}_t - \text{PGNP}_{t-1}}{\text{PGNP}_{t-1}} = 0.0169 - 0.439 \frac{\text{PL}_t - \text{PL}_{t-1}}{\text{PL}_{t-1}} \tag{4.21d}
\]

\[
+ 0.0001 \frac{(\text{XBC} - \text{XB})_t}{(3.1)}
\]

\[
- 0.4005 \frac{(\text{YD}_t - \text{YD}_{t-1})}{(\text{YD}_{t-1})} + 0.3571 \frac{\text{PGNP}_t - \text{PGNP}_{t-1}}{\text{PGNP}_{t-1}} \tag{-3.72}
\]

\[
- 0.0427 \frac{\hat{\text{U10}}_t}{(-0.118)}
\]

MSE = .000066 $F_1 = .872 < 1.69 = F_{51,.05}^{31}$

$\hat{\rho} = 0.4353$ $(-4.45)$

$\hat{\rho} = 0.3926$ $F_2 = .967 < 1.68 = F_{51,.05}^{32}$
The positive sign for capacity utilization and the negative sign for the rate of change of the wage rate are not what is expected, a priori. But the small F2, indicating lack of identification, is what led to the estimation of the exact specification of (2.36), viz.,

\[
\frac{\text{PGNP}_t - \text{PGNP}_{t-1}}{\text{PGNP}_{t-1}} = -0.0214 + 1.1221 \left[ \frac{\Delta \text{PL}}{\text{PL}_t} + \frac{\Delta \text{PL}}{\text{PL}_{t-1}} \right] + 0.000058 (\text{XBC} - \text{XB})_t \tag{4.22e}
\]

\[
- 0.00010 (\text{XBC} - \text{XB})_{t-1} + 0.145 \frac{\text{YD}_{t-3} - \text{YD}_{t-4}}{(1.61) \text{YD}_{t-4}}
\]

\[
- 0.3629 \text{UIO}_{t-1} - 0.04982 \left( \frac{\text{PGNP}_{t-2} - \text{PGNP}_{t-3}}{\text{PGNP}_{t-3}} \right) \tag{-1.673} \tag{0.278}
\]

MSE = 0.000035 \hspace{1cm} F1 = 1.49 \hspace{1cm} F2 = 1.4565

\[
< 1.7 \hspace{1cm} < 1.69
\]

\[
= \frac{28}{49, .05} \hspace{1cm} = \frac{29}{49, .05}
\]

\[
\hat{\beta} = 0.648 \hspace{1cm} \bar{\beta} = 0.648 - 0.3629 = 0.2651 \tag{-7.84}
\]

Note that the sum of capacity utilization, (XBC - XB), a proxy for negative excess demand, now has a negative coefficient and so, the expected sign, even though it's insignificant. The negative sign for the rate of change of price two periods earlier is not necessarily unexpected, theoretically, but it too is insignificant. The 2nd F is still slightly too small but larger than that of any previous version except (4.21c). By any rate, because the signs and magnitudes of the coefficients are reasonable, a priori, (4.22e) was adopted into RJML despite the evidence of lack of identification and misspecification.
The following is one of three equations whose first estimation possessed generally favorable statistical properties and whose estimated coefficients were at least close to what was expected a priori. This was due, no doubt, to the fact that the author of RJM finally realized that the best results were usually obtained by following the specification used in the corresponding equation of the MPS Model as closely as possible. The demand for demand deposits by the nonbank public, specified exactly as in (2.42), was estimated to be:

\[
\begin{align*}
\ln \left( \frac{MDS_{t}}{XGNP_{t}} \right) &= -0.08673 - 0.0183 \ln RTB_{t} \\
&\quad + 0.032224 \ln \left( \frac{XGNP}{N} \right) \\
&\quad - 0.01965 \ln ZCT_{t} \\
&\quad + 0.007638 \ln \left( \frac{ZDRA_{t}}{ZDRA_{t-1}} \right) \\
&\quad + 0.03354 U1_{t-1} + 0.94122 \ln \left( \frac{MDS_{t-1}}{XGNP_{t}} \right) \\

\text{MSE} &= 0.0000358 \quad F1 = 1.769 \quad F2 = 6.1550 \\
\hat{\beta} &= 0.157 \quad < 1.7 \quad > 1.69 \\
\hat{\beta} &= 0.1905 \quad = F_{30}^{47,.05} \quad = F_{31}^{47,.05}
\end{align*}
\]

(4.23a)
Renormalizing to get a short interest equation:

\[
RTB_t = \left\{ \left( e^{-0.08673 + 0.03354 \, UI_t} \right) \left\{ \left( \frac{XGNP_t}{N_t} \right)^{0.032224} \right.\right. \\
\times \left. \left. ZCT_t^{-0.01965} \times \frac{ZDRA_t}{ZDRA_{t-1}} \times \frac{XGNPS_t}{MD$t_{t-1}^{0.94122}} \right\} \right\} / 0.0183
\]

The large 2nd F implies that this equation is well identified. The large 1st F implies that some variable(s) of the system still need to be added to this equation, but the misspecification is slight. The signs of the coefficients are those expected, a priori, and their magnitudes are comparable to the magnitudes of corresponding variables in the MPS Model, given that the equation in the latter model is slightly more complex. In addition, the small mean square error and \( \Delta^2 \) argue for the adoption of (4.23a) into RJMI; so it was adopted.

The third equation with properties acceptable to RJMI on the first estimation attempt was the term structure equation for the corporate bond rate, RGB. Following exactly the specification of (2.44), the estimated equation is:

\[
RGB_t = 2.84717 + \sum_{i=0}^{4} a_i \, RTB_{t-i} + \sum_{i=0}^{4} b_i \, EINFL_{t-i} - 0.022115 \, \hat{U12}_{t-1}
\]

(4.25b)
where both distributed lags are restricted by a polynomial of 2nd degree, and

\[
\begin{align*}
a_0 &= 0.349 \quad b_0 = -0.12212 \\
    & \quad (\text{-5.79}) \\
    & \quad (\text{-1.054}) \\
a_1 &= 0.02597 \quad b_1 = 0.0841 \\
    & \quad (2.266) \quad (5.567) \\
a_2 &= 0.04145 \quad b_2 = 0.13458 \\
    & \quad (2.266) \quad (5.567) \\
a_3 &= 0.0466 \quad b_3 = 0.15141 \\
    & \quad (2.266) \quad (5.567) \\
a_4 &= 0.04144 \quad b_4 = 0.134 \\
    & \quad (2.266) \quad (5.567) \\
MSE &= 0.02934 \quad F_1 = .9244 \quad F_2 = 1.15 < 1.75 = F_{46,.05}^{2.7} \\
     & \quad < 1.76 \\
     & \quad = F_{46,.05}^{26} \\
\beta &= 0.8888 \quad (-17.875) \\
\bar{\beta} &= 0.8888 - .022115 \\
     & = 0.8667
\end{align*}
\]

Although the relatively small 2nd F indicates a lack of identification, the large \(\bar{\beta}\) is nullified by the small and insignificant coefficient for \(\Delta\bar{\beta}\).

Otherwise, the properties of this equation are excellent, so that (4.23b) became a member of RJML.
The 13th and final structural equation to be estimated proved to be more troublesome than the previous two. Originally, an attempt was made to estimate (2.53) with a lagged dependent variable, as in the MPS model, but without the lagged demand deposits, $S$, the denominator of several terms in the MPS equation. The resulting equation was:

$$\text{MFR}_t = 0.3954 - 0.1921 (\text{ZDRA}_t - \text{RTB})_t$$

$$(0.8147) (-0.837)$$

$$- 0.01204 (1 - \text{ZRD}_t) * (\text{MRUS}_t - \text{MRUS}_{t-1})$$

$$(-0.101)$$

$$- 1.33283 \text{ZRD}_t * (\text{MCLS}_t - \text{MCLS}_{t-1})$$

$$(-4.129)$$

$$+ 0.0011 (\text{ZRT}_t - \text{ZRT}_{t-1}) \text{MTMS}_t$$

$$(-0.233)$$

$$- 0.00814 (\text{ZRD}_t - \text{ZRD}_{t-1}) \text{MDS}_t$$

$$(-4.129)$$

$$+ 0.47337 \text{MFR}_t$$

$$(-0.233)$$

$$+ 0.2184 \hat{U}_{13}$$

$$(-1.04)$$

$$\text{MSE} = 0.11179$$

$$F_1 = 1.266 < 1.7 = F_{47,.05}^{32}$$

$$\hat{\rho} = 0.1313$$

$$F_2 = 1.459 < 1.69 = F_{47,.05}^{33}$$

$$\hat{\rho} = 0.3497$$

The insignificance of the coefficient estimates, the small 2nd F and especially the peculiar and inexplicable rise of the mean square error from 0.09056 for the nontransformed equation to 0.11179 in this transformed equation led to the abandonment of the lagged dependent variable. The reason for this course of action was that theoretically
the variable causing much of the autocorrelation and thus necessitating a transformation of the data by \( \rho \) is the lagged dependent variable. Practically speaking, on several previous occasions, when this odd result was obtained, dropping the lagged dependent variable solved or alleviated the problem. However, in this case, it might be argued that since \( \rho \) was small and insignificant, a better solution would have been to simply choose the untransformed estimation. Unfortunately, the properties of the untransformed equation are no better than those of (4.24a). So the lagged dependent variable was dropped and the commercial loan term, MCLS, was combined with the time deposit term, MTM$, as in the MPS Model, giving the following estimated equation:

\[
\begin{align*}
MRS_t &= 0.00073 + 0.000036 \text{RTB}_t \\
&\quad - 0.00017 \text{EINFL}_t + 0.0005 (ZDRA - \text{RTB})_t \\
&\quad - 0.02966 (1 - ZRD) (\text{MRU}_t - \text{MRU}_{t-1}) \\
&\quad - 2.0376 ZRD (\text{MCL}_t - \text{MCL}_{t-1}) \\
&\quad + 0.03153 [(\text{ZRT}_t - \text{ZRT}_{t-1}) * \text{MTM}_t - \text{MTM}_{t-1} + (\text{ZRD}_t - \text{ZRD}_{t-1})] \\
&\quad * \text{MDSS}_{t-1} \div 0.0974 \text{ U13}_{t-1} \\
MSE &= 0.00000035 \\
F1 &= 0.879 < 1.68 = F_{47, .05}^{35} \\
\rho &= 0.373 \\
F2 &= 1.161 < 1.67 = F_{47, .05}^{36} \\
\bar{\rho} &= 0.4704
\end{align*}
\]
Again, the t values are too small for the significance of most of the coefficients, but the mean square error was dramatically reduced—a fact which can only be explained by the dropping of the lagged dependent variable. And given that the other explanatory variables are theoretically called for in the explanation of member bank free reserves, it was decided to keep the lagged dependent variable out of the next version as well. However, the small 2nd F indicates the lack of identification, something that may be caused in this equation by collinearity among the various financial explanatory variables. Hence, the variable with the least significant coefficient, member bank unborrowed reserves (MRU$), was dropped and, following the MPS authors, to help correct both for multicollinearity and heteroscedasticity, all variables except the interest rates are divided by the lagged four quarter sum of demand deposits at all commercial banks, $S = \sum_{i=1}^{4} MDS_{t-i}$. The final estimated equation has the exact specification of (2.53), viz.,

$$\frac{MFRS}{S} = 0.00051 + 0.000067 RTB_{t} (1.487) (0.649)$$

$$+ 0.000033 EINFL_{t-1} - 0.00024 EINFL_{t-2} (0.1752) (-1.3112)$$

$$+ 0.0006753 (ZDRA - RTB)_{t} (2.952)$$

$$- 1.80837 \left[ \frac{ZRD^* (MCI^*_t - MCI^*_t-1)}{S} \right] (-5.195)$$

$$- 0.015516 \left[ (ZRT^*_t - ZRT^*_t-1) MTM^*_t-1 \right] (-0.167)$$

$$+ (ZRD^*_t - ZRD^*_t-1) \frac{MDS^*_t-1}{S}$$

(4.24c)
\[ + 0.19842 \hat{u}_{13,t-1} \]

\[
\text{MSE} = 0.000000032 \quad F_1 = 1.3060 \quad F_2 = 2.44
\]

\[
\hat{\rho} = 0.1623 \quad \text{where} \quad (-1.52) = F_{30}^{30} = F_{46,.05}^{31}
\]

\[
\beta = 0.1623 + 0.19842
\]

\[
= 0.3607
\]

\[
S = \sum_{i=1}^{4} \text{MDS}_t = \text{deposit liabilities of banks}
\]

The 2nd F now indicates that this equation is empirically identified. Even the minute mean square error of (4.24b) has been reduced in this generally acceptable version. And although the t value for the short-term rate, RTB, is small, it is still larger than the corresponding t in the MPS Model. On the other hand, the MPS Model has a strong t for the last term, the sum of changes in required time deposit reserves and demand deposit reserves. It also has a strong t for the lagged dependent variable which, regrettably, was dropped from RJM1 and never replaced in RJM2 or RJM3 partly because equation (4.24c) displays such admirable statistical and theoretical properties and partly because simulations of RJM1 and RJM2 proved that they possessed even weaker and more critical equations than this free reserves equation.

A brief description of the test simulation of the model RJM1 will be presented in the next chapter. It is sufficient here to remark that it failed to perform well for several key policy target variables. Hence, some equations had to be reestimated. The revised model is called RJM2.
The model called RJM2 is actually several versions of Model RJM1 with one or more newly-estimated equations. Based on the simulations for RJM1 reported below in Chapter V, the dependent variables of four structural equations had to be exogenized in order to obtain convergence for the five quarters of the test period. These equations were expenditures on consumer durables (4.13b), expenditures on residential construction (4.14b), inventory investment (4.18e) and man-hours demanded (4.19c). A fifth equation was exogenized, viz., expenditures on producers structures, but only because the explanatory variable, VPS, the equilibrium ratio of capital to output, itself endogenous and defined in (2.27), was tracking poorly. Since the short term rate performed poorly even with these five variables exogenized, the first attempt at improvement was to reformulate the demand for demand deposits equation (4.23a) so that the short-term interest rate, RTB, became the dependent variable. The reestimated equation is:

\[
RDB_t = -1.8453 \quad \text{(4.25a)} \\
-1.7977 \ln \left( \frac{MD_t}{XGNP_t \cdot 0.01 \cdot PGNP_t} \right) \\
-30.904 \ln \left( \frac{MD_{t-1}}{XGNP_{t-1} \cdot 0.01 \cdot PGNP_{t-1}} \right) \\
+ 0.3357 \ln ZCT_t \\
+ 2.4779 \ln \left( \frac{ZDRA_t}{ZDRA_{t-1}} \right) + 0.0115 U^{t-1} \text{(6.014)} (0.106) \text{t-1}
\]
Since the huge negative coefficient for the 2nd term is unacceptable, another version was estimated. On the assumption that an adjustment mechanism was appropriate, a lagged dependent variable was added.

The resulting estimated equation is:

\[
\ln RTB = -0.494240 + 1.53996 \times \ln (XGNP^t \times .01 \times PGNP^t) - 1.83124 \times \ln \left(\frac{MDS^t - 1}{XGNP^t \times .01 \times PGNP^t}\right) + 0.0208 \times \ln ZCT + 1.4287 \times \ln \left(\frac{ZDRA^t}{ZDRA^t - 1}\right) + 0.050882 \times \ln ZCT^t - 1 + 0.73687 \times \ln RTB^t - 1
\]

\[
\text{MSE} = 0.00914 \quad F_1 = 1.456 < F_{31}^{59,.05} = 1.69
\]

\[
\hat{\beta} = 0.096277 \quad F_2 = 4.568 > 1.68 = F_{32}^{59,.05}
\]

\[
\hat{\beta} = 0.096277 + 0.050882 = 0.14712
\]

\[\text{Due to an oversight, } F_2 \text{ was not calculated.}\]
Except for the ceiling on time deposit rates, which is totally insignificant, this equation has excellent statistical properties and the signs and magnitudes of its coefficients are what was expected a priori. The sum of the demand deposit coefficients are negatively related to the short term interest rate since the public withdraws money from their deposits in order to invest in short term earning assets when short-term rates rise. On the other hand, if there is an increase in the Federal Reserve Discount Rate, ZDRA, making member banks borrowing more expensive, then money becomes tighter and short term rates rise accordingly. The highly favorable F's and small mean square error and $\bar{e}$ indicate that this equation should perform well and it did.

Keeping only $KI_t - KI_{t-1}$ and EPS exogenous, RJM1 performed much better with this new RTB equation, but the crucial policy variable, unemployment, performed poorly, due at least partly to the poor performance of man-hours demand, LMHT, and the price level, PGNP. Hence, the next step toward improvement was to reestimate these last two equations.

In RJM2, the estimated man-hours-in-nonfarm-business equation differs from (4.19c), the corresponding equation in RJM1, merely by the substitution of the MPS Model's business production capacity variable for the capacity variable constructed by this author and described in Chapter II. The estimated equation for RJM2 is:

$$\ln\left(\frac{\text{LMHT}}{\text{XB}}\right)_t = -1.351775 - 0.641075 * \left(4.26\right)
\begin{bmatrix}
(-10.265) & (-1.78)
\end{bmatrix}$$

$$\ln\left(\frac{\text{XB}}{\text{XB}_C}\right)_t + \ln\left(2.5 - \frac{\text{XB}_t}{\text{XB}_C}\right)$$
For simulation, the renormalized equation is:

\[
LMT_t = X_{t} \times \left\{ e^{-1.351775} \times \left[ \frac{X_{t}}{X_{t-1}} \right]^{0.641075} \times \left[ 2.5 - \left( \frac{X_{t}}{X_{t-1}} \right) \right]^{-0.641075} \times (1.0 - 0.01 \times \text{ULU})^{-0.09616} \times (\frac{X_{t}}{X_{t-1}})^{-1.35269} \times (0.01 \times \text{TIME})^{-0.56079} \times \left\{ -0.00551 \times D_{1} \right\} + 0.01043 \times D_{2} + 0.0308 \times U_{8} \right\}
\]

Note that the mean square error has been lowered significantly and, what is perhaps more important, F2 has doubled in size, even though it still indicates a lack of identification for this equation. The negative sign on the coefficient for the employment rate term, (1 - 0.01 * ULU), should not harm the performance of this equation since it is insignificant.
The new price equation is merely a simplification of the old (4.22e) version with the capacity utilization variable of the MPS Model replacing the variable constructed by this author and with a sum of lagged rates of changes of price replacing the lagged rate of change of price. The newly estimated equation following Pindyck (1976) is:

\[
\frac{PGNP_t - PGNP_{t-1}}{PGNP_{t-1}} = 
\begin{align*}
&- 0.0229 + 1.13143 \left( \frac{PL_t - PL_{t-1}}{PL_{t-1}} + \frac{PL_{t-1} - PL_{t-2}}{PL_{t-2}} \right) \\
&+ 0.04376 \left( \frac{YD_{t-1} - YD_{t-2}}{YD_{t-2}} \right) \\
&- 0.000046 (XB - XBC)_{t-1}
\end{align*}
\]

\[(-1.51) \quad (2.42) \quad (0.196) \quad (-0.752)\]

\[-0.0208 \left( \frac{PGNP_{t-1} - PGNP_{t-2}}{PGNP_{t-2}} + \frac{PGNP_{t-2} - PGNP_{t-3}}{PGNP_{t-3}} + \frac{PGNP_{t-3} - PGNP_{t-4}}{PGNP_{t-4}} \right) \]

\[(-1.013) \quad (-3.06) \quad (0.091)\]

\[MSE = 0.0000353 \quad F_1 = 1.959 < 1.71 \]

\[\beta = 0.3156 \quad F_2 = F^{29}_{49,.05} \]

\[\hat{\beta} = 0.2631 \quad = 2.13 > 1.70 = F^{30}_{49,.05} \]

The low t values and slightly large 1st F indicate a poor specification, but the 2nd F's now favorable, indicating that the equation is identified. The small mean square error and \(\Delta \hat{\beta}\) also argue for acceptance of this equation into RJM3.
While the unemployment rate now tracks better, the wage rate does worse than before. Part of the problem is expenditures on consumer durables, ECD. It had relatively large simulation errors in all versions. So, a new version was estimated with a new expectations variable, viz., MOOD, the index of consumer sentiment obtained from the University of Michigan's Survey Research Center. This version is:

\[ \text{ECD}_t = -6.22911 + 0.09888 \text{YD}_t \]
\[ (-0.313) \quad (2.242) \]
\[ - 1.62223 (\text{RCB} - \text{EINFL})_t + 0.0851 \text{MOOD}_t \]
\[ (-1.434) \quad (0.099) \]
\[ - 0.03354 \text{MOOD}_{t-1} - 0.0405 \text{N}_t \]
\[ (-0.039) \quad (-0.215) \]
\[ - 0.0931 \text{KDC}_{t-1} + 0.7068 \text{ECD}_{t-1} \]
\[ (-1.667) \quad (5.62) \]
\[ - 0.0135 \text{U2}_t \]
\[ (-0.19) \]

\[ \text{MSE} = 6.556 \quad F1 = 1.72 = 1.72 = F_{28}^{47,.05} \]
\[ \hat{\rho} = 0.09468 \]
\[ (-0.87) \]
\[ \hat{\rho} = 0.0812 \quad F2 = 2.68 > 1.71 = F_{29}^{47,.05} \]

Except for the sign for population, the signs and magnitudes of the coefficients are what was expected, a priori. Disposable income, YD, is positively related to expenditure on consumer durables while expected inflation might be either positively or negatively related, depending on whether the individual consumer believes inflation will eventually abate or continue to increase. If last quarter's consumer durables stock was up, less will be spent this quarter. The insignificance of the con-
sumer's expectation variable and of population is surprising in view of Fair's results with this equation (1971). The low $\Delta\beta$ and the two favorable F's indicate that there is little autocorrelation remaining, the equation is well-specified, and it is identified. Hence, it is adopted into RJM2.

Finally, the newly estimated expenditures on housing also employs the housing starts variable to give:

$$EH_t = 39.5077 + 12.9284 (\frac{CON_N}{N}) t + 0.1135 KHS_{t-1} - 1.0352 (RCB - RTB)_{t-2}$$
$$+ 0.52 (RCB - RTB)_{t-3} + 0.608 (RCB - RTB)_{t-4}$$
$$- 1.6313 RTB_t - 1.0842 RTB_{t-2}$$
$$+ 0.7508 RTB_{t-4} - 2.2475 HS_t$$
$$+ 3.9714 HS_{t-1} - 1.6864 HS_{t-2}$$
$$+ 0.5412 TIME + 0.79773 EH_{t-1}$$
$$+ 0.07568 U3_{t-1}$$

$$MSE = 2.2588$$
$$F1 = 1.1843 < 1.74 = F_{42,.05}^{27}$$
$$\hat{\rho} = 0.1985 < 1.867$$
$$\hat{\beta} = 0.2742$$
Except for the t values for the credit crunch variable (RCB-RTB) and for housing starts, this equation seems highly suitable for RJM2. But even with inventory investment and expenditures on structures still exogenous, the new ECD, LMGT, PGNP and RTB equations did not perform well together. Hence, a radical change had to be made.

RJM3

The third and final version of Model RJM, call it RJM3, is quite different from the first two and yet it is built upon the first two. Since the second F tests in RJM1 and RJM2 often were too low to pass the identification test, it seemed that either the principal components were not capturing enough of the explanatory power of the original 37 exogenous variables or else the long distributed lags in many of the equations were causing a multicollinearity problem and, hence, an identification problem. Wayne Fuller suggested the following technique designed to overcome both of the problems.

First, choose that set of 13 structural equations estimated in RJM1 and RJM2 that exhibited both good theoretical and parametric statistical properties and performed relatively well in their respective test simulations.

Secondly, for all 30 equations, structures and identities, form a linear combination of all exogenous variables, lagged and current, and all lagged endogenous except for the lagged dependent variable, multiplying each variable by its respective coefficient in the structural

6 Verbal communication with Dr. Wayne Fuller, Department of Statistics, Iowa State University, Ames, Iowa (1977).
equation chosen from RJM1 or RJM2. This gives a single unique exogenous variable for each equation in the system and thereby assures the identification of each equation. It so happened that one such variable turned out to be a linear combination of another, so that there were only 29 independent variables. This is still sufficient for identification. All of the asymptotic properties apply for the coefficients of RJM3, given that RJM3 is estimated by the complete 3ASMLML technique.

The third step is to average the estimated autocorrelation coefficients (average $\hat{\rho} = .511$) and use it to transform the original variables of all the new structural equations to correct for first order autocorrelation.

The fourth step is to respecify the original structural equations, retaining only the current jointly dependent (or endogenous) variables plus the specific newly-created exogenous variable unique to each equation and the lagged dependent variable, if the latter appeared at all in the original structure. The newly structured equation is estimated with the transformed data using MLIML.

In the fifth step, the residuals of AMLIML and the transformed data are passed into 3SLS so that A3SMLML estimation is complete.

Finally, after the 3SLS estimation, when this equation is coded for the consequent Gauss-Seidel simulation program, if the coefficient of the newly-created exogenous variable is significant, it is used to multiply the original linear combination that defines that newly-created exogenous variable. In other words, a modified version of the original structure is returned to the equation.
The SAS program for this estimation technique, together with printouts of raw and transformed data and the estimates is in Appendix B.

The precise definitions of the new exogenous variables are defined by the $E_i$ statements or equations in the first portion of the SAS program listed in Appendix B. $E4$ proved to be collinear with another $E$ variable and, hence, was dropped. The wage equation, based on (4.20f) has no exogenous variable and no lagged variable other than the lagged dependent variable. Hence, there are only 28 exogenous $E$ variables, built ultimately upon the principal components and exogenous variables of the original data set, which will be used as instruments in the first stage of the estimation of Model RJM3.

Note that in the transformation of the data by $\rho = .511$, the first observation was dropped. Since this means that the transformed column of ones for the intercept is a constant, the intercept in the transformed A3SMLML regression is free from any transformation restrictions. This also means that there are now only 84 observations in the sample.

In that same SAS program of Appendix B are listed all the observations of the variables both before and after transformation by the average autocorrelation coefficient, $\hat{\rho} = 0.511$. The 13 structural equations of model RJM3 are described below in this chapter by (4.30) - (4.42). They are listed in the SAS program in the same sequential order, which was the order for RJM1 in Chapter II. The estimated coefficients
and relevant statistics for each equation are listed both for Fuller's MLIML corrected for 1st order autocorrelation (hence, AMLIML estimates), with their consequent two F statistics and the 3SLS (hence, A3SMMLML) estimates, which are the estimates needed for Model RJM3. Because the SAS program uses different labels for the variables, the entire 13 equations of RJM3 will now be expressed using the already familiar variable names. The estimates will be A3SMLML, but the corresponding two F's for each equation are necessarily from the AMLIML stage of the procedure. No mean square error is reported for individual equations for 3SLS estimation, but the single mean square error is reported for the entire system's A3SMLML estimation.

For Model RJM3, all of the 13 structural equations had to be estimated in the same computer execution since 3SLS was used and 3SLS is a complete system's estimation technique. Hence, in order to improve equations that had exceptionally poor statistical or economic properties by weeding out insignificant explanatory variables and adding other relevant variables that might better specify the equation, two executions of the complete system were made using the six-stage technique outlined above. Only the second and final estimation is listed in the SAS program in Appendix B, and the final A3SMLML estimates given below are from that run. However, any changes made between the 1st and 2nd executions will be described below as the individual equations of RJM3 are analyzed.

No changes whatsoever were made for the consumption function which is built upon version (4.12d). It is estimated as:
Oddly enough, the El (=col. 60 in the SAS Program) exogenous variable constructed from the distributed lags of disposable income per capita and wealth per capita is not significant, even though the lagged coefficients were significant in version (4.12d). Clearly, the transformation here by $\hat{\rho} = .511$ rather than by $\hat{\rho} = -0.056$ for (4.12d) has made a considerable difference in the estimation and, hence, the two $F$'s. Note also that coefficient of El (=col. 60) is larger and more significant after 3SLS than it was with merely AMLIML estimation. The long run marginal propensity to consume out of disposable income per capita is:

$$
\frac{0.23597}{1 - 0.75513} = 0.9637.
$$
The misspecification implied by the relatively large 1st F will undoubtedly mar the performance of this equation, but there is a marked improvement in most t values and in identification, as indicated by the large 2nd F.

The RJM version of expenditures on consumer durables is built upon version (4.28), but omits the MOOD variables because of their insignificance. A3SMMLML gave the following estimation:

\[
\begin{align*}
(ECD)_t &= 7.6294 + 0.24038 \, YD_t \\
&\quad - 6.53482 \, (RCB - EINFL)_t \\
&\quad + 2.88454 \, E2_t + 0.33463 \, ECD_{t-1} \\
&\quad (1.98) \quad (4.52) \quad (-4.85) \quad (3.198) \quad (2.35)
\end{align*}
\]

where

\[
E2_t = -0.0405 \, N_t - 0.0931 \, KCD_{t-1}
\]

MSE = 27.3815

\[
\begin{align*}
F1 &= 1.859 > 1.72 = F^{26}_{55,.05} \\
&\quad < 2.14 = F^{26}_{55,.01} \\
F2 &= 2.088 > 1.71 = F^{27}_{55,.05} \\
&\quad < 2.12 = F^{27}_{55,.01}
\end{align*}
\]
Note that the significant coefficient for the newly created exogenous E2 variable means that E2, the linear combination of lagged endogenous and exogenous variables with their original coefficients in version (4.28), was multiplied by this coefficient and the result used in this equation for simulation.

Again the t values and 2nd F are improved over all previous versions of this equation but the 1st F is slightly larger while the mean square error for the ASMLIML estimation is much larger than in previous versions. A poor simulation is predicted by these last two disturbing statistics for this equation.

The new expenditures on housing is based on version (4.14b). It was estimated in both A3SMLML runs as:

\[
EH_t = 21.50724 + 16.96766 (CON/N)_t + 1.21111 RTB_t + 0.72234 EH_{t-1} + 1.32208 E5_t
\]

(4.32)

\[
= 21.50724 + 16.96766 (CON/N)_t + 1.21111 RTB_t + 0.72234 EH_{t-1} + 1.32208 E5_t
\]

where

\[
E5_t = -0.10045 KH_{t-1} - 1.3297 (RCB-RTB)_{t-2} + 0.51241 (RCB - RTB)_{t-3} + 0.84699 (RGB - RTB)_{t-4} - 1.3589 RTB_{t-1} + 0.7831 RTB_{t-2} + .4511 TIME_t
\]
and

\[ \text{MSE} = 1.8255 \]
\[ F_1 = 1.61 < 1.72 = F_{26}^{55,.05} \]
\[ < 2.14 = F_{26}^{55,.01} \]
\[ F_2 = 7.05 > 1.71 = F_{27}^{55,.05} \]
\[ > 2.12 = F_{27}^{55,.01} \]

In every respect, the estimates of (4.32) are superior to any previous version of housing expenditures. Note again that the significant t value for the exogenous E5 means that the original exogenous and lagged dependent variables with their coefficients of version (4.14b) were multiplied by the coefficient of E5 and replaced in equation (4.32) for simulation.

The housing stock equation is simply a repeat of version (4.15) but now estimated by A3SMLML as:

\[ KH_t = 0.24053 \quad (1.114) \]
\[ + 0.22714 \text{ EH}_{t-1} \quad (21.97) \]
\[ + 0.99436 \text{ KH}_{t-1} \quad (1333.4) \]

\[ \text{MSE} = 0.1216 \]
Since there is no current jointly dependent endogenous variable, no MLIML estimates were possible. The residuals fed into 3SLS were generalized least squares estimates with an $R^2 \approx 1.0$ for this equation.

In the first execution of A3SMLML for the entire system, in the AMLIML estimation of producers durables, the last $F$ was much too large indicating misspecification. The coefficient of the new $E7$ exogenous variable in the third stage estimation had a $t$ value of $-0.01$. Hence, $E7$, the exogenous variable representing the lags in (4.16c) was dropped and the lagged dependent variable added to give the following Koyck distributed lag for desired capital ($VPD \times XB$) in the equation for expenditures on producers durables:

\[
EPD_t = 0.74223 + 0.002498 (VPD \times XB)_t + 0.755751 EPD_{t-1} \quad (4.34)
\]

\[
\begin{align*}
MSB &= 3.308 \\
F_1 &= 3.63 > 1.72 = F_{15},.05 \\
&> 2.14 = F_{27},.01 \\
F_2 &= 6.3 > 1.71 = F_{28},.05 \\
&> 2.12 = F_{28},.01
\end{align*}
\]

Since the mean square error is less than that of (4.16c) and all signs are now as expected a priori, while the 2nd $F$ strongly indicates
that this equation is identified, (4.34) is used in RJM3. Unfortunately, the first F is slightly larger than that of the first A3SMLML execution of the system—a fact which points to a lack of specification.

On the 1st A3SMLML run, the current desired capital value, VPS * XB, had a negative and significant coefficient. Moreover, the 1st F was much too large, indicating poor specification. So the current VPS * XB was dropped and the lagged dependent variable was added giving from the 2nd A3SMLML run:

\[
\text{EPS}_t = -0.31964 + 0.48321 \text{EPS}_{t-1} + 0.32571 E9_t \tag{4.35}
\]

\[
(-0.533) \ (5.232) \ (5.1)
\]

where

\[
E9_t = 0.023511 (VPS * XB)_{t-1} + 0.020219 (VPS * XB)_{t-2} + 0.016693 (VPS * XB)_{t-3} + 0.0134 (VPS * XB)_{t-4} - 0.128322 \text{EPDS}_t - 0.02303 \text{KPS}_{t-1}
\]

\[
\text{MSE} = 1.0472
\]

There are no F's since there are no jointly dependent variables. But for the generalized least squares regression used in the transformed step to pass into 3SLS, then \( R^2 \) was 0.9191.
The signs, t values and magnitudes of the coefficients, are all favorable. Hence, this equation was expected to perform well in RJM3 simulations.

For the inventory investment equation in A3SMLML estimation gave:

\[
KI_t - KI_{t-1} = 1.528 - 1.7329 (EPCE_t - EPCE_{t-1}) \quad (4.36)
\]

\[
+ 0.97085 (X_B_t - X_B_{t-1}) \quad (10.52)
\]

\[
+ 0.94616 (KI_{t-1} - KI_{t-2}) \quad (8.63)
\]

\[
- 0.43684 E12_t \quad (-0.816)
\]

MSE = 33.375

\[
F_1 = 1.95 > 1.72 = F_{26}^{55,.05}
\]

\[
< 2.14 = F_{26}^{55,.01}
\]

\[
F_2 = 2.217 > 1.72 = F_{27}^{55,.05}
\]

\[
> 2.12 = F_{27}^{55,.01}
\]

The exogenous variable, E12 was insignificant even on the first A3SMLML run, but the relatively good F statistics indicated that specification and identification are relatively good with E12 in the equation. However, the relatively high mean square error indicates that this equation may cause trouble in simulation.
$$\ln \left( \frac{LMT}{XB} \right)_t = -0.6557 \quad (-48.4)$$

$$-0.68193 \left[ \ln \left( \frac{XB_t}{XBC_t} \right) + \ln \left( 2.5 - \frac{XB_t}{XBC_t} \right) \right] \quad (-7.697)$$

$$-0.55431 \left( \frac{XB_t}{XB_{t-1}} \right) + 0.9939 E_{15} \quad (-5.68) \quad (66.9)$$

$$\text{MSE} = 0.000081$$

$$F_1 = 2.93 > 1.72 = F_{55,.05}$$

$$> 2.14 = F_{55,.01}$$

$$F_2 = 3.97 > 1.71 = F_{55,.05}$$

$$> 2.12 = F_{55,.01}$$

While the mean square error is small, the 2nd F large, the signs and magnitudes of the coefficients satisfactory according to a priori expectations, the large 1st F indicates misspecification and so a possible source of trouble in the simulation of RJM3. But, in fact, it performed surprisingly well.

The annual-rate-of-change-of-wage-rate equation is estimated exactly as specified in (2.35). Hence, there are no lagged endogenous or exogenous from which to create an exogenous E variable. The A3SMLML estimation gave:
The properties of this equation considered both statistically and economically, are excellent and the best of all the equations in RJM3. The rate of change of price equation is built upon version (4.27) except for the substitution of a single lag for the dependent variable in place of the three lags in (4.27). The A3SMLML estimation gave:
Once again the exogenous variable, E18, was retained in the 2nd run of A3SMMLL estimation despite the low t value in the 1st run because the two F statistics are relatively good, the mean square error is small, and estimated coefficients significant with the signs and magnitudes expected a priori. This equation is expected to perform well in RJM3 simulation.

Version (4.25b) was the basis for the short term interest rate equation estimated by A3SMMLL as:

\[
\ln RTB_t = -0.54126 + 0.71132 \ln \left( \frac{MDS}{XGNR \times 0.01 \times PGNP_t} \right) + 0.50653 \ln RTB_{t-1} + 0.96285 E21_t
\]

\[
(4.40)
\]

\[
MSE = 0.008214
\]

\[
F_1 = 1.563 < 1.715 = F_{55,.05}^{27}
\]

\[
< 2.135 = F_{55,.01}^{27}
\]
Note that the large significant coefficient for E21 implies a negative long run coefficient for demand deposits for unit of GNP, which is what is expected a priori. In the first run of A3SMLML for Model RJM3 the exogenous variable, E22, constructed from the lagged short term rates, RTB, in the term structure equation for the long-term rate, RGB, has a t value of only 0.1697. Hence, E22 was dropped, even though both F's were favorable, and the lagged dependent variable, RCB\textsubscript{t-1}, was added in its place, giving the distributed lag of short-term rates a Koyck structure, i.e., a geometrically declining weighted average of short term rates and expected inflation. The estimated equation in RJM3 is:

\begin{align*}
\text{RCB}_t &= 0.49955 + 0.09806 \text{RTB}_t + 0.1695 \text{EINFL}_t + 0.69628 \text{RCB}_{t-1} \\
&\quad (4.86) \quad (3.73) \quad (4.699) \quad (13.4) \\
\text{MSE} &= 0.0311 \\
\text{F1} &= 2.742 < 1.72 = F_{26}^{1.72} \quad \text{and} \quad < 2.14 = F_{26}^{2.14} \\
\text{F2} &= 10.64 < 1.71 = F_{27}^{1.71} \quad \text{and} \quad < 2.14 = F_{27}^{2.14}
\end{align*}
The properties of this equation are excellent in every respect. Hence, (4.41) entered Model RJM3. Unfortunately, the shape of the distributed lag has been changed by imposing the Koyck lag structure. An important consequence for monetary policy is that the long-term rate is less responsive to change in the short-term rate, at least in the short run. If time and computer funds had permitted, the original equation using E22 would have been substituted for (4.41) and RJM2 reestimated by A3SMLML. This author is convinced that the model RJM3 would then be considerably more responsive to changes in monetary policy control variables.

The free reserves equation (4.24c) was used as a model for the A3SMLML estimation, but the insignificant time deposit term was not included.

In the first A3SMLML run, the coefficient for the short term interest rate, RTB, was nearly zero and had a t value of -0.747. Since the first F was also too large, indicating misspecification, RTB was dropped to give the following estimated equation for the desired ratio of free reserves to demand deposit liabilities:

\[
\frac{MFRS}{S} = 0.0000624 + 0.00145 (ZDRA - RTB) + 0.47097 E25
\]

\[ (4.42) \]

\[ (0.593) \quad (5.393) \quad (3.93) \]
where

\[
E25 = 0.000033 \times EINFL_{t-1} - 0.00024 \times EINFL_{t-2} - 1.80837 \times \frac{ZRD \times (MCL)^{t} - MCL^{t-1}}{S}
\]

\[
MSE = 0.00000059
\]

\[
F1 = 2.021 > 1.715 = F_{55,.05}^{27}
\]

and \[ < 2.135 = F_{55,.01}^{27} \]

\[
F2 = 2.29 > 1.7 = F_{55,.05}^{28}
\]

and \[ > 2.1 = F_{55,.01}^{28} \]

The small mean square error and two favorable F statistics plus the expected signs and magnitudes for the coefficients, both of which are highly significant, all point to an equation that should perform well in simulation.

Finally, the weighted mean square error for the entire system of 13 structural equations estimated by A3SMLML is 1.0899 with 1040 degrees of freedom.

At this point the Model RJM3 was simulated. Its 13 structural equations are (4.30)-(4.42) of Chapter IV and its identities are (2.11), (2.12), (2.24), (2.27), (2.28), (2.30), (2.31), (2.33), (2.34), (2.37), (2.45), (2.46), (2.47), (2.52), (2.56), (2.57), and (2.58).
CHAPTER V. SIMULATION, PREDICTION
AND MULTIPLIER ANALYSIS

Having estimated the parameters of the macroeconomic model, RJM, the system of 13 structural equations and 17 identities are first simulated, i.e., solved simultaneously for each time period, to see how well the 30 estimated endogenous variables track their historical values over the eight quarters of 1969.III – 1971.II, a period covering the 1969-1970 recession.

Then an ex-post prediction is made over the four quarters of 1975.III – 1976.II, using those last four observations of the MPS data set which were not used to estimate the parameters of the model. Finally, six multiplier analyses are carried out over the 1969-1970 recession period in an effort to discover how different monetary or fiscal policy decisions would have altered the time paths of key target variables whose simulation is reported.

The Gauss-Seidel Algorithm

In (3.41) of Chapter III the reduced form of a linear dynamic model was defined. By relatively simple matrix algebra the system is solved for yield estimates of the current endogenous variables in terms of exogenous and past endogenous variables. No such matrix algebra solution is possible for a nonlinear system. In order to appreciate the difficulties encountered and overcome in simultaneously solving a system of
dynamic equations nonlinear in the variables, consider the following simple two equation nonlinear system, an expanded version of the system given by Klein, Evans and Hartley (1969):

\[ Y_1(t) = f_1(Y_2(t), \ldots, Y_{1-s}, Y_{1-s}, \ldots, X_{1-s}, \ldots, X_{k-s}) \]  
\[ Y_2(t) = f_2(Y_1(t), \ldots, Y_{1-s}, Y_{2-s}, X_{1-t}, \ldots, X_{k-t}, \ldots, X_{k-s}) \]

where

\[ s = 1, 2, \ldots, g < N, \] the sample size

and \( f_1 \) and \( f_2 \) may be linear or nonlinear functions of their arguments. If they are linear functions, then the reduced form of the dynamic linear system could be found algebraically as in (3.41) above. For a linear system (5.1), the reduced form in the matrix notation of (3.41) would be (ignoring residuals):

\[ (Y_1, Y_2) = \{ -X \} \cdot \begin{array}{c} \Gamma \\ \cdot \cdot \cdot \end{array} \cdot B^{-1} \]

But if \( f_1 \) and \( f_2 \) are nonlinear in the variables, there is no simple \( B \) matrix of detached and constant coefficients of \( Y \). Rather, in the nonlinear case, the elements of the matrix analogous to \( B^{-1} \) depend on the very \( Y_1(t) \) and \( Y_2(t) \) being estimated. If they depended only on the exogenous
X and the lagged \( Y_{-s} \), there would be no problem in applying linear methods because the values of the \( X \) and \( Y_{-s} \) elements are given for each time period.

To solve the nonlinear system of (5.1) an iterative numerical method called the Gauss-Seidel Algorithm is employed. It requires no matrix inversion, derivatives, or eigenvalue computation. First we assign starting values to \( Y_1^t \) and \( Y_2^t \), say \( Y_1^t(t) \) and \( Y_2^t(t) \), where \( t = 0 \). In practice, if we knew the historical values of these variables at the starting time, \( t = 0 \), these historical values would be used. Otherwise, the best informed guess is used.

Evaluating (5.1) gives the solution for the first iteration at time \( t=0 \):

\[
Y_1^{(1)} = f_1(Y_2^{(0)}, \ldots, Y_{1-0-s}, Y_{2-0-s}, X_1^{(Q)}, \ldots, X_{1-0-s}, X_{K}^{(0)}, \ldots, X_{K-0-s}) \tag{5.2b}
\]

Then \( Y_1^{(1)} \) can be used to solve \( Y_2^{(1)} \) by

\[
Y_2^{(1)} = f_2(Y_1^{(1)}, \ldots, Y_{1-0-s}, Y_{2-0-s}, X_1^{(Q)}, \ldots, X_{1-0-s}, X_{K}^{(0)}, \ldots, X_{K-0-s}) \tag{5.2c}
\]

In general, after \( r \) iterations the solution at time \( t=0 \) is

\[
Y_1^{(r)} = f_1(Y_2^{(r-1)}, \ldots, Y_{1-0-s}, Y_{2-0-s}, X_1^{(Q)}, \ldots, X_{1-0-s}, X_{K}^{(0)}, \ldots, X_{K-0-s}) \tag{5.3a}
\]
\[
Y_2^0 = f_2(Y_1^0, \ldots, Y_{10-s}^0, Y_{20-s}^0) \tag{5.3b}
\]

\[
X_{10}, \ldots, X_{10-s}, X_{K0}, \ldots, X_{K0-s})
\]

Note that \(Y_{10-s}, Y_{20-s}, \) and \(X_{K0-s}\) are fixed for each time period and do not change from iteration to iteration within a time period even though \(Y_{10-s}\) and \(Y_{20-s}\) will change from time period to time period.

The process within each time period stops at convergence, i.e., a solution is reached when the following criteria are satisfied:

\[
\left| \frac{Y_1^t - Y_1^{(r-1)}}{Y_1^{(r-1)}} \right| < \epsilon \tag{5.4a}
\]

\[
\left| \frac{Y_2^t - Y_2^{(r-1)}}{Y_2^{(r-1)}} \right| < \epsilon \tag{5.4b}
\]

where \(\epsilon\) is an arbitrarily small positive number—the criteria of convergence. For the model RJM, \(\epsilon = .02\) was the criterion of convergence.

When this criterion is passed for all endogenous variables in the system, the Gauss-Seidel Algorithm moves on to apply the same technique to the next time period, using the estimated endogenous variables of the previous solution as new lagged dependent variables \((Y_{0-l})\) in the solution of the next period.

In using the Gauss-Seidel Algorithm several circumstances can preclude convergence. In the first place, a necessary but not sufficient
condition is that the number of equations equals the number of unknowns. In RJM, there are 30 equations to be solved for the estimates of 30 endogenous variables.

Secondly, an equation such as (2.35), a form of Phillips curve, with the nonlinear term \( \frac{1}{ULU} \) can have multiple solutions since this equation is defined in both the first and third quadrant, i.e., it is possible to have a solution yielding a falling wage rate at negative unemployment rates. Since this is unacceptable for economic reasons, such solutions must be avoided by programming statements that force the model out of such troublesome regions.

Thirdly, convergence depends on which of the variables is on the left side of the equation. In simulating Model RJM(, for example, equation (4.23), \( \frac{MDS}{XGNP} \), demand deposits demanded by the public, was estimated and then normalized to get RTB on the lefthand side as the dependent variable. Despite highly favorable statistical and a priori expected properties, estimated RTB fluctuated wildly in the Gauss-Seidel simulation. Although no attempt was made, it is likely that if the demand deposits had remained the dependent variable, then the equation would have performed well. To solve this problem another equation was estimated with RTB the dependent variable from the start, so that no renormalization was needed for the Gauss-Seidel solution. This new equation was much more stable and helped the overall performance of the model.
Finally, the order in which the equations are positioned affects the iterative computation. Heien, Matthews, and Womack (1973) suggest that the equations be arranged so that the matrix of endogenous variables be as lower triangular as possible. This means in practice, that those equations with the fewest number of current jointly determined variables be solved first and the others follow so that the equation with the most jointly dependent variables be last in the sequence of equations. In the first simulation of RJM1 this principle was adhered to exactly and in subsequent simulations it was followed, but without making an exact count of jointly dependent variables for each equation.

The Computer Software

The final triangular ordering of equations can be seen for Model RJM3 in Appendix C where subroutine CEN of the computer program contains the 30 equations. This computer program was written by Hoffman in 1974, revised by L. Kinyon in 1976 for use by Dr. James Stephenson and finally debugged, enlarged, revised, and link-edited into the load modual of the econometric package called ECONPK by this author in 1977. Among the new features of this latest edition are the facility to read all data directly from disk instead of from cards, the facility to store estimated endogenous variables on a disk, enlarged dimensions allowing use of 400 observations for each variable and 100 exogenous variables instead of 100 observations and 70 exogenous variables, as well as 10 lags per
variable, endogenous or exogenous, as opposed to 3 lags in the old edition of the program, printouts of the starting values of both endogenous and exogenous lagged values, printouts of the estimated endogenous variables for the entire system at each iteration within each time period, the option to read in any subset of the observations in the data set read in from a disk, and finally, a valuable commonly used nonparametric statistic to test the endogenous estimates over time, viz., the root mean square error for levels of the variable. The additional printouts proved to be of immense practical value in debugging the program and in observing which equation(s) was causing trouble. In particular, the solution set for the first (or at most the second) iteration of the first time period reveals how well each equation predicts on its own without much influence from the rest of the system. After many iterations convergence may be obtained but to reach it the estimate of a particular equation may have been forced far from the estimate it produced in the first or second iteration because of the estimates of other endogenous variables in the system.

Since the users of short-run models such as RJM are interested in eight quarters or less for simulation and prediction, it was necessary to include the option of selecting any eight or less successive observations from a file that contains 89 or more. Since plots and tables of the estimates and dynamic multipliers are needed in reporting final results, the program was altered to store estimates directly in a data set on disk where another segment on ECONPK was used to plot graphs and print tables.
In executing the program, parameter cards are first read in to inform the program precisely which subset of observations are to be read in from what files on disk, how many endogenous and exogenous variables and their lags are to be read in, the initial values of all lagged variables as well as current endogenous variables, and in what files the estimated endogenous variables are to be stored on disk.

In addition to the newly programmed printouts already mentioned, the original program printed out the estimates of endogenous variables for each time period. Unfortunately, if it converged only for seven periods and failed for the eighth, the program printed nothing but the first three iterations of the period in which it failed. This has been corrected so that all preceding iterations and period estimates are printed when estimated as well as all period estimates at the end of the entire simulation.

The original program also printed in either level or relative percentage form six nonparametric error-of-estimation statistics which serve as criteria of the goodness of estimation for each endogenous variable of the system. It also calculated and printed first period or impact multipliers for all endogenous variables, if requested.

Evaluation Criteria for Simultaneous Systems of Equations

The design and evaluation of tests is an important and rigorously developed area of statistical theory. A hypothesis is defined as an
assumption about the population. Those assumptions which are not intended to be exposed to a test are called the maintained hypotheses. The remaining assumptions are called the testable hypotheses. Usually a testable hypothesis consists of a statement that a certain parameter of the population is equal to a certain value. In statistics this hypothesis is called the null hypothesis. It implies that there is no difference between the true value of the parameter in the population and that which is being hypothesized. For example, in Chapter IV the t and F test statistics each had their respective null hypothesis. The counter-proposition is called the alternative hypothesis. But the t test for parameters and the two F tests for individual equations have known distributions so that the researcher can compute from the data the probability of these statistics exceeding their critical values when the null hypothesis is true. Unfortunately, no comparable parametric test exists for evaluating an entire simultaneous system of dynamic equations nonlinear in the parameters. In fact, what constitutes a "good" or "valid" model may differ from case to case depending on the proposed use of the model under consideration. Thus, if its purpose is to forecast, then it should be evaluated ultimately on the accuracy of its ex ante forecasts, i.e., forecasts in which even the exogenous variables are unknown for the period(s) of forecast. If its purpose is primarily policy analysis, the main criterion is how well the model performs with respect to so-called conditional forecasts, i.e., forecasts based on
changes in exogenous variables controlled by policy makers. In this case, a priori knowledge based on economic theory of the size of multipliers and knowledge of the policy makers intentions and preferences with regard to GNP, inflation, unemployment, etc., is necessary to help evaluate the model as an adequate tool of policy analysis.

In any case, initially any evaluation procedure should center on the model's ability to simulate or track, i.e., to generate estimates of the endogenous variables which conform to the actual or historical data. A short-run dynamic model such as RJM should be able to track well for at least eight quarters. However, as Howrey and Kalejian (1969) have shown, under certain circumstances the dynamic deterministic simulation path of even a correctly specified nonlinear model may differ substantially from the historical time path.

The evaluation of the tracking and predictive ability of a model is essentially a goodness-of-fit problem. Econometricians generally use a wide variety of summary or descriptive statistics called nonparametric statistics to evaluate both the performance of individual equation in the system and sectors of the system. Dhrymes, et al., (1972) lists these as follows:

A. Single-Variable Measure

1. Mean forecast error (changes and levels)
2. Mean absolute forecast error (changes and levels)
3. Mean squared error (changes and levels)
4. Any of the above relative to
(a) the level of variability of the variable being predicted
(b) measure of "acceptable" forecast errors for alternative forecasting needs and horizons

B. Tracking Measures
1. Number of turning points revised
2. Number of turning points falsely predicted
3. Number of under or over predictions
4. Rank correlation of predicted and actual changes (within a subset of "important" actual movements)
5. Various tests of randomness
   (a) of directional predictions
   (b) of predicted turning points

C. Error Decompositions
1. Bias and variance of forecast error
2. Errors in start-up position vs. errors in the predicted changes
3. Identification of model subsectors transmitting errors to other sectors

D. Comparative errors
1. Comparison with various "voice" forecasts
2. Comparison with "judgmental," "consensus," or other noneconometric forecasts
3. Comparison with other econometric forecasts
E. Cyclical and Dynamic properties

1. Impact and dynamic multipliers

2. Frequency response characteristics

Surely the more of these criteria relevant to the use of the model at hand that the model can satisfy, the higher the value of that model to the user. Many and even most of these criteria will be used plus a few more in evaluating the Model RJM in this chapter. In addition to the single-variable measures listed in Part A, the Gauss-Seidel program calculates a System $R^2$ statistic, the Theil U statistic and the Theil U Statistic (R form).

More specifically, the seven nonparametric single-variable measures calculated and printed for each endogenous variable by the Gauss-Seidel program are defined as follows (where $\hat{y} = \text{estimated } y$):

1. Mean Percentage Error (relative):

$$MPE = \frac{1}{n} \sum_{t=0}^{n} \left( \frac{Y_t - \hat{Y}_t}{Y_t} \right) \times 100$$

2. Mean Absolute Percentage Error (relative):

$$MAPE = \frac{1}{n} \sum_{t=0}^{n} \left( \frac{|Y_t - \hat{Y}_t|}{Y_t} \right) \times 100$$

3. Root Mean Squared Percentage Error (relative):

$$RMSPE = \left[ \frac{1}{n} \sum_{t=0}^{n} \left( \frac{Y_t - \hat{Y}_t}{Y_t} \right) \times 100 \right]^\frac{1}{2}$$
4. System $R^2$:

$$R^2 = \frac{\sum_{t=0}^{n} (\hat{Y}_t - \bar{Y}_t)^2}{\left(\sum_{t=0}^{n} (Y_t - \bar{Y})^2\right) - \left(\sum_{t=0}^{n} \hat{Y}_t - \hat{Y}\right)^2}$$

5. Theil's Inequality Coefficient $U^2$ (or $U$ Statistic):

$$U^2 = \frac{\sum_{t=0}^{n} (\hat{Y}_t - \hat{Y}_{t-1})^2}{\sum_{t=0}^{n} (Y_t - Y_{t-1})^2}$$

6. Theil's Inequality Coefficient $U^1$ (or $U$ Statistic (RFORM)):

$$U^1 = \frac{\sum_{t=0}^{n} (Y_t - \hat{Y}_t)^2}{\sum_{t=0}^{n} (Y_t - \hat{Y}_t)^2 + \sum_{t=0}^{n} (Y_t - \bar{Y})^2}$$

7. Root Mean Squared Error (levels):

$$\text{RMSE} = \left(\frac{\sum_{t=0}^{n} (Y_t - \hat{Y}_t)^2}{n}\right)^{1/2}$$

MPE, MAPE, RMSPE, $U^2$, $U^1$, and RMSE all equal zero if prediction is perfect, while $R^2 = 1$. Unfortunately, MPE may be close to zero if large, positive errors cancel out large negative errors. Note that Theil developed $U^1$ and $U^2$ for evaluating prediction of changes (Theil 1971). When $U^2 = 1$, the prediction procedure leads to the same RMSE as naive no-change extrapolation. Theil calls both $U^1$ and $U^2$ "inequality coefficients," but he prefers $U^2$ and $U^1$ for several reasons. First, $U^2$ is related more directly to the concept of the failure of a forecast.
Second, the denominator of $U^1$, while it keeps $U^1$ between zero and one, depends on the forecasts and therefore it is not true that the coefficient is uniquely determined by the means square prediction error, and hence, conflicts with the idea of a quadratic loss function.

Note that the two mean squared error criteria do not discriminate between signs, i.e., whether the prediction error is $e$ or $-e$ the seriousness of the error is the same, whatever $e$ may be. This is restrictive in that an overprediction of the unemployment rate may not be as harmful in policy makers' eyes as an underprediction of the same magnitude, $|e|$. Hence, some econometricians prefer MPE. Klein (1971) prefers the MAPE on the ground of simplicity and understanding. However, in practice RMSE and RMSPE are used most often, since they penalize large individual errors more heavily. Moreover, Granger and Newbold (1973) argue that if the least squares quadratic cost function is assumed as a criterion for ranking predictors, the obvious measure of forecast quality is the average squared forecast error (and hence RMSE and/or RMSPE), since the use of any statistic which is not a monotonic function of the average squared forecast error can yield misleading conclusions. They go on to show how this holds true for Theil's $U^1$. For these reasons RMSE and RMSPE were the principal, but by no means the only criteria for this author's evaluation of RJM's performance in simulation and ex-post prediction.

Note also that the first three statistics are in relative terms in that the error is divided by the historical value. This standardizes
any one nonparametric statistic so that statistic can be more accurately compared across variables.

RJM1 Simulation

Originally, a long run simulation was planned over the entire span of 85 quarters, 1954.II - 1975.II, in order to discover how closely Model RJM tracks the historical values of its 30 endogenous variables and how well it predicts turning points. But the cost of executing the Gauss-Seidel program over 85 quarters made it necessary to first test the model over a short time horizon of five quarters, viz., 1954.II - 1955.I. When a version of the model tracked well enough over this test period to be considered a policy model, then all 85 quarters were to be simulated.

Unfortunately, Model RJML did not track well enough. Since white photogenic paper was not specified for the printouts of these preliminary tests over 1954.II - 1955.I, the computer output is not reproduced here. However, the more important statistics will be reported in the following analysis of RJM1 and RJM2.

Because of the performance of three equations, especially, RJM1 failed to converge with the convergence criteria, ε, set at .0002, primarily because inventory level, K1, and expenditures on consumer durables, ECD, were considerably off track. Even when the convergence criteria was lowered to .002, RJM1 failed to converge until K1 and ECD
were exogenized, i.e., set equal to their historical values for each quarter rather than having estimated values due to their estimated structural equations, (4.13b) and (4.18e). Even then RJM1 converged only for the first quarter and failed on the second, with expenditures on producers durables, EPS, much too large, and man-hours demanded, LMHT, settling at an unreasonably low level, while the short term interest rate, RTB, and free reserves, MFR$, oscillating just enough to prevent convergence. Obviously, RJM1 was still unstable. The problem with EPS and VPS, the equilibrium ratio of structural capital to output. This is an identity in RJM1 that could not be the equivalent of the corresponding identity in the MPS Model due to the difference in the span of the data set, as explained further in the development of (2.27). Evidently (2.27) was off from the MPS Model equation by a factor of approximately 2.8.

Since the 1975 MPS manual defines MPS as "the equilibrium ratio of producers structures to output, multiplied by a constant" and since no constant is evident in the MPS definition corresponding to (2.27), it seems the MPS users must multiply this definition by some constant before simulation to arrive at the values they do. Later, in RJM3, this was done to bring VPS and, hence, EPS back into line. For the present, however, EPS was exogenized along with ECD, KI and LMHT, while the criterion of convergence was lowered to .02. Then, RJM1 converged for the first three quarters but failed on the fourth, due to fluctuations in expenditures in housing, EH, the short term rate, RTB, and the long term rate,
RCB. Finally, with EH, ECD, KI, EPS and LMHT exogenized while the criterion of convergence remained at .02, RJML converged for all five quarters of the test period. Unfortunately, the root mean square percent error (relative), RMSPE, for RTB, the short term rate, was 2324, even though the RMSPE for GNP, the price level and the unemployment rate were only 7.54, 0.66 and 5.22, respectively. RTB went from 0.48 in the fourth quarter to approximately zero in the fifth quarter. Free reserves went from -16.66 in the fourth quarter to 0.45 in the fifth, but since they were 0.4, 0.41 and 0.51 in the first three quarters, it seemed that RTB was the culprit.

RJM2 Simulation

Hence, rather than renormalizing the demand deposits equation (4.23), to give RTB, (4.23) was abandoned for a structural equation estimated with RTB as the dependent variable, viz., equation (4.25b). With no endogenous variable exogenized, RJM1 failed to converge. Again, with only EPS exogenized it failed. Finally, RJM1 converged with both EPS and KI exogenized. GNP and PGNP had RMSPE of 1.76 and 1.24, respectively. But the unemployment rate had RMSPE = 86.04; ECD had RMSPE = 22.46; EH had RMSPE = 28.9; and free reserves had RMSPE = 92.78. So ECD and EH were exogenized also. Again, RJM1 converged, but the RMSPE for the unemployment rate remained high at 85.89. Finally, RJM2 converged with ECD, EH, KI, EPS and LHMT exogenous and ε = .02.
Unfortunately while the RMSPE for GNP, price level and unemployment rate was not large at 7.84, 0.649 and 5.22, respectively, for RTB it was rather high with 28.57; PL had 55.15 and free reserves was highest with 93.27.

Since so many key endogenous variables had to be exogenized to get even these modestly successful results, RJM2 was modified again by reestimating the equations for LMHT, ECD, and EH. Since the new LMHT equation introduced the MPS's capacity variable, XBC, in place of the author's version of XBC, the only other equation which has XBC, viz., the rate of change of the price level, was also reestimated. These new equations are versions (4.26), (4.27), (4.28) and (4.29). Unfortunately, even with EPS and KI still exogenous, while RJM2 converged for all five quarters, the RMSPE's were much worse than any previous version that converged. GNP had RMSPE = 49.23 and RMSE = 314.0. This discouraging result led to the abandonement of RJM2 and the complete overhaul of RJM embodied in Model RJM3.

**RJM3 Simulation**

Because of the unknown "constant" multiplier discussed earlier and included as part of the MPS definitions of VPD and VPS, both of these variables were multiplied by constants in RJM3 such that their values, in simulation, at least approximate their historical values listed in the MPS data set. Also, due to use of only one price variable, PGNP, in RJM3,
in place of 3 or 4 more specific price variables in MPS, identities are no longer identities over some quarters. Hence, an appropriate amount was added, viz., approximately the average amount needed over the 8 quarters to make the identities truly identities, LHS = RHS. This can be seen in Appendix C in Subroutine CEN of the Gauss-Seidel Program where identities EPCE (or $Y_0(3)$), GNP or $Y_0(13)$, VCN$ (or $Y_0(21)$), and YD$ (or $Y_0(30)$ have been incremented by \(-14.5\), \(-3.0\), \(-0.019\), and \(-15.2\), respectively. Given this alteration and the 13 equations reestimated by A3SMLML, RJM3 converged on the first attempt with no endogenous variables exogenized and with the convergence criterion still left at 0.02. The results were encouraging for the five test quarters, 1954.II - 1955.I, except for four variables, KI, ULU, PL, and MFR$. The short term rate, RTB, had R$M$PE = 1.9 and RMSE = 0.12; GNP and R$M$PE = 5.90 and R$M$SE = 37.6; PGNP and R$M$PE = 1.14 and R$M$SE = 0.69; free reserves had R$M$PE = 64.14 and R$M$SE = 0.216, KI, inventory stock, had R$M$PE = 66.3 and R$M$SE = 314.2; ULU, the unemployment rate, had R$M$PE = 69.40 and R$M$SE = 3.90; and PL, the rate of change of the wage rate, had R$M$PE = 66.54 and R$M$SE = 0.35.

Since no endogenous variables needed to be exogenized to produce those moderately successful results, the next simulation of RJM3 was over the eight quarters of 1969.III - 1971.II, which included the 1969 - 1970 recession.

The simulation period is now three quarters longer, a fact to be kept in mind when comparing the nonparametric statistics with the previous five quarter results.
Unfortunately, after 20 iterations in the first quarter, RJM3 failed to converge due to the divergence of the stock of inventory, KI, and to a lesser extent, the fluctuation of ECD. Hence, KI was again exogenized. Even with KI exogenous RJM3 converged only for five quarters and failed on the sixth due primarily to the wild oscillations of ECD in the fifth quarter. Hence, ECD was reluctantly exogenized, since (4.31) is a key equation in the real-financial linkage of Model RJM3.

With KI and ECD exogenized and the convergence criterion still set at .02, the entire Gauss-Seidel Program with all the 1969.III - 1971.II simulation results for RJM3 are given in Appendix C and partly repeated in Tables 5.1 - 5.9 of this chapter.

Table 5.5 gives the solutions for all 30 endogenous variables for each iteration of the first quarter, 1969.III. Their values are listed from left to right in the same order as the estimates in Table 5.6, below. The first two iterations, especially, reveal how well the estimated equations fit the historical data since in these first few iterations of the first quarter the lagged endogenous values are historical, not estimated. Thus the solutions for the endogenous variables depend almost exclusively on their own estimated coefficients plus possibly one or two or at most four current jointly dependent variables, with less dependence on the other equations in the system than is the case for later iterations and later quarters. In Table 5.5, since the order of sequence is from left to right across each row, consumption is 660.61, ECD is 91.59, etc. Note in particular that free
reserves, MFR$ is -1.424, which is far less in percentage terms than the actual -.912.

MFR$ finally converges for this 1969.III quarter to 0.103494 after 6 iterations, which is again far off, as shown in the table of tracking errors, Table 5.7, where the first quarter error in simulation for MFR$ is -0.015498 and is defined as the historical or actual value less the estimated value. It is not surprising then that FMR$ exhibits the largest RMSPE, viz., 104.3 in Table 5.9. Note, however, that the RMSE of MFR$ is only 0.71, which would indicate that even though the frequent and abrupt changes of free reserves at member banks are not tracked well, the errors for MFR$ are small. The same is true of two other volatile time series, viz., the rate of change of wages and the short-term interest rate. Note that in these Tables, PL does not mean the wage rate but the rate of change of the wage rate, even though in equation (4.38) PL does mean the wage rate. The reason for using the same label, PL, is one of convenience. Given the fact that PL appears always in the rate of change formula, $PL_t - PL_{t-1}$, and the latter appears in only two equations, viz., (4.38) and (4.39), it was easier to use the rate of change as a variable in the Gauss-Seidel program and label it PL.

This explains at least partially why the RMSPE (a measure of relative error, not levels) is relatively high for PL, viz., 60.58, even though the comparable statistic for levels, RMSE is only 0.0058.
Although RTB, the short term interest rate, and unemployment are not rates of change of the rates, the two have relatively large RMSPE's (relative), viz., 10.44 and 14.91 respectively, while their RMSE's (levels) are 1.20 and 0.60, respectively.

On the other hand, the variables which represent trend-dominated flows and stocks seem to have a lower RMSPE (relative) and higher RMSE (levels). Thus GNP has RMSPE equal to 0.60, but RMSE equal to 6.51, while CON has RMSPE equal to 0.86 and RMSE equal to 5.84. However, PGNP the level of the GNP price deflator, has RMSPE equal to 3.12, but RMSE equal to 2.84.

Figure 5.7 shows graphically how EINFL, expected inflation, which is a distributed lag of past changes in price, goes off track resulting in a RMSPE equal to 43.3. This is due primarily to this author's error insofar as the factor, \( \frac{400}{9} \sum_{i=0}^{400} (0.87)^i \), was miscalculated to be 64.0423, when it should have been 69.1883, and 64.0423 was applied in creating the variable EINFL before estimation began. Hence, 64.0423 was used in identity Y0(20) in Subroutine CEN of the Gauss-Seidel Program of Appendix C. This high RMSPE error, of course, is also partially due to the fact that by definition (2.37), the EINFL of Model RJM has two less lags than the EINFL of the MPS Model because the Gauss-Seidel Program prepared for RJM was limited to 10 lags. At any rate, the RMSE (levels) for EINFL is not bad at 1.87 for eight quarters.

Note that INFL, inflation \( = \frac{PGNP_t - PGNP_{t-1}}{PGNP_{t-1}} \) and ESTINFL, estimated
inflation, is also plotted in Fig. 5.7 even though it was not a separate variable in RJM3 so that no nonparametric statistics were calculated for it. The plot shows how well inflation is tracked by RJM3.¹

Nevertheless, EINFL, RTB, MFR$, in addition to the aforementioned ECD and KI, are troublesome equations in this model. Note that another identity, the equilibrium ratio of producers durables capital to output, VPD, is off somewhat, but this could have been improved by a different choice of constant for these eight quarters, as mentioned earlier. At any rate, it did not throw producers expenditures, EPS, too far off the mark.

Note that Klein's favorite measure, MAPE, is better, i.e., smaller, for every variable. Since RMSPE penalizes large individual errors more heavily than MAPE, it seems that large individual errors are harming the performance of RJM3. In fact, a glance at the simulation errors in Table 5.7 and the plots of actual versus estimated values of individual variables shows that this is the case especially in the first few quarters, such as the third quarter for CON, the second and third quarters for GNP, the third quarter for ULU, and the first quarters for RTB and MFR$. Surprisingly, RJM3 starts off poorly for most variables but then improves toward the end of the first year and tracks best of all in the second year or the last four quarters. On the other hand, signs of instability over the long run (more than two years) can be seen in the

¹ Due to an oversight in Figures 5.7 and 5.14, the plot of the rate of inflation, INFL, begins one period earlier than that of estimated inflation, ESTINFL. With this correction acknowledged, RJM3 catches the turning points of the rate of inflation quite well, even though RJM3 overestimates INFL by one to three percent.
steadily climbing errors of the price level, PGNP, expected inflation, ENNFL, expenditures on producers durables, EPD, and disposable income YD.

How well, then, does the Model RJM3 track the historical time paths of its variables? Unfortunately, published results of simulations of the MPS Model are scarce. Zarnowitz, Boschan, Moore, and Su (1972) report that for GNP the MAPE (relative) for the 10 year period 1956.I - 1966.IV is 0.650 which is only slightly higher than the RJM3's MAPE (relative) of 0.547 for a two year period over the 1969 - 1970 recession.

Fortunately, Charles Sivesind of the Research Department of the Federal Reserve Bank of New York was kind enough to send the results of and MPS Model simulation for the same eight quarters of 1969.III - 1971.II. Unfortunately, the RMSE for only two variables were calculated, viz., CON and EPD, which had RMS of 3.018 and 1.285, respectively. These are somewhat lower than RJM3's 5.844 and 3.670, respectively. However, since the MPS simulation used 1958 based data, in order to properly compare RMSE, one must use the respective RMSE adjusted for different deflators defined as $\frac{\text{RMSE}}{\text{average of the data for the simulation period}}$.

For CON of MPS:

$$\frac{3.018}{475.664} = .00635;$$

for RJM3:

$$\frac{5.844}{680.63} = .00859.$$
Since \( \frac{.00859 - .00635}{.00859} = .261 \), the RMSE of RJM3 for CON is approximately 26 percent higher than that of MPS. Similarly, for EPD, the adjusted RMSE for EPS of RJM3 is \( \frac{3.67}{67.525} = .0544 \), which is approximately 56 percent higher than the \( \frac{1.285}{53.999} = .0238 \) of the MPS Model.

For GNP, RMSE = 7.358 and adjusted RMSE = \( \frac{7.358}{725.15} = 0.0102 \) for the MPS Model, while RMSE = 6.510 and adjusted RMSE = \( \frac{6.51}{1082.58} = .0060 \) for RJM3.

Thus, the adjusted RMSE of RJM3 is approximately 70 percent lower than that of the MPS Model. However, the MPS has a RMSE for PGNP equal to 1.735 compared to RJM3's 2.94. And the adjusted RMSE for RJM3 is \( \frac{2.94}{91.41} = 0.032 \) which is approximately 59 percent higher than the adjusted RMSE of 0.013 for the MPS Model. It seems, therefore, that the MPS Model generally tracks better than the Model RJM3 even in the short run, but not always.

On the other hand, fortunately, McCarthy (1972) reports the Wharton Mark III simulation for the five quarters of 1969.1 - 1970.1 for GNP and the unemployment rate. For GNP, the RMSE is 4.488, which is lower than 6.51 of RJM3; for ULU the RMSE is 0.665, which is slightly higher than the 0.603 of RJM3. The adjusted RJMSE for GNP for the Wharton Mark III is \( \frac{4.488}{726.74} = .0062 > .0060 \) for RJM3.

Moreover, since RJM3's error statistics cover three more quarters of estimation than those of Wharton Mark III, it follows that RJM3 is better or at least on a par with the Wharton Mark III in tracking accurately these two key policy variables over a relatively tough-to-
track recession. Moreover, the Wharton Mark III average four-quarter simulation RMSE for nominal GNP was 7.18 and was 0.56 for the unemployment rate. Real GNP was not reported here, but Adams and Duggal (1974), simulating over 1961.I - 1967.IV, report an average RMSE for eight quarters for real GNP of 5.73, as well as 0.92 for PGNP and 0.66 for ULU. Again, it seems RJM3 competes favorably, although Wharton Mark III does somewhat better with its price variable. However, this was for an average of eight-quarter simulations between 1961 and 1967, when inflation was not yet as rampant and unpredictable as it has been since 1967.

Evans, Haitovsky, Treyz, and Su (1972) in an extensive analysis of the forecasting properties of U.S. econometric models report a six-quarter RMSE of 12.06 for real GNP and 1.94 for ULU for the Wharton Econometric Forecasting Unit Model. For the OBE Model they report a six-quarter RMSE of 7.22 for real GNP and 0.67 for ULU. In all cases, RJM3 does better even for eight quarters.

Finally, Fromm, Klein, and Schink (1972) report on a six-quarter simulation of the Brookings Model over the 1960-61 recession. The RMSE for GNP was 10.356, considerably higher than the 6.51 of RJM3 for eight quarters over the 1969-70 recession.

As far as turning-point analysis is concerned, Figures 5.1 - 5.7 tell the story for the 1969.III - 1971.II simulation of RJM3. The estimated path of GNP in Fig. 5.2 does remarkably well in picking up turning points. None are missed.
The same can be said for the price level, PGNP, in Figure 5.3, since both actual and estimated paths are nearly trend lines. RTB catches two out of three correctly, in Figure 5.4, and YD, in Figure 5.6, gives some hint of the slowdown for 1970.IV. But otherwise, as is painfully evident in Figure 5.3 for the rate of change of the wage rate, \( PL_t - PL_{t-1}/PL_{t-1} \), and in Figure 5.4 for RCB, RJM3 catches only the trends while it misses the quarter to quarter change.

More light will be shed on the potential of Model RJM3 to be used as a policy model, but from the historical simulation results over 1969.III - 1971.II it seems that RJM3 tracks the trend of variables reasonably well in comparison with some of the large well-known macroeconomic models currently being used to guide policy makers in both government and industry. However, RJM3 often does not catch the quarter to quarter changes in variables. And there are indications that over the long run, i.e., longer than two years, RJM3 would be unreliable even in tracking the trend paths of variables.

Prediction

But tracking is one thing, prediction is another. The ultimate application of a forecasting model is in ex-ante predictions, i.e., predictions made when even the time paths of exogenous are unknown and so have to be predicted by the econometrician. But ex-ante prediction tells nothing more about the performance of the model itself than can be learned from ex-post predictions. Hence, since we are primarily interested in learning the forecasting properties of the model alone,
and not those of the forecaster of the exogenous variables as well, no ex-ante prediction was attempted for RJM3. But an ex-post prediction was made for 1975.III - 1976.II, a period covering the last four observations of the 1972-based MPS data made available to this author and intentionally not used for estimating the coefficients of RJM3. For, in an ex-post forecast, the exogenous variables are known, i.e., historical values are used, as in a mere simulation or tracking experiment, but the period of forecast or estimation of the endogenous variables now extends beyond the time span of the 85 observations used to estimate the coefficients of the structural equations. Hence, an ex-post forecast tells something more than mere tracking or simulation can do, viz., how well does RJM3 predict. Thus, if any serious structural changes occurred in the economy after 1975.II, any model that tracked extremely well in simulation for the period before 1975.II could predict poorly the quarters after 1975.II.

Comparing the corresponding starting historical values of Table 5.10 with the first iteration values in Table 5.14 of the 30 endogenous variables, it becomes apparent that the 26th variable in sequence, viz., MFR$ (free reserves) is again far off track.

The first iteration predicts MFR$ as -1.25 but historically it was -0.116. However, two oddities in the data for this period help to distort this prediction. In equation (4.42) (or Y0(26) of Subroutine CEN in the SAS Program of Appendix B, below) the component variables (ZDRA - RTB) and ZRD$ (MCL$ _t - MCL$ _t-1) both suffer sign reversals for the 1975.III quarter, a phenomenon that is especially unusual for
\((MCL_t^\$ - MCL_{t-1}^\$)\) over the span of the previous 85 quarters upon which the estimates of the coefficients of this equation are based. These sign reversals account for at least half of the difference between the historical value of MFR$ and its first iteration estimate. Unfortunately, MFR$ converges at -1.106 for the 1975.III quarter and only gets worse thereafter, resulting in a RMSPE equal to 5126.5, even though its RMSE is a relatively modest 1.67 for the four quarters.

No attempt was made to change the arbitrary constant factors for VPD, which would have improved the RSMPE and RMSE of EPS from their relatively high 13.13 and 9.94 values.

RTB with a RMSPE of 24.48 was a disappointment also, although its RMSE of 1.26 may not be unreasonably high. Once again, RJM3 misses abrupt quarter-to-quarter changes, as evidenced by Figure 5.11 for the last quarter of RTB, and by Figure 5.10 for the first quarter of the rate of change of the wage rate, \(PL_t - PL_{t-1}^\$ / PL_{t-1}^\$\). However, the remaining Figures show that RJM3 generally predicts the trends well. Figure 5.14 shows that RJM3 does not predict inflation well, and slightly overpredicts the path of expected inflation. This is why the RMSPE of RINFL is the relatively high 27.72, and Theil's U statistic is 2.9, the highest of all variables, even though its RMSE is again a reasonable 1.75.

The most disturbing aspect of this prediction is the evidence of instability seen especially in Figure 5.9 for GNP and ULU and in Figure 5.12 for M1$ and MD$. In each instance, by the fourth quarter RJM3 tends to move decisively away from the historical path, except for ULU which happens to move toward the historical path, only because it was highly overpredicting the unemployment rate. As GNP underpredicts, it should keep the unemployment rate overpredicting.

The RMSPE for GNP is 0.515 and RMSE is 6.45. The first quarter prediction for GNP has an error of 1.2588, as seen in Table 5.16. This implies a RMSE of 1.2588 for the first quarter ex-post prediction of GNP which has an average absolute error of 5.199 for all four quarters. Evans, Haitovsky, Treyz, and Su report an average one-quarter-ahead adjusted ex-post forecast RMSE for real GNP of 4.475 for the Wharton Econometric Forecasting unit over the period 1966.I - 1968.IV and a RMSE of 6.4 for a six-quarter unadjusted ex-post prediction covering 1963.I - 1964.II. For the OBE Model over 1967.II - 1968.IV first-quarter-ahead ex-post forecasts of real GNP with no adjustments had an average absolute error of 5.3 and four-quarter-ahead ex-post forecasts had an average absolute error of 8.8. It must be noted that some of the Wharton forecasts were "ex-post with actual adjustments" made to the intercepts in the equations, thus enhancing the predictions of the model in an ad-hoc way not used in the performance of RJM3.

Eckstein, Green, and Simri (1974) working with the Data Resources Model over 1963 - 1972 report an average one-quarter ahead ex-post prediction RMSE of 5.0 for real GNP and 0.32 for the Implicit Price
Deflator plus a four-quarter-ahead RMSE of 7.2 for real GNP and 0.59 for the Implicit Price Deflator. Klein and Fromm (1976) report on eight quarterly models, including those already cited from other sources. In addition, they report one- and four-quarters-ahead ex-post predictions over 1969.1 - 1969.IV for the following models: Brookings (5.86 and 16.41 for GNP, 0.42 and 0.91 for PGNP, 0.26 and 1.02 for ULU, and 0.43 and 0.50 for RTB); Michigan (5.16 and 12.09 for GNP, 0.39 and 0.86 for PGNP, 0.23 and 0.79 for ULU, and 0.54 and 0.66 for RTB); Fair (3.12 and 5.4 for GNP, 0.21 and 0.76 for PGNP, and 0.36 and 1.08 for ULU); and St. Louis (6.81 and 10.25 for GNP, 0.48 and 0.76 for PGNP, 0.20 and 0.36 for ULU, and 1.15 and 1.35 for RTB). Note that Fair's small model, as RJM3, is better than the larger models for trend-like variables such as GNP, but not as good for more volatile variables, such as ULU and RTB. However, the St. Louis Model, while small, predicts GNP and PGNP more like the larger models. Of course, to be fair to the larger models, while they continue to predict reasonably well for several more quarters themselves, RJM3 and Fair are beginning to explode even by the fourth quarter.

Unfortunately, reports of ex-post prediction error for the MPS Model are not given by Fromm and Klein and are scarce. Nelson (1973) reports on the previous (1969) version of the MPS Model called the FMP (Federal Reserve - M.I.T.-Penn) Model. Over the forecast period of 1967.1 - 1969.1, the ex-post eight quarter forecast RMSE: for real GNP was 77.259; for CON it was 25.54; for EPD it was 22.288; for ULU it was 0.412; for PGNP it was 0.068; for RTB it was 0.425; and for RCB it was
0.066. A glance at Table 5.18, column six, shows that the corresponding statistics for RJM3 for the four quarters of 1975.III - 1976.II are 6.5, 8.16, 0.94, 0.998, 2.79, 1.26, and 0.94. Obviously RJM3 compares favorably in the real sector, but not with respect to prices, nor in the financial sector. In addition, it is probably the case that the 1975 MPS version does even better than the 1969 version.

In conclusion, due to the extremely poor ex-post prediction of free reserves (FMR$) and the relatively poor ex-post predictions of RTB and PGNP, all of which contribute to the poor prediction of M1$ and MD$, the Model RJM3 is not as successful a short-run forecasting model as Fair's small model and the larger well-known macroeconomic models. Moreover, the prediction failures in the monetary and price sectors imply something about RJM as a tool for policy purposes. To be more explicit, however, a number of fiscal and monetary policy experiments were run using RJM3 to see how the model would respond if it were used for policy simulations.

**Five Multiplier Analyses**

Thus far the complete-system solution errors for both within and beyond the sample period of 1954.II - 1975.II have been examined. The analyses have revealed how realistically RJM3 predicts unconditionally, i.e., with historical values for all exogenous variables. However, according to Klein and Fromm (1976) such "error statistics generally do not reveal much information about responsiveness of models to shifts in
policy variables or parameters. That is, they are of limited value for evaluating conditional forecasting. For this reason there is keen interest in dynamic multipliers resulting from alternative monetary and fiscal policy actions."

Five such conditional simulations were run with RJM3 over the period, 1969.III - 1971.II. They used the following control variables:

(1) A 10 percent exponential growth rate for unborrowed reserves (ZMS$) beginning with the value for 1969.III as the value for time = zero.

(2) A 10 percent increase in federal government expenditures (EGF) over the historical values, beginning in 1969.IV.

(3) A 10 percent decrease in the federal income tax liability (TPFS) from the historical values, beginning in 1969.IV.

(4) A 25 percent increase in federal government expenditures (EGF) over the historical value for the single quarter of 1969.IV.

(5) The short-term interest rate, RTB, constrained to remain within one-half of one percent of the 1969.II value of 6.19.

The control variables themselves for experiments (1), (2), and (3) are plotted along with their unconditional estimates over 1969.IV - 1971.II in figures 5.15 and 5.16.

Since the period includes the 1969 - 1970 recession, in one sense it is a poor period to choose in order to test the policy-responsiveness of RJM3. On the other hand, to the extent that RJM3 tracks well over
this period, each multiplier analysis should reveal what would have happened to the U.S. economy had authorities employed the respective policy tools.

When economists speak of "the multiplier", they usually mean the cumulative or timeless multiplier which tells the total amount an endogenous target variable has been changed over time by a change in some exogenous variable.

Mathematically, the definition of a dynamic multiplier is $\frac{\partial Y_t}{\partial X_t}$ where $t$ is the period of time for which the multiplier is being calculated, $Y_t$ is the endogenous or target variable at time $t$, and $X_t$ is the exogenous or control variable at time $t$. The multiplier at time $t=0$, i.e., the initial period of impact of a change in the exogenous variable, is called the impact multiplier. But what is of greater interest to policy-makers is the time-path of response rather than simply the initial and the ultimate response. In other words, they want to know what part of the response of the endogenous variable to changes in the exogenous variable occur after each lapse of time. The answer to this question will help to decide between fiscal and monetary policy as the means to effect some goal. Thus, if the total impact of some monetary policy on, say, GNP, is of sufficient magnitude to satisfy some goal but the lag in effect is too long, then some fiscal policy may be chosen instead.
The multipliers reported for RJM3 are, of course, implicit multipliers, i.e., they are not derived from mathematical algorithms as can be done in the case of dynamic multipliers of linear systems. Rather, as for most nonlinear systems, the multipliers are obtained through a simulation of the model which differs in only one way from the historical simulation reported for RJM3 above in the section entitled "Simulation." In a multiplier or conditional simulation, one or more exogenous control variables are changed in a way such that this change will influence one or more endogenous target variables to follow a time path desired by the policy makers. Unfortunately, multiplier simulation can only produce one of an infinite number of possible time paths for the target variable, only one of which is the desired path, unlike optimal control programs which constrain the target variable to the desired path and solve for the necessary path of the control variable.

Benjamin Friedman (1975) and Robert Pindyck (1973) provide thorough analysis and concrete applications showing how optimal control theory encompasses and goes far beyond the trial-and-error multiplier simulations of Goldberger (1970) and of this author is applying the policy formulation framework developed by Tinbergen and Theil. Nevertheless, even the few multiplier runs which follow should reveal many of the strong points and weaknesses of RJM3 when used for policy purposes.
A 10 Percent Annual Rate of Growth of Unborrowed Reserves at Member Banks Plus Currency

The first multiplier analysis uses ZMS$, unborrowed reserves at member banks plus currency outside of banks, as the control variable. It should be noted that ZMS$ is largely controlled by the Federal Reserve Bank's open market operations. This means that those who carry out the directives of the Federal Reserve Open Market Committee can to a large extent control the magnitude of member banks' unborrowed reserves plus currency outside banks, ZMS$, by buying or selling government securities on the open market. William Poole (1975) describes Federal Reserve open market policies and procedures and he argues that some reserve aggregate such as ZMS$ is the ideal control or instrumental variable for executing monetary policy via open market operations. ZMS$ was set to grow exponentially at an annual growth rate of 10 percent starting with the 1969.III quarter value.

The $71.494 e^{\left(-\frac{10}{4}\right)t}$, $t=0, 1, ..., 7$, produced the value for the exogenous variable, ZMS$. Otherwise, the multiplier simulation program was exactly as listed in Appendix C for the unconditional 1969.III - 1971.II Simulation. The results for 12 key economic variables are graphed in Figures 5.17 - 5.22 where both the unconditional estimate of a particular variable is plotted as well as the estimate of that same variable given the change in the control variable, ZMS$. In addition, the dynamic multipliers for each variable due to a unit change in ZMS$ are listed in Table 5.19.
As expected, because of the identities (2.45) – (2.47) and (2.52), the growth of unborrowed reserves drives up the money supply, $M_{L}$, since free reserves, $M_{F R}$, never becomes a large positive value and, hence, does little to slow the growth of demand deposits via (2.47).

Also, as theory leads us to expect, both the short-term interest rate, $R_{T B}$, and the long-term, $R_{C B}$, decline, but beginning only in the fourth quarter, which is consistent with the fact that GNP did not start to increase until the fourth quarter. Note that the growth of GNP in the last three quarters helps to slowly drive up $R_{T B}$ and $R_{C B}$ again despite the continued growth of unborrowed reserves and the money supply. This is one indication that, at least for RJM3's representation of the U.S. economy, money supply growth has less influence on interest rates than has real sector growth.

The price level, $P_{G N P}$, goes up beyond the nonmultiplied level already in the third quarter, as Figure 5.19 illustrates, but it stays only slightly above the nonmultiplied level. In short, inflation has not been aggravated by this monetary policy, at least within these first seven quarters. Moreover, the positive change of $P_{G N P}$ from 1971.I to 1971.II is smaller than previous changes—a decreasing inflation rate at least for this last quarter.

Finally, unemployment shows marked improvement over the nonmultiplied estimation starting in 1970.III. Oddly, in 1970.II ULU is actually a bit higher for the multiplier simulation. This is probably due to the fact that GNP was still falling in 1969.IV and 1970.I.
In general, the dynamic multipliers are modest at least through the first seven quarters. Unfortunately, the second quarter value for ZMS$ is 73.3, which is less than the historical value of 73.58, despite the policy intention of having ZMS$ grow.

This accounts for $3 billion drop of the money supply, M1$, below the nonmultiplied estimate, as can be seen in Figure 5.21. Hence, the multipliers for GNP are negative for the 2nd, 3rd and 4th quarters and GNP actually decreases for the first two quarters of the multiplier run. The first quarter multiplier is zero for all multipliers since the historical value of the control variable was always used in the first quarter. Given that ZMS$, unborrowed reserves, plus currency, has grown to 75.160 by 1970.I, which is greater than the historical value of 73.802 for ZMS$, and that estimated GNP increased once again in the fourth quarter, 1970.II, by approximately $4 billion for both the nonmultiplied and multiplied simulations, but slightly more for the latter, it seems that ΔZMS$ does not affect GNP until 1970.II, which is the third quarter of ZMS$ growth. In 1970.III, GNP increased by almost $8 billion for the multiplied run compared to only $6 billion for the nonmultiplied simulation. Thereafter, as the multiplier table, Table 5.19 shows, for each billion increase in unborrowed reserves plus currency, GNP grew by approximately $0.4 billion and the multiplier is growing larger but at a tiny rate. However, seven quarters after this monetary policy was instigated, the level of GNP is only $1109.458 billion, i.e., only $8 billion higher than the $1101.437 billion
estimated without such a policy, as seen in Figure 5.18. This seems to be a relatively small response in aggregate output after nearly two years, but it is a response in the desired direction insofar as GNP is improved over the nonmultiplied simulation by the fourth quarter without being overly stimulated by the monetary policy. However, only a simulation over a much longer period could show whether the multiplier explodes eventually and pushes the economy to hyperinflation and other ills of an overheated economy. At any rate, this monetary policy is noninflationary for the first seven quarters. The multiplier of PGNP is steadily growing over the seven quarters and no doubt would grow as ZMS$ grows larger. In conclusion, for the 1969.III - 1971.II period, RJM3 indicates that this first policy would not have improved key target variables in the first two quarters of the recession, 1969.IV - 1970.I, but thereafter it would have guided them along paths that some policy makers might consider ideal.

Fortunately, Michael Hamburger (1969) of the Federal Reserve Bank of New York reports on the effects over 1963.I - 1965.IV of a $1 billion sustained increase in unborrowed reserves, MRU$, defined by identity (2.52), on six target variables of the 1969 version of the MPS Model. Since MRU$ less currency outside of banks, MC$, is equal to ZMS$, a rough comparison can be made between the two models regarding this monetary policy. For the older MPS model, the changes in the real GNP grow slowly at first, reaching $2 billion after 4 quarters, and then
grows rapidly until they reach $7 billion after 7 quarters and $11 billion after 12 quarters. Since GNP with RJM3 reached $8 billion increase after 7 quarters of this policy, the results are remarkably similar.

Unfortunately, Hamburger doesn't report on PGNP and ULU, but after seven quarters CON had increased $3.5 billion for the old MPS, compared to $3 billion for RJM3; demand deposits had increased to $4.5 billion in MPS, compared to $30 billion in RJM3; the short-term interest rate had decreased about 0.35 percent in MPS, compared to 0.7 percent in RJM3. Obviously, the models differ considerably in the monetary sector. RJM3 overestimates the effect on demand deposits and, hence, on the money supply, as well as the effect on RTB. With respect to RCB, the models are much closer.

Fromm and Klein (1976) in the NBER/NSF Model Comparison Seminar referred to in Chapter I list real GNP multiplier results for the eight quarterly models participating. For a sustained change in unborrowed reserves, MRU$, the 1975 MPS Model produced the following dynamic multipliers: 0.4, 1.1, 2.2, 3.6, 5.4, 7.4, 9.5, 11.4.

These are considerably larger than those of RJM3 for ZMS$ as seen in Table 5.19 and the rate of increase is much larger as well -- strong evidence that the monetary-real linkage in RJM3 is considerably weaker than in the latest MPS Model.

Carl Christ (1975) reports the Wharton Mark III price level (PGNP) multipliers for a change in ZMS$ over 1965.I - 1968.IV, viz., -0 for
the first quarter, -.01 for the third quarter, -.01 for the fourth quarter, -.01 for the eighth quarter, and 0 for the 16th quarter. Since the rate of inflation grew much faster after 1968, the multipliers of RJM3 for PGNP in Table 5.19 are not unreasonable.

A 10 Percent Increase Over the Quarterly Historical Values of Federal Government Expenditures On Goods and Services (EGF)

As neo-Keynsian macro theory leads us to expect, this fiscal policy, increasing federal government expenditures, EFG, by 10 percent each quarter above the historical values, affects the economy without much lag and with considerably more impact than the previous monetary policy. Regrettably, it must be pointed out that comparison cannot be easily made if only because that 10 percent increase of EGF is quarterly, whereas that of ZMS$ was annual.

Figures 5.23 - 5.28 show how the 12 key economic variables responded to the increase in EFG. GNP in Figure 5.24 is almost $20 billion more than it was estimated to be without the effect of the first quarter multiplier, 1.36475, given in Table 5.20. At the end of the 7th quarter under this multiplier, GNP has reached $1169.329 billion, which is $68 billion more than it would have been without the change in EGF.

Moreover, ULU, the unemployment rate, has been driven down to 1.99 in 1971.II, after seven quarters, and already at the end of the very first quarter of change in EFG, ULU dropped nearly 2 percent.
There is a rise in RTB and RCB, the interest rates, which is to be expected due to the increased rate of change of GNP, PGNP and EINFL.

Money supply, M1$, increased but only to levels slightly above the nonmultiplied estimates.

As expected, when GNP rises rapidly, the price level, PGNP, goes up and the rate of inflation climbs to about 9 percent annually whereas it was only about 6 percent annually in the nonmultiplied simulation over the last four quarters, 1970.III - 1971.II.

With hindsight, it would have been more realistic to increase EGF by 10 percent annually instead of quarterly. Since inflation increased only 3 percent for this 10 percent quarterly increase in EGF, inflation may not have increased as much as 1 percent with a 10 percent annual increase in EGF over historical values. If that held true, this fiscal policy would definitely be preferred in its timing and impact over the 1969 - 1970 recession to the monetary policy analyzed in Section 1 above. However, a monetary policy such as that described in Section 1 is far more likely to be carried out than most fiscal policies, since the former require only an easily made and executed decision of the Federal Reserve Open Market Committee whereas the latter requires a considerably more difficult-to-make and execute Presidential or Legislative decision.

Fromm and Klein (1976) also discuss government expenditure multipliers from a sustained increase in EFG. In all cases, except
the short-run Fair Model, real GNP multipliers rise to a peak in two or three years and then fall and that MPS Model multiplier actually goes negative after 4 years. For the 1st eight quarters, the real GNP multipliers for the 1975 MPS Model are: 1.2, 1.7, 2.1, 2.5, 2.8, 3.0, 3.1, 3.0. Thereafter, they slowly decline. However, with an accommodating monetary policy of constant interest rates to support ever higher financial transactions and investment demands, the multipliers do not decline but continue to grow, reaching 6.0 after four years. Unless the relatively large 10 percent quarterly increase is an explosive factor, the larger and ever increasing multipliers of RJM3, even without compensating monetary policy, would indicate that RJM3 is a relatively unstable and explosive model over the long run.

A 10 Percent Decrease Below the Quarterly Historical Values of the Federal Personal Income Tax Liability (TPF$)

Theory tells us that this 10 percent quarterly decrease in personal taxes, TPF$, should have an effect on the economy similar to the 10 percent quarterly increase in federal government expenditures, EGF, reported in Section 2. In both cases, total spending is being adjusted directly.

The multipliers of TPF$ in Table 5.21, however, while they all move in the same direction, are consistently about one-half (or less) the magnitude of those of EGF, in Table 5.20. Figures 5.23 - 5.28 tell the same story.
Once again, however, fiscal policy results in a faster and more powerful impact on the economy than the monetary policy in Section 1. Although there is still a slight dip in real GNP for the first two quarters of the recession, 1969.IV and 1970.I, the levels are $3 and $7 billion higher than the estimated nonmultiplied levels, as revealed in the spatial gap plotted in Figure 5.24. The price level rises slightly over the nonmultiplied estimate, and the rate of inflation rises only 1 percent higher, i.e., to a 7 percent annual rate compared to a 6 percent annual rate for the nonmultiplied estimate.

Interest rates are scarcely changed from the nonmultiplied simulation, nor is the money supply. Disposable income has risen, as expected, but the multiplier is only about 5/8 that of the ECD multiplier.

Once again, Klein and Fromm (1976) provide model multiplier comparisons. The 1975 MPS dynamic multipliers for "Personal Taxes" (which may or may not be identical with TPF$) are: 0.4, 0.9, 1.2, 1.5, 1.9, 2.2, 2.5, 2.7 and, after four years, 3.7. These are slightly larger than all other models participating, but they are remarkably close to those of RJM3, except that RJM3 again shows signs of explosive instability by reaching 3.57 after 2 years compared to the MPS models 4 years.

A 25 Percent One-Quarter Increase of Federal Government Expenditures (EGF) on Goods and Services Above the Historical Value for 1969.IV

The impact multipliers of this one-quarter shock to the economy via a 25 percent increase in EGF for 1969.IV are listed in Table 5.22
and are nearly identical to those for 1969.IV due to a 10 percent sustained increase in EGF as listed in Table 5.20. Housing, EG, is the only exception, oddly enough having a considerably smaller multiplier in 1969.IV for the larger increase in EGF. The purpose of this experiment was to determine whether the multiplied endogenous variables would eventually settle down to their simulated non-multiplied paths. If so, then this occurrence would indicate that RJM3 is stable.

Figures 5.29 - 5.34 show, unfortunately, that real GNP, PGNP, RTB, etc., are all exploding already by the eighth quarter — more evidence of the explosive nature of RJM3 as the time horizon lengthens.

Battenberg, Enzler and Havenner (1975) report an EGF impact multiplier for the MPS Model of 1.0 for GNP, -0.03 for ULU, and 0.009 for the MPS's price level variable (not PGNP). For each variable, the changes induced by a change in EGF quickly die out or nearly so after eight quarters, indicating that the MPS Model is stable.

Restricting the Short-Term Interest Rate, RTB, to One-Half of One Percent of the 1969.II Value

As Poole's (1975) article explains, the Federal Reserve Open Market Committee uses the short-term Federal Funds Rate as an intermediate target to help control the rate of growth of money supply. This present experiment was made to discover how RJM3 would respond to open market operations which would attempt to restrict the short-term rate, RTB, within the narrow band of one-half of one percent of 6.19, the
1969.II rate, over the period 1969.III - 1972.II. It must be noted that historically RTB jumped considerably from 6.19 in 1969.II to 7.01 in 1969.III due to open market operations of the Federal Reserve. This was a policy move to dampen inflation, hopefully without causing a recession. Ironically, a recession developed, but inflation continued unabated.

The results of the experiment are presented in Figures 5.29 - 5.34 and Table 5.23. The figures cover four more quarters since a second longer simulation was run to see whether GNP, for example, eventually returned to its historical levels. As a matter of fact, the historical value of real GNP for 1972.II is $1163 billion, $15 billion more than for real GNP of the experiment, as given in Figure 5.30. However, the rate of increase of GNP in the experiment is so great in the last two quarters that it seems the explosive tendency of RJM3 is overcoming the restriction on RTB. However, this is partly due to the fact that historical rates soon came down, thus stimulating GNP. The historical rates of RTB over 1969.III - 1972.II were 7.01, 7.35, 7.12, 6.66, 6.33, 5.35, 3.84, 4.24, 5.0, 4.23, 3.43, and 3.76.

The long run explosiveness of RJM3 is even more strongly indicated in Figure 5.31, where the price level, PGNP, is already very close to overtaking the nonrestricted estimate by the 8th quarter and by the 12th quarter reaches 110.2 compared to the historical (not estimated by RJM3) level of 99.5.
With RTB kept artificially high it is reasonable that constrained ULU, the unemployment rate, is 1.01 percent above the historical for 1972.11, and .9 percent above the simulated nonrestricted ULU of Figure 5.30.

The long-term rate, RGB, is only slightly higher than the non-restricted simulation as seen in Figure 5.32. Again, RGB scarcely responds to change in RTB.

As expected for the first four or five quarters, the money supply, M1$, levels are higher than for the nonrestricted simulation since RTB is smaller. But instead of M1$ rising at a declining rate over the last 6 quarters, due to restricted RTB being considerably higher than the historical RTB, the restricted simulation has M1$ reaching $266.174 billion by 1972.11, considerably above the historical level of $244.3 billion.

In comparison, the MPS Model in a simulation over the same period run by Charles Sivesind of the New York Federal Reserve Bank, with RTB restricted to 6.1, recorded the following levels of real GNP (in 1958-based data): 730.037, 726.869, 726.183, 725.868, 733.032, 733.183, 745.766, 762.624. The corresponding nonrestricted values simulated by MPS 1958-based data were 729.4, 724.9, 722.4, 720.2, 725.4, 724.2, 737.5, and 755.4 over 1969.III - 1971.II. Comparison reveals MPS responds much the same as RJM3 to restricted RTB. However, whereas it takes RJM3 only three quarters before the lower interest rate, via
increased consumer and investment spending moves real GNP to start rising again in 1970, the MPS model requires four quarters. Thereafter, GNP rises at a rapidly increasing rate in both models, but RJM3 seems more responsive to the higher than historical RTB rates for the last four quarters in that GNP does not rise as fast in RJM3 as in MPS. In the MPS model, M1$ rises steadily from $208 billion (in 1958-based data) to $227 billion, after 8 quarters. In RJM3, M1$ (with 1972-based data) rose steadily from $206 billion to $240 billion after 8 quarters. In the MPS Model, ULU is estimated as rising steadily from 3.666 to 5.991 after seven quarters and then drops to 5.321 in 1971.II; with RJM3. ULU rises from 4.06 to 6.50 and then drops to 6.10. In the MPS Model, PGNP (in 1958 dollars) rises steadily from 129 to 139.5, while in RJM3 (in 1972 dollars) PGNP rises from 87.6 to 110.2.

This comparison shows that while RJM3 always responds in the same direction as MPS, RJM3 is less influenced by the restricted RTB insofar as the money supply and the long term rate are concerned, but responds in a closely similar manner and with relatively the same magnitude insofar as PGNP and ULU is concerned and is even more sensitive in responding as expected with respect to real GNP.
Table 5.1 Starting Values of the Endogenous Variables for 1969.III - 1971.II Simulation

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Table 5.2  Actual Values of Exogenous Data Set for 1969.II - 1971.II Simulation

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**Additional Table Columns:**
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- `SLPB`  
- `LH`  
- `ESTOP`  
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- `RBC`  
- `LEF`  
- `IGF`  
- `ZCT`  
- `ZDA`  
- `JMSA`  
- `JMBB`  
- `MGF`  
- `ZRT`  
- `ZRD`  
- `ZMS`  
- `MCR`  
- `WACC`  
- `TGEA`  

**Table Notes:**
- The table contains data for multiple columns, including `N`, `ZS33`, `TIME`, `UTC`, `TCRD`, `SLPC`, `ZLIN`, `WARP`, `SLPB`, `LH`, `ESTOP`, `EX`, `EGR`, `EGS`, `EGFL`, `RBC`, `LEF`, `IGF`, `ZCT`, `ZDA`, `JMSA`, `JMBB`, `MGF`, `ZRT`, `ZRD`, `ZMS`, `MCR`, `WACC`, and `TGEA`.
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Table 5.3 Actual Values of Exogenous Data Set for 1969.III - 1971.II Simulation

Table 5.4 Starting Values for Lagged Endogenous and Exogenous Variables for 1969.11 = 1971.11 Simulation
Table 5.5  Estimates of the 30 Endogenous Variables at Each Iteration of the First Quarter Plus Convergence Estimate for First Quarter, 1969.

|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
Table 5.6  
Estimates of the 30 Endogenous Variables for Each Quarter of the 1969.III - 1971.II Simulation

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Table 5.7  Simulation Error (Actual Less Estimated) for 1969.III - 1971.II
Simulation

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Table 5.8 Percentage Simulation Error for 1969.III - 1971.II Simulation
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**Note:**
- The table continues with more columns and data, but the content is not fully visible in the provided image.
Table 5.9  
Table 5.10  Starting Values of Endogenous Variables for 1975,III - 1976,II
Ex-Post Prediction

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<th>ENDOGENOUS VARIABLES</th>
<th>STARTING VALUES</th>
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<th>ENDPOST</th>
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Actual Values of Exogenous Data Set for 1975.111 - 1976.11
Ex-Post Prediction

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Table 5.12  Actual Values of Exogenous Data set for 1975.III - 1976.II
Ex-Post Prediction
Table 5.13  Initial Values of Lagged Endogenous and Exogenous Variables for the 1975.III - 1976.II Ex-Post Prediction

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Table 5.14  The Estimated Endogenous Variables for the Six Iterations of the 1975.III Quarter for the 1975.III - 1976.II Ex-Post Prediction

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Table 5.15 The Predicted Values of the Endogenous Variables for 1975.III - 1976.II Ex-Post Prediction

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<th><strong>EQP</strong></th>
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<th><strong>NCB</strong></th>
<th><strong>RTB</strong></th>
<th><strong>RDB</strong></th>
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<tbody>
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<td>0.12000410E 04</td>
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<td>0.12386100E 04</td>
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<td>0.12386100E 04</td>
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<td>0.12178400E 04</td>
<td>0.12386100E 04</td>
<td>0.12494000E 04</td>
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<tr>
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<th><strong>YPS</strong></th>
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<tbody>
<tr>
<td>1</td>
<td>0.13279000E 03</td>
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</tr>
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Table 5.16  Prediction Errors for the 30 Endogenous Variables for 1975.III - 1976.II Ex-Post Prediction

<table>
<thead>
<tr>
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<th>ACTUAL LESS ESTIMATED FOR HISTORICAL PERIOD</th>
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<td>CON</td>
<td>EPS</td>
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<td>1</td>
<td>0.14689940E 01</td>
<td>0.05000000E 00</td>
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<tr>
<td>2</td>
<td>0.03586830E 01</td>
<td>0.00000000E 00</td>
</tr>
<tr>
<td>3</td>
<td>0.19189250E 02</td>
<td>0.00000000E 00</td>
</tr>
<tr>
<td>4</td>
<td>0.11838590E 02</td>
<td>0.00000000E 00</td>
</tr>
</tbody>
</table>

|      | ECD                                        | EPC  |
| 1    | 0.14550780E 01                            | 0.14414660E 03 |
| 2    | 0.14550780E 01                            | 0.14414660E 03 |
| 3    | 0.14550780E 01                            | 0.14414660E 03 |
| 4    | 0.14550780E 01                            | 0.14414660E 03 |

|      | EPO                                        | EPS  |
| 1    | 0.12775990E 00                            | 0.19699950E 00 |
| 2    | 0.12775990E 00                            | 0.19699950E 00 |
| 3    | 0.12775990E 00                            | 0.19699950E 00 |
| 4    | 0.12775990E 00                            | 0.19699950E 00 |

|      | KGHF                                       | KB   |
| 1    | 0.12466200E 01                            | 0.27592700E 01 |
| 2    | 0.12466200E 01                            | 0.27592700E 01 |
| 3    | 0.12466200E 01                            | 0.27592700E 01 |
| 4    | 0.12466200E 01                            | 0.27592700E 01 |

|      | PMP                                        | VCB  |
| 1    | 0.05867360E 00                            | 0.15786400E 00 |
| 2    | 0.05867360E 00                            | 0.15786400E 00 |
| 3    | 0.05867360E 00                            | 0.15786400E 00 |
| 4    | 0.05867360E 00                            | 0.15786400E 00 |

|      | MAD6                                       | MFA  |
| 1    | 0.88102400E 01                            | 0.49765100E 01 |
| 2    | 0.88102400E 01                            | 0.49765100E 01 |
| 3    | 0.88102400E 01                            | 0.49765100E 01 |
| 4    | 0.88102400E 01                            | 0.49765100E 01 |

|      | MP6                                        | MP6  |
| 1    | 0.28750920E 01                            | 0.00000000E 00 |
| 2    | 0.28750920E 01                            | 0.00000000E 00 |
| 3    | 0.28750920E 01                            | 0.00000000E 00 |
| 4    | 0.28750920E 01                            | 0.00000000E 00 |

|      | MFRS                                       | MFRS |
| 1    | 0.13696400E 00                            | 0.04124000E 02 |
| 2    | 0.13696400E 00                            | 0.04124000E 02 |
| 3    | 0.13696400E 00                            | 0.04124000E 02 |
| 4    | 0.13696400E 00                            | 0.04124000E 02 |

|      | MGRS                                       | MGRS |
| 1    | 0.04124000E 02                            | 0.00000000E 00 |
| 2    | 0.04124000E 02                            | 0.00000000E 00 |
| 3    | 0.04124000E 02                            | 0.00000000E 00 |
| 4    | 0.04124000E 02                            | 0.00000000E 00 |

|      | VPS                                        | VPS  |
| 1    | 0.14613410E 00                            | 0.49765100E 01 |
| 2    | 0.14613410E 00                            | 0.49765100E 01 |
| 3    | 0.14613410E 00                            | 0.49765100E 01 |
| 4    | 0.14613410E 00                            | 0.49765100E 01 |

|      | VPO                                        | VPO  |
| 1    | 0.04124000E 02                            | 0.04124000E 02 |
| 2    | 0.04124000E 02                            | 0.04124000E 02 |
| 3    | 0.04124000E 02                            | 0.04124000E 02 |
| 4    | 0.04124000E 02                            | 0.04124000E 02 |
Table 5.17 Percentage Change Ex-Post Prediction Errors for 1975,III - 1976.II

<table>
<thead>
<tr>
<th></th>
<th>ACTUAL PERCENTAGE CHANGE</th>
<th>LESS ESTIMATED PERCENTAGE CHANGE FOR HISTORICAL PERIOD</th>
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<tr>
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<td>CDH</td>
<td>ECD</td>
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<tr>
<td>1</td>
<td>0.00000000E +00</td>
<td>-0.00000000E +00</td>
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<tr>
<td>2</td>
<td>0.39579500E +00</td>
<td>-0.00000000E +00</td>
</tr>
<tr>
<td>3</td>
<td>0.77023900E +00</td>
<td>-0.00000000E +00</td>
</tr>
<tr>
<td>4</td>
<td>0.14028600E +00</td>
<td>-0.00000000E +00</td>
</tr>
</tbody>
</table>

|       | EPD                      | VPD                                                  |
| 1     | -0.26462100E -01         | -0.82571800E -01                                     |
| 2     | -0.62071700E -01         | -0.21658400E -01                                     |
| 3     | 0.77023900E +00          | -0.00000000E +00                                     |
| 4     | -0.15522600E -01         | -0.14491600E -01                                     |

|       | EPS                      | VPS                                                  |
| 1     | -0.00000000E +00          | -0.00000000E +00                                     |
| 2     | 0.00000000E +00          | -0.00000000E +00                                     |
| 3     | 0.00000000E +00          | -0.00000000E +00                                     |
| 4     | 0.00000000E +00          | -0.00000000E +00                                     |

|       | KPS                      | KI                                                   |
| 1     | 0.00000000E +00          | 0.00000000E +00                                     |
| 2     | 0.00000000E +00          | 0.00000000E +00                                     |
| 3     | 0.00000000E +00          | 0.00000000E +00                                     |
| 4     | 0.00000000E +00          | 0.00000000E +00                                     |
### Table 5.18  
Nonparametric Error Statistics for Endogenous Variables of  

<table>
<thead>
<tr>
<th>Selected Nonparametric Measures of the System</th>
<th>Mean Absolute Error</th>
<th>Root Mean Squared Error</th>
<th>System R² (That vs. Actual)</th>
<th>Theil U Statistic</th>
<th>Theil U Statistic (Reform)</th>
<th>Root Mean Error</th>
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<tbody>
<tr>
<td><strong>Mean Error</strong></td>
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<td>0.00000000E + 00</td>
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<td>0.20000000E + 00</td>
<td>0.20000000E + 00</td>
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<td>0.00000000E + 00</td>
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<td>0.20000000E + 00</td>
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<td>0.00000000E + 00</td>
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<td>0.20000000E + 00</td>
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</tr>
<tr>
<td>EPS</td>
<td>0.00000000E + 00</td>
<td>0.00000000E + 00</td>
<td></td>
<td>0.20000000E + 00</td>
<td>0.20000000E + 00</td>
<td></td>
</tr>
<tr>
<td>VPS</td>
<td>0.00000000E + 00</td>
<td>0.00000000E + 00</td>
<td></td>
<td>0.20000000E + 00</td>
<td>0.20000000E + 00</td>
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<td><strong>Mean Percent Error</strong></td>
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<tr>
<td><strong>THIEL U Statistic (Reform)</strong></td>
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<tr>
<td><strong>Root Mean Error</strong></td>
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</tbody>
</table>
Table 5.19 Dynamic Multipliers of 12 Endogenous Variables Due to a $1 Billion Increase in ZMS$ starting in 1969.IV

<table>
<thead>
<tr>
<th>TIME</th>
<th>CON-ZMS.1</th>
<th>EIO-ZMS.1</th>
<th>GNP-ZMS.1</th>
<th>ULU-ZMS.1</th>
<th>WAGE-ZMS.1</th>
<th>PRICE-ZMS.1</th>
<th>RTB-ZMS.1</th>
<th>RCR-ZMS.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969 QRT3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1969 QRT4</td>
<td>3.01293</td>
<td>-0.03460</td>
<td>-0.30784</td>
<td>0.000151</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>1970 QRT1</td>
<td>-0.05614</td>
<td>-0.42877</td>
<td>-0.00023</td>
<td>0.00000</td>
<td>0.00012</td>
<td>0.37465</td>
<td>0.03331</td>
<td>0.032405</td>
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<tr>
<td>1970 QRT2</td>
<td>-0.05192</td>
<td>-0.03460</td>
<td>-0.19000</td>
<td>0.01030</td>
<td>-0.00001</td>
<td>-0.00116</td>
<td>-0.07282</td>
<td>-0.03410</td>
</tr>
<tr>
<td>1970 QRT3</td>
<td>0.10881</td>
<td>0.04538</td>
<td>0.69968</td>
<td>-0.00235</td>
<td>0.00001</td>
<td>0.0009</td>
<td>0.00837</td>
<td>-0.13078</td>
</tr>
<tr>
<td>1970 QRT4</td>
<td>0.36013</td>
<td>0.17045</td>
<td>1.10404</td>
<td>-0.04419</td>
<td>0.00009</td>
<td>0.00008</td>
<td>0.00320</td>
<td>-0.04053</td>
</tr>
<tr>
<td>1971 QRT1</td>
<td>0.48731</td>
<td>0.23417</td>
<td>1.43466</td>
<td>-0.00675</td>
<td>0.00004</td>
<td>0.01161</td>
<td>0.00007</td>
<td>0.15997</td>
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<tr>
<td>1971 QRT2</td>
<td>3.70578</td>
<td>0.20007</td>
<td>1.08422</td>
<td>-0.00003</td>
<td>0.00010</td>
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<td>-0.03646</td>
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<table>
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<th>YD-ZMS.1</th>
<th>EH-ZMS.1</th>
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<tbody>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>1969 QRT4</td>
<td>10.03643</td>
<td>10.03643</td>
<td>0.05519</td>
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<td>10.87780</td>
<td>-0.24152</td>
<td>-0.41430</td>
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<td>7.68012</td>
<td>7.68012</td>
<td>-0.12502</td>
<td>-0.07081</td>
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<td>1970 QRT3</td>
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<td>5.55927</td>
<td>1.01059</td>
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<td>7.03814</td>
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<td>6.99043</td>
<td>6.99043</td>
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Table 5.20  Dynamic Multipliers of 12 Endogenous Variables Due to a $1 Billion Increase in EGF Starting in 1969.IV

<table>
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<th>TIME</th>
<th>CON-EGF.I</th>
<th>LGP-EGF.I</th>
<th>GNP-EGF.I</th>
<th>UCL-EGF.I</th>
<th>WAGE-EGF.I</th>
<th>PRICE-EGF.I</th>
<th>RIB-EGF.I</th>
<th>WCB-1.F.1</th>
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<tbody>
<tr>
<td>1969 QRT3</td>
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<td>5.0</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>5.0</td>
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<tr>
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<td>3.12396</td>
<td>3.32356</td>
<td>1.36479</td>
<td>0.01319</td>
<td>0.00023</td>
<td>0.00023</td>
<td>0.03945</td>
<td>1.00121</td>
</tr>
<tr>
<td>1970 QRT1</td>
<td>2.37010</td>
<td>7.25961</td>
<td>1.02788</td>
<td>-0.00821</td>
<td>0.00016</td>
<td>0.01590</td>
<td>0.01841</td>
<td>2.0404</td>
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<tr>
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<td>2.02125</td>
<td>0.12135</td>
<td>2.08195</td>
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<td>0.08016</td>
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<td>5.01204</td>
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<td>2.45844</td>
<td>0.14712</td>
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<td>0.00031</td>
<td>0.07771</td>
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<tr>
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<td>2.02858</td>
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<tr>
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<td>0.49410</td>
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<td>0.00049</td>
<td>0.19816</td>
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<td>3.04312</td>
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<td>0.00011</td>
<td>0.34383</td>
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<table>
<thead>
<tr>
<th>TIME</th>
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<th>FY-EGF.I</th>
<th>EH-EGF.I</th>
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<td>1969 QRT3</td>
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Table 5.21 Dynamic Multipliers of 12 Endogenous Variables Due to a $1 Billion Decrease in TPF$ Starting in 1969.IV

<table>
<thead>
<tr>
<th>TIME</th>
<th>COM-TPF$</th>
<th>EPD-TPF$</th>
<th>GNP-TPF$</th>
<th>UV-TPF$</th>
<th>WAGE-TPF$</th>
<th>PRICE-TPF$</th>
<th>GSB-TPF$</th>
<th>AGB-TPF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969 QRT3</td>
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<td>0.0</td>
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<td>0.0</td>
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<td>0.0156</td>
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<td>1970 QRT2</td>
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<td>4.20285</td>
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<td>1971 QRT2</td>
<td>0.25795</td>
<td>4.98658</td>
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Table 5.22  Impact Multipliers of 12 Endogenous Variables for a $1 Billion Increase of Federal Government Expenditures (EGF) in 1969.IV

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<td>1971</td>
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<tr>
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<td>1971</td>
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240
Table 5.23  Changes in 12 Endogenous Variables Due to Restricting the Short-Term Rate, to One-Half of One Percent of the 1969.II Rate

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<th>TIME</th>
<th>CON-RTB.6</th>
<th>ED-RTB.6</th>
<th>GNP-RTB.6</th>
<th>ULU-RTB.6</th>
<th>WAGE-RTB.6</th>
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<td>1969 QRT3</td>
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<td>-0.14108</td>
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<td>-1.69531</td>
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<td>-0.0024</td>
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<td>1970 QRT2</td>
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<td>-9934</td>
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<td>1970 QRT3</td>
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<td>1970 QRT4</td>
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<th>MDS-RTB.6</th>
<th>YD-RTB.6</th>
<th>EM-RTB.6</th>
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<td>1970 QRT1</td>
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<td>11.18087</td>
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Figure 5.1  1969,III - 1971,II Actual and Simulated Values of Consumption (CON) and Expenditures on Producers Durables (EPD)
Figure 5.2 1969.III - 1971.II Actual and Simulated Values of GNP and the Unemployment Rate (ULU)
Figure 5.3  1969.III - 1971.II Actual and Simulated Values of the GNP Price Deflator (PGNP) and the Rate of Change of the Wage Rate \( \left( \frac{P_{t} - P_{t-1}}{P_{t-1}} \right) \)
Figure 5.4  1969.III - 1971.II Actual and Simulated Values of the Short-Term Interest Rate (RTB) and the Long-Term Interest Rate (RCB)
Figure 5.5 1969.11 - 1971.11 Actual and Simulated Values of the Money Supply (M1$) and Demand Deposits at Commercial Banks (MD$)
Figure 5.6  1969.III - 1971.II Actual and Simulated Values of Disposable Personal Income (YD) and Expenditures on Housing (EH)
Figure 5.7 1969.III-1971.II Actual and Simulated Values of the Inflation Rate $\left(\frac{PGNP_t - PGNP_{t-1}}{PGNP_{t-1}}\right) \times 400$ and the Expected Inflation Rate (EINFL)
Figure 5.8  1975.III - 1976.II Actual and Predicted Values of Consumption of Nondurables (CON) and Expenditures on Producers Durables (EPD)
Figure 5.9  1975.III - 1976.II Actual and Predicted Values of GNP and the Unemployment Rate (ULU)
Figure 5.10 1975.III - 1976.II Actual and Predicted Values of the GNP Price Deflator (PGNP) and the Rate of Change of the Wage Rate \( \left( \frac{PL_t - PL_{t-1}}{PL_{t-1}} \right) \)
Figure 5.11 1975,III - 1976,II Actual and Predicted Values of the Short Term Interest Rate (RTB) and the Long-Term Interest Rate (RCB)
Figure 5.12 1975.III - 1976.II Actual and Predicted Values of the Money Supply (ML$) and Demand Deposits at Commercial Banks (MD$)
Figure 5.13  1975. III - 1976. II Actual and Predicted Values of Disposable Personal Income (YD) and Housing Expenditures (EH)
Figure 5.14 1975.III - 1976.II Actual and Predicted Values of the Inflation Rate \(\left(\frac{PGNP_t - PGNP_{t-1}}{PGNP_{t-1}}\right) \times 400\) and Expected Inflation Rate (EINFL)
Figure 5.15 1969.III - 1971.II Actual Values of the Control Variable, Unborrowed Reserves plus Currency (ZMS$), and 10% Exponential Annual Growth Rate Values; Simulated and 10%-Above-Actual Values of the Income Tax Liability Control Variables (TPF$)
Figure 5.16  1969.111 - 1971.11 Actual and 10%-Above-Actual Values of Federal Government Expenditures (EGF), and the 25%-Above-Actual Value of EGF for 1969.IV
Figure 5.17  1969.III - 1971.II Simulated and ZMS$ - Multiplied Values of Consumption (CON) and Expenditures on Producers Durables (EPD)
Figure 5.18  1969.III - 1971.II Simulated and ZMS$ - Multiplied Values of GNP and the Unemployment Rate (ULU)
Figure 5.19 1969, III - 1971, II Simulated and ZMSS - Multiplied Values of the GNP Price Deflator (PGNP) and the Rate of Change of the Wage Price \( \{(P_L_t - P_{L_{t-1}})/P_{L_{t-1}}\} \)
Figure 5.20  1969. III - 1971. II Simulated and ZMS$ - Multiplied Values of the Short-Term Interest Rate (RTB) and the Long-Term Interest Rate (RCB)
Figure 5.21 1969.III - 1971.II Simulated and ZMS$ - Multiplied Values of the Money Supply (M1$) and Demand Deposits at Commercial Banks (MD$)
Figure 5.22  1969.III - 1971.II Simulated and ZMSS - Multiplied Values of Personal Disposable Income (YD) and Housing Expenditures (EH)
Figure 5.23 1969.III - 1971.II Simulated and EGF,1 - and TPF$ - Multiplied Values of Consumption (CON) and Expenditures on Producers Durables (EPD)
Figure 5.24  1969.11 - 1971.II Simulated and EGF.1 - and TPF$ - Multiplied Value of GNP and the Unemployment Rate (ULU)
Figure 5.25 1969.III - 1971.II Simulated and EGF.1 - and TPFS - Multiplied Values of the GNP Price Deflator (PGNP) and the Rate of Change of the Wage Rate \((PL_t - PL_{t-1})/PL_{t-1}\)
Figure 5.26 1969.III - 1971.II Simulated and EGF,1 - and TPF$ - Multiplied Values of the Short-Term Interest Rate (RTB) and the Long-Term Interest Rate (RCB)
Figure 5.27 1969.III - 1971.II Simulated and EGF.1 - and TPF$ - Multiplied Values of the Money Supply (M1$) and Demand Deposits at Commercial Banks (MD$)
Figure 5.28  1969.11 - 1971.11 Simulated and EGF.S - and TPFS - Multiplied Values of Personal Disposable Income (YD) and Housing Expenditures (EH)
Figure 5.29  1969.III - 1971.II Simulated and EGF.25 - and (RTB = 6) - Multiplied Values of Consumption (CON) and Expenditures on Producers Durables (EPD)
Figure 5.30  1969.III - 1971.II Simulated and EGF 25 - and (RTB = 6) - Multiplied Values of GNP and the Unemployment Rate (ULU)
Figure 5.31 1969.III - 1971.II Simulated and EGF.25 - and (RTB = 6) - Multiplied Values of the GNP Price Deflator (PGNP) and the Rate of Change of the Wage Rate $(PL_t - PL_{t-1})/PL_{t-1}$
Figure 5.32 1969.III - 1971.II Simulated and EGF, 25 - and (RTB = 6) - Multiplied Values of the Short-Term Interest Rate (RTB) and the Long-Term Interest Rate (RCB)
Figure 5.33 1969.III - 1971.II Simulated and EGF.25 - and (RTB = 6) - Multiplied Values of the Money Supply (M1$) and Demand Deposits at Commercial Banks (MD$)
Figure 5.34  1969.III - 1971.II Simulated and EGF.25 - and (RTB = 6) - Multiplied Values of Personal Disposable Income (YD) and Housing Expenditures (EH)
CHAPTER VI.  CONCLUSION

In this dissertation, a model consisting of 13 structural equations and 17 identities, nonlinear in the variables, was first specified according to currently acceptable macroeconomic theory. A technique was developed which first applies Fuller's newly-developed modified limited information maximum likelihood estimator, uses second degree polynomials and principal components of the exogenous data set as instrumental variables and corrects for first order autocorrelation to obtain consistent estimates of the structural equations. In addition, Fuller's two F statistics were used for the first time on a large macro-model to test empirically for the specification and identification of each structural equation. Finally, efficiency of estimation was increased by obtaining three-stage least squares estimates.

The estimated structural equations, together with the identities were then simulated over the recession period of 1969.III-1971.II using a Gauss-Seidel program that solves nonlinear systems.

To achieve acceptable simulation results, the original model was reestimated and a third model, RJM3 was estimated and simulated.

Over the period 1969.III-1971.II, the Model RJM3 tracks reasonably well in unconditional simulation compared to larger well-known macroeconomic models, such as the 1975 MPS Model, for trend-dominated variables such as real gross national product (GNP), consumption of nondurables (CON), and the price deflator (PGNP). However, RJM3 tracks less well the more volatile variables such as the short-term interest rate (RTM), the rate of change of the wage rate (PL), the unemployment...
rate (ULU), and free reserves (MFR$), as well as the important policy variable M1$, the money supply. Moreover, there are indications that RJM3 is explosively unstable in the long run.

An ex-post prediction was made for 1975.III-1976.II. The results were similar to those of the 1969.III-1971.II simulation in that RJM3 predicts reasonably well only trend-dominated variables such as GNP and PGNP. Partly because of the initial values MFR$ is badly predicted, a fact which contributes to RJM3's generally poor prediction performance for the financial sector variables. Again, there are strong indications that RJM3 is explosively unstable as the time of simulation lengthens.

Finally, five multiplier analyses were made using unborrowed reserves at member banks plus currency (FMS$), federal government expenditures on goods and services (EGF), federal personal income income tax liability (TPF$), and RTB as control variables. RJM3 exhibits a definite slughishness in responding to the monetary policies, viz., ZMS$ and RTB, in both length of lag in effect and magnitude of effect, but it does respond correctly with respect to direction of response. Only in the third quarter did RJM3 respond positively to the growing ZMS$, due partly to the fact that, despite the intention of growth in the control variable, controlled ZMS$ was less than its historical value for the first quarter. However, RJM3 did respond more quickly and with greater response to the restricted RTB experiment.

With regard to the three fiscal policies, using EGF and TPF$, the key variables of RJM3 responded from the first quarter and with greater multipliers than those reported for several well-known and larger
macroeconomic models. In all five experiments, however, the long run explosive instability of RJM3 was obvious and especially so when the control variable was EGF, federal government expenditures.

In conclusion, the consistent technique developed and applied in this dissertation produces estimates of the parameters of a model that should increase its simulation and prediction capabilities. The model RJM3 did not perform as well as expected considering the time and money invested in it and considering its purpose as a policy model. In particular, the financial-real sector linkage is weaker than expected and the inability of RJM3 to predict well RTB, MFR$, and M1$, as well as its strong long run explosive tendencies in predicting GNP and PGNP, make it suspect as a tool for policy-making. Possible reasons for the poor performance are poor specification of structural equations and perhaps the high level of aggregation, sensitivity of the MLIML estimator to long distributed lags and nonlinearities, undiscovered errors in data processing, programming, Fortran language coding, or the setting of initial values in the Gauss-Seidel program.

RJM does respond qualitatively as neo-Keynesian macroeconomic theory leads one to expect. One reason for this is that the model was built using neo-Keynesian theory as the theoretical guideline. But to the extent the model successfully tracks and predicts ex-post, it also helps to confirm the theory upon which it is built.

The estimation technique applied to RJM3 can be practically applied to much larger nonlinear models, including the 1975 MPS Model. If so applied, theoretically at least, it would enhance their value both as forecasting and as policy models.
BIBLIOGRAPHY


APPENDIX A

Alphabetical Listing of All Variables
CON = Consumption (non-durables)

D1 = \{1, 1969.i, i.e., TIME = 59\}, a strike dummy
     {0, otherwise}

D2 = \{1, TIME > 1969.II, i.e., TIME \geq 60\}, a strike dummy
     {0, otherwise}

ECD = Expenditures on Consumer Durables

(EEX - EIM) = (Exports - Imports)

EGF = Federal Government Expenditures on Goods and Services

EGFL = (Compensation of Federal Government Employees)

EGS = (State - Local Government Expenditures)

EGSL = Compensation of State - Local Employees

EH = Expenditures on Residential Construction

EIF = Farm Inventory Investment

EINFL = Expected Inflation

EPCE = Personal Consumption Expenditures

EPD = Expenditures on Producers Durables

EPDS = Expected Expenditures on Plant and Equipment

EPS = Expenditures on Producers Structures

ESTOP = \{TIME, if TIME \leq 43\}
        \{53, if TIME > 43\}

GFG$ = Federal Subsidies less Surpluses of Government Enterprises

GYT$ = Other Items of YP$

HSI = Housing Starts

JMSA = Seasonal Adjustment Factor for MD$

JMSB = Blow-Up Factor to Convert MD$ to MI$

KCD = Stock of Consumer Durables
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<th>Symbol</th>
<th>Description</th>
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<td>KH</td>
<td>Stock of Housing</td>
</tr>
<tr>
<td>KI</td>
<td>Stock of Inventory</td>
</tr>
<tr>
<td>KPS</td>
<td>Stock of Producers Structures</td>
</tr>
<tr>
<td>LA</td>
<td>Total Employment including Armed Forces</td>
</tr>
<tr>
<td>LE</td>
<td>Total Civilian Employment</td>
</tr>
<tr>
<td>LEF</td>
<td>Federal Government Employment</td>
</tr>
<tr>
<td>LEO</td>
<td>Employment, Difference Between Household and Payroll Surveys</td>
</tr>
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<td>LES</td>
<td>State - Local Government Employment</td>
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<td>LF</td>
<td>Civilian Labor Force</td>
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<tr>
<td>LH</td>
<td>Total Hours per Man</td>
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<td>LMHT</td>
<td>Man-Hours in Non-Farm Business</td>
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<td>Demand for Commercial Loans</td>
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<td>Currency Outside Banks</td>
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<td>Net Demand Deposits Subject to Reserves at All Member Banks</td>
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<td>MD$</td>
<td>Demand Deposits Adjusted at All Commercial Banks</td>
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<td>MFR$</td>
<td>Free Reserves at All Member Banks</td>
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<td>MGF$</td>
<td>U.S. Government Deposits at All Commercial Banks</td>
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<td>Ml$</td>
<td>Money Supply</td>
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<td>MRU$</td>
<td>Unborrowed Reserves at All Member Banks</td>
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<td>Total Time Deposits at Member Banks</td>
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<td>Population, 16 and Over</td>
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<td>PGNP</td>
<td>The GNP Deflator (1972-Base)</td>
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<td>PL</td>
<td>Compensation Rate for Non-Farm Business</td>
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\begin{itemize}
\item \texttt{RCB} = The Corporate Bond Rate
\item \texttt{RDP} = Dividend-Price Ratio
\item \texttt{RTB} = Treasury Bill Rate (90 Day)
\item \texttt{SLPD} = Service Life of Producers Durables for Tax Purposes
\item \texttt{SLPS} = Service Life of Producers Structures for Tax Purposes
\item \texttt{TCPD} = Rate of Tax Credit on Producers Durables
\item \texttt{TEGF\$} = Federal Estate and Gift Taxes
\item \texttt{TIBF\$} = Federal Indirect Business Taxes
\item \texttt{TIBS\$} = State and Local Indirect Business Taxes
\item \texttt{TIME} = Time (1 = 1954.II)
\item \texttt{TO\$} = OASI Contributions
\item \texttt{TPF\$} = .01 \times \texttt{UTPF} \times \texttt{YTF\$} = Indirect Income Tax Liability, where \texttt{UTPF} = Income Tax Rate
\item \texttt{TPS\$} = State - Local Personal Income Tax and Non-Tax Payments
\item \texttt{TSC\$} = State - Local Contribution to Social Insurance
\item \texttt{TSS\$} = Current Surplus of State - Local Enterprises
\item \texttt{ULU} = Unemployment Rate of Total
\item \texttt{UTC} = Marginal Rate of Corporate Income Tax.
\item \texttt{UTPF} = Effective Rate of Personal Income Tax
\item \texttt{VCN\$} = Net Worth of Households, \$ Trillions, Beginning of Quarter
\item \texttt{VG\$} = Residual in Net Worth Identity
\item \texttt{VPD} = Equilibrium Ratio of Producers Durables to Output
\item \texttt{VPS} = Equilibrium Ratio of Producers Structures to Output
\item \texttt{WAPD} = Proportion of New Equipment Depreciated using Accelerated Depreciation Methods
\end{itemize}
WAPS = Proportion of New Structures Depreciated Using Accelerated Depreciation Method = 0.534

WCAA$ = Capital Consumption Allowance

XB = Gross Private Domestic Business Product

XBC = Production Capacity of Private Business = \((387.0)e^{(\frac{t-1947.1}{4})}\)

XGNP = Gross National Product

YBT$ = Business Transfer Payments

YD = Disposable Personal Income

YDVS$ = Corporate Dividends

YH = Household Product

YPC$ = Corporate Profits and Inventory Valuation Adjustment

YP$ = Personal Income (Nominal)

YRCS$ = Interest Paid by Consumers

YRW = Income Originating in Rest of World

ZCT = Ceiling Rate on Passbook Savings Deposits

ZHS = Value of Subsidized Housing Starts

ZDRA = Federal Reserve Discount Rate

ZLING = Dummy Variable for Long Amendment on Depreciation Basis

\begin{align*}
0, & \text{ TIME < 1964.1} \\
1, & \text{ TIME > 1964.1}
\end{align*}

ZMS$ = Unborrowed Reserves at Member Banks plus Currency Outside Banks

ZRD = Reserve Requirements Against Net Demand Deposits at all Member Banks

ZRT = Reserve Requirements Against Time Deposits at all Member Banks
APPENDIX B

The Computer Program Written in SAS Language and Used to Estimate the 13 Structural Equations of the Model RJM3 According to the A3SMLML Method
DATA One;

INFILE DISK1:FIRSTBS5=221;

INPUT X117 X167 X317 X467 X477 X617 X627 X616;

PROC;

X111 X261 X411 X456 X458 X561 X606 X617 X711;

X831 X866;

X412;

X462;

X552;

X553;

X503 X553 X203 X53;

X712 X562 X412 X262 X112;

X676 X516 X376 X226 X76;

X614 X469;

X713 X563 X413 X263 X113;

X620;

X470;

X480 X530 X380 X230 X80;

X618 X581 X814 X777;

X269 X552 X815 X778;

X603 X453 X303 X153 X3;

X740 X590 X440 X200 X140;

X781 X561 X441 X291 X141;

X705 X706;

X707;

X701;

X643 X476;

X555;

X611 X644 X655 X732;

X604;

X607 X577;

X47;

X547;

X388;

X326;

X470;

X326;

X629 X470;

X329;

X656;

X507;

X667 X659 X516 X504;

X502 X352 X202 X52;

X502 X412.
INFILE DISK INN ISS
DSNAME=PSO
UNIT=SYST, VOL=SCF=PUBPK1. DISP=OLD,
DCB=(RECFM=U, LRECF=4000, LRECF=4000, RECFM=F, ORG=PS)

DATA A1:
INPUT (KPSI VPO) ($3 7.3 $45 5.3);
CARDS;
NOTE: DATA SET WORK.A1 HAS 89 OBSERVATIONS AND 2 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.29 SECONDS AND 52K.

DATA A2:
INPUT (XBC) ($3 7.3); CARDS;
NOTE: DATA SET WORK.A2 HAS 89 OBSERVATIONS AND 1 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.27 SECONDS AND 92K.

DATA A3:
INPUT (NAP0) ($3 7.3); CARDS;

NOTE: INFILE DISKIN HAS 90 LINES.
NOTE: DATA SET WORK.A1 HAS 89 OBSERVATIONS AND 147 VARIABLES.
NOTE: THE DATA STATEMENT USED 3.09 SECONDS AND 116K.
NOTE: DATA SET WORK.A2 HAS 89 OBSERVATIONS AND 1 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.29 SECONDS AND 92K.

413 DATA A4;
414 INPUT (SLPD) (S 4:1);
415 CARDS;

NOTE: DATA SET WORK.A4 HAS 89 OBSERVATIONS AND 1 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.29 SECONDS AND 92K.

505 DATA A5;
506 INPUT (SLPD) (S 6:3)
507 CARDS;

NOTE: DATA SET WORK.A5 HAS 89 OBSERVATIONS AND 1 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.27 SECONDS AND 92K.

597 DATA NEW;
598 MERGE IN1 A1 A2 A3 A4 A5;
599 IF _ > 15 THEN DELETE;

NOTE: DATA SET WORK.NEW HAS 85 OBSERVATIONS AND 165 VARIABLES.
NOTE: THE DATA STATEMENT USED 1.23 SECONDS AND 158K.

600 DATA GOOD;
601 SET NEW1
602 RETAIN VPD1 5.986 VPD2 5.537 VPD3 5.369 VPD4 5.321
603 X700L 5.285.543
604 X850 030.92
605 P0 5.957 P6 5.65 P7 5.4 P8 5.64 P9 5.69 P10 5.61
606 OUTPUT
607 VPC4 = VPD3;
608 VPD2 = VPD1;
609 VPD0 = VPD1;
610 VPD1 = VPD1;
611 X700L = X7001
612 X850 = X8C 1;
613 P0 = P01;
614 P9 = P01;
615 P8 = P01;
616 P7 = P01;
617 P6 = P01;
618 P5 = P01;

NOTE: DATA SET WORK.GOOD HAS 85 OBSERVATIONS AND 165 VARIABLES.
NOTE: THE DATA STATEMENT USED 1.13 SECONDS AND 108K.

619 DATA A6;
620 SET GOOD1
621 X682 = X582/10001
622 X682 = X6821
623 X687 = X687/10001
624 X687 = X577/10001
625 X687 = X587/10001
626 X687 = X677/10001
627 X687 = X777/10001
```
736  SET A6;
737  ODCP K17 X317 X287 X327 X377 X27 XDP X111 X261 X411
738  Z176 Z226 Z76 Z6 Z7 Z6 Z9 Z10
739  X456 X561 X231 X665 X552 X363 X203 X553 X452 X862 X112 X376 X226 X76
740  X463 X713 X563 X263 X113 X360 X230 X60 X888 X851 X141
741  X777 X809 X552 X615 X778 X603 X463 X303
742  X151 X3 X700 X500 X440 X290 X140 X741 X501 X441 X201 X141 X863 X226
743  X555 X601 X605 X327 X857 X536 X306 X326 X476 X671 X521 X371
744  X221 X71 X262 X26 X479 X329 X906 X666 X699 X801 X202 X929
745  X479 X326 X479 X326 X479 X326 X479 X326 X479 X326 X479 X326
746  X221 X71 X262 X26 X479 X329 X906 X666 X699 X801 X202 X929
747  X807 X552 X602 X452 X807 X602 X452 X807 X602 X452 X807 X602
748  SLPS VP01 VP02 VP03 VP04 VP05 PS P6 P8 P9 P10 X887 X409 X259 X109
749  D2 Z411 Z261 Z111 T145 Z469 XV1 XV2 XV3 XV4 EPCI XAD1 XAD2 XAD3 T221
750  T59 T670 T602 T557 T52 L807 L857 L860 L902 L902 L902 T676

NOTE: DATA SET WORK.ABOV HAS 85 OBSERVATIONS AND 88 VARIABLES.
NOTE: THE DATA STATEMENT USED 1.78 SECONDS AND 124K.
752  PROC PRINT;

NOTE: THE PROCEDURE PRINT USED 9.30 SECONDS AND 150K AND PRINTED PAGES 1 TO 11.
753  DATA EX;
754  SET ABOV1;

NOTE: DATA SET WORK.EX HAS 85 OBSERVATIONS AND 88 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.72 SECONDS AND 100K.
755  PROC MATRIX;
756  FETCH M DATA=EX;
757  M3 = M2 M+1 M+1;
758  M4 = M1 M2 M+1 M+1;
759  M1 = M40+5111;
760  M2 = M3 M1;
761  FREE M M1 P+41;
762  OUTPUT M2 OUT = A7;

NOTE: DATA SET WORK.A7 HAS 84 OBSERVATIONS AND 89 VARIABLES.
763  DATA PUN;
764  SFT A7;

NOTE: DATA SET WORK.PUN HAS 84 OBSERVATIONS AND 89 VARIABLES.
NOTE: THE DATA STATEMENT USED 0.99 SECONDS AND 100K.
765  PROC PRINT;

766  PROC SYTREG ALPHA =1 OUT = DSN 10=1000001
767  M1 BLOCK
768  COL4
769  COL2
```
STATISTICAL ANALYSIS SYSTEM

770  COL3
771  =
772  COL5
773  COL6-Col62  CCL64-Col6A
774  /LINL1
775  MII MODEL
776  COL4
777  =
778  COL2
779  COL3
780  COL5
781  COL60
782  I
783  OUTPUT PREDICTED
784  PHI1
785  RESIDUALS
786  #1
787  I
788  K1  MODEL  COL2  *  COL3  /NORUN1
789  K1  MODEL  COL2  *  COL3  /NORUN1
790  K1  MODEL  COL2  *  COL3  /NORUN1
791  K1  MODEL  COL2  *  COL3  /NORUN1
792  K1  MODEL  COL2  *  COL3  /NORUN1
793  K1  MODEL  COL2  *  COL3  /NORUN1
794  K1  MODEL  COL2  *  COL3  /NORUN1
795  K1  MODEL  COL2  *  COL3  /NORUN1
796  K1  MODEL  COL2  *  COL3  /NORUN1
797  K1  MODEL  COL2  *  COL3  /NORUN1
798  K1  MODEL  COL2  *  COL3  /NORUN1
799  K1  MODEL  COL2  *  COL3  /NORUN1
800  K1  MODEL  COL2  *  COL3  /NORUN1
801  K1  MODEL  COL2  *  COL3  /NORUN1
802  K1  MODEL  COL2  *  COL3  /NORUN1
803  K1  MODEL  COL2  *  COL3  /NORUN1
804  K1  MODEL  COL2  *  COL3  /NORUN1
805  K1  MODEL  COL2  *  COL3  /NORUN1
806  K1  MODEL  COL2  *  COL3  /NORUN1
807  K1  MODEL  COL2  *  COL3  /NORUN1
808  K1  MODEL  COL2  *  COL3  /NORUN1
809  K1  MODEL  COL2  *  COL3  /NORUN1
810  K1  MODEL  COL2  *  COL3  /NORUN1
811  K1  MODEL  COL2  *  COL3  /NORUN1
812  K1  MODEL  COL2  *  COL3  /NORUN1
813  K1  MODEL  COL2  *  COL3  /NORUN1
814  K1  MODEL  COL2  *  COL3  /NORUN1
815  K1  MODEL  COL2  *  COL3  /NORUN1
816  K1  MODEL  COL2  *  COL3  /NORUN1
817  K1  MODEL  COL2  *  COL3  /NORUN1
818  K1  MODEL  COL2  *  COL3  /NORUN1
819  K1  MODEL  COL2  *  COL3  /NORUN1
820  K1  MODEL  COL2  *  COL3  /NORUN1
821  K1  MODEL  COL2  *  COL3  /NORUN1
822  K1  MODEL  COL2  *  COL3  /NORUN1
823  K1  MODEL  COL2  *  COL3  /NORUN1
824  #21BLOCK
825  COL7
"STATISTICAL ANALYSIS SYSTEM

COL 39
COL 9
COL 6
COL 5
COL 60-COL 62 COL 64-COL 68
/SML 1
/H3: MODEL
COL 7
= COL 39
COL 9
COL 6
COL 11
1 OUTPUT PREDICTED=
PAE 2
RESIDUALS=
RS 2
1 H:LOCK
COL 9
COL 4
COL 11
COL 10
COL 64
1 OUTPUT PREDICTED=
PAE 3
RESIDUALS=
RS 3
1 H:LOCK
COL 34
= COL 35
COL 10
COL 60-COL 62 COL 64-COL 68
/SML 1
/H3: MODEL
COL 34
= COL 35
COL 10
1 OUTPUT PREDICTED=
PAE 4
RESIDUALS=

300"
M7
1
#1: BLOCK
COL12
COL23
COL25
=
COL60-COL62 COL64-COL66
/L1NL1
M8: MODEL
COL22
COL23
COL25
COL74
1
OUTPUT PREDICTED=
PREV
RESIDUALS=
PSB
1
#9: BLOCK
COL46 COL13
COL27
COL47
=
COL50-COL62 COL64-COL66
/L1NL1
M9: MODEL
COL46 COL13 COL27 COL48 COL49 COL50
1
OUTPUT PREDICTED=
PREV
RESIDUALS=
PSB
1
#10: BLOCK
COL48 COL49 COL50
=
COL51
COL60-COL62 COL64-COL66
/L1NL1
M10: MODEL
COL48
COL49 COL51 COL77
1
OUTPUT PREDICTED=
NOTE: DATA SET WORK.DSN HAS 84 OBSERVATIONS AND 115 VARIABLES.*
NOTE: THE PROCEDURE SYSREG USED 24.10 SECONDS AND 216K AND PRINTED PAGES 29 TO 45.

DATA FIVE;
SET DSN;
FILE PRINT;
PUT (RS1-RS13 PRE1-PRE13# (12*5):);
NOTE: FILE PRINT HAS 252 LINES.*
NOTE: DATA SET WORK.FIVE HAS 84 OBSERVATIONS AND 115 VARIABLES.*
NOTE: THE DATA STATEMENT USED 1.41 SECONDS AND 108K AND PRINTED PAGES 46 TO 50.

DATA SIX:
SET FIVE;
FILE PRINT;
NOTE: DATA SET WORK.SIX HAS 84 OBSERVATIONS AND 115 VARIABLES.*
NOTE: THE DATA STATEMENT USED 0.71 SECONDS AND 108K.

PROC SYSREG 10*10000;
RA: MODEL
COL34 = COL35
COL10
COL60-COL62 COL64-COL85
S1: MODEL
COL34 = COL35
COL10
COL60-COL62 COL64-COL85
IOTE: DATA SET W39A.SEVEN HAS 84 OBSERVATIONS AND 115 VARIABLES.

NOTE: THE DATA STATEMENT USED 0.69 SECONDS AND 103 KB.

DATA SET 'W39A.SEVEN' HAS 84 OBSERVATIONS AND 115 VARIABLES.

NOTE: PROC SYSTAT REG 10=10000 ALPHA = 1;

NOTE: DATA SET W39A.SEVEN HAS 84 OBSERVATIONS AND 115 VARIABLES.

NOTE: THE DATA STATEMENT USED 0.69 SECONDS AND 103 KB.

DATA SET W39A.SEVEN HAS 84 OBSERVATIONS AND 115 VARIABLES.
NOTE: THE PROCEDURE SYSREG USED 8.75 SECONDS AND 150K AND PRINTED PAGES 65 TO 69.
NOTE: SAS USED 40K MEMORY.
NOTE: BARR, GOODNIGHT, SALL AND HELMIG
SAS INSTITUTE INC.
P.O. BOX 10066
RALEIGH, NC 27608
RJMS
PROCESSED MODEL STATEMENTS

L1: MODEL COL29 = COL64
L2: MODEL COL25 = COL64
L3: MODEL COL29 = COL64
L4: MODEL COL23 = COL64
### Model 1

<table>
<thead>
<tr>
<th>ANALYSIS OF CF</th>
<th>SSE</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>0.01088505</td>
<td>0.0001571526</td>
</tr>
</tbody>
</table>

**NOTE:** LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES K = 2.46071

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>B VALUE</th>
<th>STD DEVIATION</th>
<th>&quot;t&quot; FOR HO: B=0</th>
<th>&quot;PROB &gt;</th>
<th>&quot;LABEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>1</td>
<td>0.0046446888</td>
<td>0.0012509153</td>
<td>0.37170</td>
<td>0.7111</td>
<td></td>
</tr>
<tr>
<td>M1 + COL5</td>
<td>1</td>
<td>0.208055303</td>
<td>0.0051850500</td>
<td>0.01221</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>M1 + COL7</td>
<td>1</td>
<td>0.007556794</td>
<td>0.0047593811</td>
<td>0.015095</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

### Model 2

<table>
<thead>
<tr>
<th>ANALYSIS OF CF</th>
<th>SSE</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>2163.138</td>
<td>27.38149</td>
</tr>
</tbody>
</table>

**NOTE:** LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES K = 1.86067

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>B VALUE</th>
<th>STD DEVIATION</th>
<th>&quot;t&quot; FOR HO: B=0</th>
<th>&quot;PROB &gt;</th>
<th>&quot;LABEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>1</td>
<td>14.006131105</td>
<td>0.03102346</td>
<td>0.61050</td>
<td>0.1113</td>
<td></td>
</tr>
<tr>
<td>M2 + COL39</td>
<td>1</td>
<td>0.47190903</td>
<td>0.14170616</td>
<td>0.33019</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>M2 + COL7</td>
<td>1</td>
<td>-1.106643513</td>
<td>0.29912609</td>
<td>-3.70277</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>COL6</td>
<td>1</td>
<td>0.070694403</td>
<td>0.23797109</td>
<td>0.32094</td>
<td>0.07461</td>
<td></td>
</tr>
<tr>
<td>COL6</td>
<td>1</td>
<td>0.63812256</td>
<td>0.23913226</td>
<td>2.72710</td>
<td>0.0076</td>
<td></td>
</tr>
</tbody>
</table>

### Model 3

<table>
<thead>
<tr>
<th>ANALYSIS OF CF</th>
<th>SSE</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>144.2149</td>
<td>1.825583</td>
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</tbody>
</table>

**NOTE:** LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES K = 1.74266

<table>
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<tr>
<th>SOURCE</th>
<th>DF</th>
<th>B VALUE</th>
<th>STD DEVIATION</th>
<th>&quot;t&quot; FOR HO: B=0</th>
<th>&quot;PROB &gt;</th>
<th>&quot;LABEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>1</td>
<td>23.30917935</td>
<td>4.32863285</td>
<td>4.01731</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>M3 + COL4</td>
<td>1</td>
<td>17.928529629</td>
<td>2.476066417</td>
<td>7.28517</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>M3 + COL7</td>
<td>1</td>
<td>-1.106643513</td>
<td>0.29912609</td>
<td>-3.70277</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>COL10</td>
<td>1</td>
<td>0.60822756</td>
<td>0.05702816</td>
<td>12.56589</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>COL6</td>
<td>1</td>
<td>0.41940579</td>
<td>0.24522013</td>
<td>5.78826</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>
### Model: N4

**Dep Variable=COL34**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2</td>
<td>246366.205296</td>
<td>123183.102649</td>
<td>1423.663442</td>
<td>0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>0.853334</td>
<td>0.0121646</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected TOT</td>
<td>83</td>
<td>4175208526</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Limited information Maximum Likelihood Estimates, K = 1.0000

| Source                     | DF | B Value       | Std Deviation | T for H0: B=0 | Prob > |T| | Label |
|----------------------------|----|---------------|---------------|---------------|---------|---------|
| Intercept                  | 1  | 0.23297636    | 0.22641260    | 1.02699       | 0.3067  | 0.0001  |       |
| COL35                      | 1  | 0.96436532    | 0.01144394    | 9.053334      | 0.0001  | 0.0001  |       |
| COL10                      | 1  | 0.2778486     | 0.2276486     | 123035020     | 0.0001  | 0.0001  |       |

### Model: N5

**Dep Variable=COL16**

| Source                     | DF | SS of Squares | Mean Square | F Ratio | Prob > |F| |
|----------------------------|----|---------------|-------------|---------|---------|---|
| Regression                 | 2  | 963.512776    | 481.756359  | 460.834 | 0.0001  |   |
| Error                      | 81 | 0.0034638     | 0.00097220  |         |         |   |
| Corrected TOT             | 83 | 1048.337018   | 1.2630574   |         |         |   |

**Note:** Limited information Maximum Likelihood Estimates, K = 2.76017

| Source                     | DF | B Value       | Std Deviation | T for H0: B=0 | Prob > |T| | Label |
|----------------------------|----|---------------|---------------|---------------|---------|---------|
| Intercept                  | 1  | 0.17016707    | 0.054031131  | 0.25982       | 0.7957  | 0.0002  |       |
| COL37                      | 1  | 0.06647792    | 0.001661446  | 3.909999      | 0.0001  | 0.0001  |       |
| COL19                      | 1  | 0.41032121    | 0.14231317   | 2.67076       | 0.0001  | 0.0001  |       |

### Model: N6

**Dep Variable=COL17**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>2</td>
<td>963.512776</td>
<td>481.756359</td>
<td>460.834</td>
<td>0.0001</td>
</tr>
<tr>
<td>Error</td>
<td>81</td>
<td>0.0034638</td>
<td>0.00097220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected TOT</td>
<td>83</td>
<td>1048.337018</td>
<td>1.2630574</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Limited information Maximum Likelihood Estimates, K = 1.0000

| Source                     | DF | B Value       | Std Deviation | T for H0: B=0 | Prob > |T| | Label |
|----------------------------|----|---------------|---------------|---------------|---------|---------|
| Intercept                  | 1  | -0.33067326   | 0.64080303   | -0.51603      | 0.6072  | 0.0001  |       |
| COL35                      | 1  | 0.48306195    | 0.1004687    | 4.61608       | 0.0001  | 0.0001  |       |
| COL65                      | 1  | 0.32563777    | 0.06220802   | 4.69991       | 0.0001  | 0.0001  |       |
### Model 47

**Analysis of Variance**

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**Note:** Limited information maximum likelihood estimates. K = 1.90632

**Coefficients**

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### Model 49

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**Note:** Limited information maximum likelihood estimates. K = 2.36782

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### Model 46

**Analysis of Variance**

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**Source of Error**

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**Note:** Limited information maximum likelihood estimates. K = 1.71330

**Coefficients**

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### Model 1: N10
#### Analysis of Variance (ANOVA)

| Source                  | DF | SS  | MSE | Value | Std. Deviation | t* for H0:β=0 | p(>|t*|) | Label |
|-------------------------|----|-----|-----|--------|----------------|----------------|---------|-------|
| Intercept               | 1  | 0.0026534*4 | 0.0000319325 | 1.67062 | 0.00343724 | -2.81969 | 0.0051 |       |
| X1, X2, X3, X4, X5     | 1  | 1.20209352 | 0.25368730 | 0.75804 | 0.002804 | -4.22894 | 0.0001 |       |
| X6                      | 1  | 0.35174423 | 0.71265900 | 0.40357 | 0.00343724 | 4.02894 | 0.0044 |       |

### Model 2: N11
#### Analysis of Variance (ANOVA)

| Source                  | DF | SS  | MSE | Value | Std. Deviation | t* for H0:β=0 | p(>|t*|) | Label |
|-------------------------|----|-----|-----|--------|----------------|----------------|---------|-------|
| Intercept               | 1  | 0.48690350 | 0.11758060 | 4.14352 | 0.0001 |       |       |       |
| X1, X2, X3, X4, X5     | 1  | 0.91756784 | 0.25679120 | 3.57321 | 0.0001 |       |       |       |
| X6                      | 1  | 0.55566108 | 0.05854945 | 9.45630 | 0.0001 |       |       |       |
| X7                      | 1  | 1.01622775 | 0.09296756 | 10.42664 | 0.0001 |       |       |       |

### Model 3: N12
#### Analysis of Variance (ANOVA)

| Source                  | DF | SS  | MSE | Value | Std. Deviation | t* for H0:β=0 | p(>|t*|) | Label |
|-------------------------|----|-----|-----|--------|----------------|----------------|---------|-------|
| Intercept               | 1  | 0.66658327 | 0.16931444 | 4.14352 | 0.0001 |       |       |       |
| X1, X2, X3, X4, X5     | 1  | 0.11122105 | 0.03906366 | 2.81969 | 0.0001 |       |       |       |
| X6                      | 1  | 0.23297758 | 0.06270869 | 3.70991 | 0.0004 |       |       |       |
| X7                      | 1  | 0.59979954 | 0.09276681 | 6.492791 | 0.0001 |       |       |       |
MODEL: .13

| SOURCE | DF | B VALUE | STD DEVIATION | 't' FOR HO10=0 | 'PR(>|t|)' | LABEL |
|--------|----|---------|---------------|----------------|------------|-------|
| INTERCEPT | 1 | -0.00210459 | 0.00014454 | -0.142354 | 0.8714 | 
| M13xCOL29 | 1 | 0.00239791 | 0.00073361 | 0.26774 | 0.7906 | 
| COLRA | 1 | 0.22218855 | 0.18685072 | 1.20740 | 0.2308 | 

ANALYSIS OF ERROR

OF ERROR: 0.00004755141

NOTE: LINEAR: INFORMATION MAXIMUM LIKELIHOOD ESTIMATES: K = 1.67378

PROB > |t|
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**Note:** The table represents correlation values between different models. Each row and column corresponds to a specific model, and the values indicate the correlation strength between them.
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**WEIGHTED MEAN SQUARE ROOT FOR SYSTEM** 1.085092 WITH 1040 CFS
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**WEIGHTED MEAN SQUARE ERROR FOR SYSTEM:** 1.064892 WITH 10000005
### Third Stage

#### Model 1

| Source        | DF | B Value | Std Deviation | 't' for H0:B=0 | 'Pr>|t'| | Label |
|---------------|----|---------|---------------|----------------|--------|-------|
| Intercept     | 1  | 0.0071890 | 0.00924866 | 0.80858 | 0.4212 |
| M1 + COL2     | 1  | 0.2354644 | 0.0359463 | 7.0286 | 0.0010 |
| M2 + COL3     | 1  | 0.6014025 | 2.9988433 | 2.0405 | 0.0200 |
| COL4          | 1  | 0.7551326 | 0.0607745 | 12.4251 | 0.0010 |
| COL6          | 1  | 0.4442645 | 0.3709976 | 1.1721 | 0.2447 |

#### Model 2

| Source        | DF | B Value | Std Deviation | 't' for H0:B=0 | 'Pr>|t'| | Label |
|---------------|----|---------|---------------|----------------|--------|-------|
| Intercept     | 1  | 7.0290835 | 3.8607501 | 1.9358 | 0.0501 |
| M2 + COL3     | 1  | 0.2493797 | 0.0531732 | 4.5206 | 0.0001 |
| M2 + COL6     | 1  | -0.5348238 | 1.3401443 | -0.0546 | 0.0001 |
| COL5          | 1  | 0.3348326 | 0.1420922 | 2.3517 | 0.0212 |
| COL6          | 1  | 2.0805328 | 0.7020479 | 3.1977 | 0.0020 |

#### Model 3

| Source        | DF | B Value | Std Deviation | 't' for H0:B=0 | 'Pr>|t'| | Label |
|---------------|----|---------|---------------|----------------|--------|-------|
| Intercept     | 1  | 21.5025245 | 3.9223495 | 5.8266 | 0.0001 |
| M2 + COL4     | 1  | 1.0907641 | 1.1972703 | 0.3918 | 0.0001 |
| M2 + COL5     | 1  | 1.1211117 | 0.2302466 | -5.2609 | 0.0001 |
| COL3          | 1  | 0.7223469 | 0.086611 | 15.9610 | 0.0001 |
| COL6          | 1  | 1.2270760 | 0.1946732 | 6.7912 | 0.0001 |

#### Model 4

| Source        | DF | B Value | Std Deviation | 't' for H0:B=0 | 'Pr>|t'| | Label |
|---------------|----|---------|---------------|----------------|--------|-------|
| Intercept     | 1  | 0.2403266 | 0.2159223 | 1.1140 | 0.2606 |
| COL3          | 1  | 0.9841002 | 0.0307457 | 13.3383 | 0.0001 |
| COL10         | 1  | 0.2271421 | 0.0103400 | 21.9472 | 0.0001 |

#### Model 5

| Source        | DF | B Value | Std Deviation | 't' for H0:B=0 | 'Pr>|t'| | Label |
|---------------|----|---------|---------------|----------------|--------|-------|
| Intercept     | 1  |         |               |                |        |       |
| COL3          | 1  |         |               |                |        |       |
| COL10         | 1  |         |               |                |        |       |
### Third Stage

#### Model 1: Intercept

| Source | DF | B Value | Std Deviation | t Value for Ho: β = 0 | P(R|β > |t|) | Label |
|--------|----|---------|---------------|-----------------------|----------|-------|
| Intercept | 1 | 0.74222550 | 0.56219617 | 1.25442 | 0.2129 |       |
| COL19  | 1 | 0.75575866 | 0.53056377 | 0.69096 | 0.2428 |       |

#### Dep Variable: COL17

| Source | DF | B Value | Std Deviation | t Value for Ho: β = 0 | P(R|β > |t|) | Label |
|--------|----|---------|---------------|-----------------------|----------|-------|
| Intercept | 1 | -0.31954585 | 0.20102864 | -1.55284 | 0.1337 |       |
| COL38  | 1 | 0.48321174 | 0.09235731 | 5.23194 | 0.0001 |       |
| COL60  | 1 | 0.32570527 | 0.09234409 | 5.10141 | 0.0001 |       |

#### Model 1: COL41

| Source | DF | B Value | Std Deviation | t Value for Ho: β = 0 | P(R|β > |t|) | Label |
|--------|----|---------|---------------|-----------------------|----------|-------|
| Intercept | 1 | 1.52802764 | 0.82413712 | 1.78897 | 0.0775 |       |
| COL43  | 1 | -1.73265210 | 0.17109666 | -10.07650 | 0.0001 |       |
| COL44  | 1 | 0.97369094 | 0.09232758 | 10.51527 | 0.0001 |       |
| COL42  | 1 | 0.94615657 | 0.10963710 | 8.62080 | 0.0001 |       |
| COL71  | 1 | -0.36656359 | 0.93540535 | -0.35659 | 0.7271 |       |

#### Model 1: COL22

| Source | DF | B Value | Std Deviation | t Value for Ho: β = 0 | P(R|β > |t|) | Label |
|--------|----|---------|---------------|-----------------------|----------|-------|
| Intercept | 1 | -0.6556984 | 0.13563327 | -10.234 | 0.0001 |       |
| COL22  | 1 | -0.66520222 | 0.09880594 | -7.00222 | 0.0001 |       |
| COL23  | 1 | -0.55430751 | 0.09783227 | -6.02214 | 0.0001 |       |
| COL74  | 1 | 0.99385100 | 0.01485453 | 65.04444 | 0.0001 |       |

#### Model 1: COL46

<p>| Source | DF | B Value | Std Deviation | t Value for Ho: β = 0 | P(R|β &gt; |t|) | Label |
|--------|----|---------|---------------|-----------------------|----------|-------|
| Intercept | 1 | 1.82793112 | 0.73000340 | 2.50277 | 0.0144 |       |
| COL13  | 1 | 1.00565511 | 0.15925211 | 6.31498 | 0.0001 |       |</p>
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**RJMS**

**MODEL: #4**

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**NOTE:** THE MODEL IS NOT FULL RANK. B VALUES WILL NOT BE UNIQUE AND SOME STATISTICS MAY BE MISLEADING.

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|--------|----|---------|---------------|-------------|-----|---|---------|
| INTERCEPT | 1 | 13.41940188 | 31.63290247 | 19.08778 | 0.0001 |
| COL.15 | 1 | 0.90090057 | 0.05085510 | - | - | - | - |
| COL.10 | 1 | 0.78529907 | 0.07295287 | - | - | - | - |
| COL.50 | 1 | 1.50534243 | 27.85510800 | - | - | - | - |
| COL.61 | 1 | -0.90574887 | 10.49307655 | - | - | - | - |
| COL.62 | 1 | 0.04430095 | 0.71792142 | - | - | - | - |
| COL.64 | 1 | 0.11126907 | 0.13141050 | - | - | - | - |
| COL.66 | 1 | -0.00187299 | 0.08085814 | -0.2108 | 0.0038 |
| COL.67 | 1 | -0.02945999 | 0.12366988 | -0.2198 | 0.0168 |
| COL.68 | 1 | 0.10090493 | 0.11100091 | 0.90905 | 0.3074 |
| COL.69 | 1 | 0.27212941 | 0.14068475 | 1.9370 | 0.0172 |
| COL.70 | 1 | 0.01255045 | 0.05904960 | 0.2100 | 0.8365 |
| COL.71 | 1 | 0.02524730 | 0.03908717 | 0.5206 | 0.8640 |
| COL.72 | 1 | -0.31323975 | 0.01652064 | -1.9817 | 0.0532 |
| COL.73 | 1 | -0.08285571 | 0.04270405 | -1.9406 | 0.0576 |
| COL.74 | 1 | -15.4904204 | 44.65865426 | -3.4155 | 0.0681 |
| COL.75 | 1 | 0.05330263 | 0.13340459 | -0.4155 | 0.6801 |
| COL.76 | 1 | 0.30226273 | 0.26409285 | 1.1434 | 0.2577 |
| COL.77 | 1 | 15.5292064 | 112.26313416 | - | - | - | - |
| COL.78 | 1 | -0.19214494 | 0.17171000 | -1.1167 | 0.2692 |
| COL.79 | 1 | 1.70944465 | 1.30325282 | 1.3035 | 0.1991 |
| COL.80 | 1 | 0.14088771 | 0.35484299 | 0.3612 | 0.7179 |
| COL.81 | 1 | -0.49545250 | 0.40023684 | -1.2384 | 0.2209 |
| COL.82 | 1 | 0.09792315 | 0.03681382 | 2.7113 | 0.0431 |
| COL.83 | 1 | 0.00053492 | 0.04365015 | 0.3723 | 0.7112 |
| COL.84 | 1 | 70.60041335 | 90.27820241 | - | - | - | - |
| COL.85 | 1 | -0.04543506 | 0.06867672 | -0.6610 | 0.5110 |
| COL.86 | 1 | 0.26369007 | 0.19140562 | 1.2962 | 0.0643 |
| COL.87 | 1 | 0.02113469 | 0.11920629 | 0.1770 | 0.8620 |
| COL.88 | 1 | 0.01395035 | 0.01197864 | 1.2043 | 0.2335 |</p>
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## Model 56

**Dep Variable: COL17**

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| COL38             | 1  | 0.48396155 | 0.10088870    | 4.81608             | 0.0001  |   |        |
| COL60             | 1  | 0.35653776 | 0.06528862    | 4.60991             | 0.0001  |   |        |</p>
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**Source:** 50% deviation from HO10D0

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| COL.60         | 1  | -0.45952793     | 0.6682932    | 0.59761     | 0.5976|
| COL.61         | 1  | -0.27002278     | 0.16441641   | 1.33032     | 0.1975|
| COL.62         | 1  | -0.07731200     | 0.0608978    | 1.27256     | 0.2081|
| COL.64         | 1  | 0.00059472      | 0.0217859    | 0.27298     | 0.7956|
| COL.65         | 1  | -0.00399001     | 0.0028517    | 0.17661     | 0.6620|
| COL.67         | 1  | 0.00165585      | 0.0013650    | 0.12109     | 0.9051|
| COL.68         | 1  | 0.00152632      | 0.0001493    | 0.95005     |       |
| COL.70         | 1  | -0.00038404     | 0.00104366   | -1.92145    | 0.0680|
| COL.71         | 1  | 0.00046056      | 0.00092499   | -0.04978    | 0.9409|
| COL.72         | 1  | 0.00033119      | 0.00027148   | 0.12509     | 0.9005|
| COL.73         | 1  | -0.00076491     | 0.00072497   | -1.05509    | 0.2961|
| COL.74         | 1  | -1.00071537     | 0.72084486   | -2.20228    | 0.0315|
| COL.75         | 1  | -0.00080111     | 0.00220054   | -0.24977    | 0.6270|
| COL.76         | 1  | 0.00034172      | 0.00433760   | 0.77007     | 0.4446|
| COL.77         | 1  | -0.07462053     | 0.0613722    | -1.38422    | 0.1724|
| COL.78         | 1  | -0.00433369     | 0.0043033    | -1.07016    | 0.2871|
| COL.79         | 1  | -0.01137768     | 0.02149502   | -1.57900    | 0.1507|
| COL.80         | 1  | 0.00022992      | 0.00440656   | 0.25670     | 0.7227|
| COL.81         | 1  | 0.00234882      | 0.00775823   | 0.03191     | 0.9474|
| COL.82         | 1  | -0.00099423     | 0.0001981    | 1.60410     | 0.1145|
| COL.83         | 1  | 0.00640445      | 0.00401442   | 1.41699     | 0.2564|
| COL.84         | 1  | -0.68556277     | 0.6492087    | -0.53231    | 0.5685|
| COL.85         | 1  | 0.00352180      | 0.00122034   | 0.26910     | 0.5895|
| COL.86         | 1  | 0.00355810      | 0.00266592   | 1.35466     | 0.1876|
| COL.87         | 1  | 0.00047550      | 0.00019248   | 2.21017     | 0.0317|
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\[ R^2 = 0.3527 \]

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**Model II**

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R SQUARED = 0.0712

| SOURCE         | DF | B VALUE      | STD DEVIATION | T FOR H0: B=0 | PROB > |T| |
|---------------|----|--------------|---------------|---------------|---------|---|
| INTERCEPT     | 1  | 0.123456     | 0.001234      | 2.3456        | 0.0202  |
| COL.00        | 1  | 123.456789   | 0.123456789   | 2.3456        | 0.0142  |
### Model 1: S1

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**Note:** Limited information maximum likelihood estimates. K = 5.93376

| Source | DF | B Value | Std Deviation | T for H0: B=0 | P(>|T|) Label |
|--------|----|---------|---------------|---------------|---------------|
| Intercept | 1 | -0.10612763 | 0.03140585 | -3.36947 | 0.0012 |
| COL3 | 1 | 0.00359285 | 0.01115085 | 0.3425 | 0.7376 |
| COL5 | 1 | 1.12508251 | 0.37510943 | 3.62631 | 0.0001 |
| COL60 | 1 | -0.13562467 | 0.25666124 | -0.56997 | 0.56997 |

### Model 2: S2

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**Note:** Limited information maximum likelihood estimates. K = 2.04396

| Source | DF | B Value | Std Deviation | T for H0: B=0 | P(>|T|) Label |
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| Intercept | 1 | -9.30457986 | 0.00121149 | -3.24093 | 0.0017 |
| COL3 | 1 | 32.47579598 | 5.40657951 | 6.00133 | 0.0001 |
| COL5 | 1 | 0.01614417 | 0.47957370 | 0.0372 | 0.9705 |
| COL61 | 1 | -17.36939349 | 1.36223568 | -10.92268 | 0.0001 |

### Model 3: S3

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**Note:** Limited information maximum likelihood estimates. K = 4.50519

| Source | DF | B Value | Std Deviation | T for H0: B=0 | P(>|T|) Label |
|--------|----|---------|---------------|---------------|---------------|
| Intercept | 1 | -3.10569528 | 2.85263013 | -1.05881 | 0.2795 |
| COL11 | 1 | 0.51184082 | 0.30974058 | 1.65244 | 0.1024 |
| COL10 | 1 | -0.00852265 | 0.01897956 | -0.47181 | 0.6393 |
| COL64 | 1 | 0.00840019 | 0.11042941 | 0.80052 | 0.4258 |
**Model: 57**

**DEPENDENT VARIABLE: COL43**

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NOTE: LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES, K= 2, 11063

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**Model: 58**

**DEPENDENT VARIABLE: COL23**

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NOTE: LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES, K= 7, 00344

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**Model: 59**

**DEPENDENT VARIABLE: COL13**

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NOTE: LIMITED INFORMATION MAXIMUM LIKELIHOOD ESTIMATES, K= 9, 00436

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**NOTE:** Limited information. Maximum Linear Coefficient Estimates, $k = 3.40836$.

**SOURCE:**

| SOURCE      | DF | B VALUE | STD DEVIATION | T' FOR HO: $b = 0$ | 'P probation $| T' | LABEL |
|-------------|----|---------|---------------|---------------------|-----------------|-------|
| INTERCEPT   | 1  | -1.21255596 | 0.24505609 | -1.75563 | 0.0820 |
| X1 (COL 11) | 1  | -1.69700114 | 0.00001737 | -1.73946 | 0.0009 |
| COL 36      | 1  | -0.3923979707 | 0.00004035 | 2.04685 | 0.0475 |
APPENDIX C

WARNING MESSAGE, EXECUTION CONTINUES
EXECUTION OF THIS STEP SUCCESSFULLY COMPLETED
ERROR MESSAGE CAUSING TERMINATION OF PROGRAM

SUBROUTINE GSSL(J9,NNUM,IERA,K)
C GENERALIZED G-S MODEL PROGRAM
C HOFFMAN - 6/27/74
C REVISED KINVOM 6/26/76
C REVISED FOR ECONPK OV AAV MICROSKI AT ISU-OCT. 1976

REAL VA1(100), TITLE10, VAS1(100), VAS2(100), VAS3(100)
INTEGER IFLD(100), IPLEX1(100)
DIMENSION ZI(1), RMS(70)
DIMENSION VV0(70), ZI(1), RMS(70)
INTEGER PREV
DATA VV/*ESTV*/, ZI/*-*/
COMMON V0(70), V1(70), V2(70), Y3(70), Y4(70), Y5(70), Y6(70), Y7(70),
X0(70), X1(70), X2(70), X3(70), X4(70), X5(70), X6(70), X7(70),
COMMON Y10(70), Y11(70), Y12(70), Y13(70), Y14(70), Y15(70), Y16(70), Y17(70),
COMMON Y18(70), Y19(70), Y20(70), Y21(70), Y22(70), Y23(70), Y24(70), Y25(70),
COMMON Y26(70), Y27(70), Y28(70), Y29(70), Y30(70), Y31(70), Y32(70), Y33(70),
COMMON Y34(70), Y35(70), Y36(70), Y37(70), Y38(70), Y39(70), Y40(70), Y41(70),
COMMON Y42(70), Y43(70), Y44(70), Y45(70), Y46(70), Y47(70), Y48(70), Y49(70),
COMMON Y50(70), Y51(70), Y52(70), Y53(70), Y54(70), Y55(70), Y56(70), Y57(70),
COMMON Y58(70), Y59(70), Y60(70), Y61(70), Y62(70), Y63(70), Y64(70), Y65(70),
COMMON Y66(70), Y67(70), Y68(70), Y69(70), Y70(70), Y71(70), Y72(70), Y73(70),
COMMON Y74(70), Y75(70), Y76(70), Y77(70), Y78(70), Y79(70), Y80(70), Y81(70),
COMMON Y82(70), Y83(70), Y84(70), Y85(70), Y86(70), Y87(70), Y88(70), Y89(70),
COMMON Y90(70), Y91(70), Y92(70), Y93(70), Y94(70), Y95(70), Y96(70), Y97(70),
COMMON Y98(70), Y99(70), Y100(70)
COMMON YOUT1(70)
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COMMON YOUT94(70)
COMMON YOUT95(70)
COMMON YOUT96(70)
COMMON YOUT97(70)
COMMON YOUT98(70)
COMMON YOUT99(70)
COMMON YOUT100(70)
COMMON ITK, IX, ISN
COMMON I, T, PREV
DEFINE FILE 21(I00, 400, U, IDK1)
DEFINE FILE 22(I00, 400, U, IDK2)
DEFINE FILE 23(I00, 400, U, IDK3)
DEFINE FILE 24(I00, 400, U, IDK4)
DEFINE FILE 25(I00, 400, U, IDK5)
DEFINE FILE 26(I00, 400, U, IDK6)
DEFINE FILE 27(I00, 400, U, IDK7)
DEFINE FILE 28(I00, 400, U, IDK8)
DEFINE FILE 29(I00, 400, U, IDK9)
DEFINE FILE 30(I00, 400, U, IDK10)
DEFINE FILE 31(I00, 12, U, IDK1)
DEFINE FILE 32(I00, 12, U, IDK1)

COMMON ITK, IX, ISN
COMMON I, T, PREV
DEFINE FILE 21(I00, 400, U, IDK1)
DEFINE FILE 22(I00, 400, U, IDK2)
DEFINE FILE 23(I00, 400, U, IDK3)
DEFINE FILE 24(I00, 400, U, IDK4)
DEFINE FILE 25(I00, 400, U, IDK5)
DEFINE FILE 26(I00, 400, U, IDK6)
DEFINE FILE 27(I00, 400, U, IDK7)
DEFINE FILE 28(I00, 400, U, IDK8)
DEFINE FILE 29(I00, 400, U, IDK9)
DEFINE FILE 30(I00, 400, U, IDK10)
DEFINE FILE 31(I00, 12, U, IDK1)
DEFINE FILE 32(I00, 12, U, IDK1)

READ MASTER CONTROL CARD WHERE

N = NUMBER OF ENDOGENOUS VARIABLES, MAX=70
N1 = NUMBER OF EXOGENOUS VARIABLES, MAX=100
IT = MAX. TIME PERIODS FOR SIMULATION, MAX=400
KLAC = NUMBER OF ENDOGENOUS LAGS, MAX=100
KLAG = NUMBER OF EXOGENOUS LAGS, MAX=100
LRM = NUMBER OF MULTIPLIER ANALYSES TO BE COMPUTED
NRM = OPTIONS 0, 1 OR 2 WHERE
0 = COMPUTE ESTIMATES OF ENDOGENOUS VARIABLES ONLY, NO DIAGNOSTIC TABLES
1 = COMPUTE AND PRINT DIAGNOSTIC TABLES, ENTER ACTUAL DATA
2 = COMPUTE IMPACT MULTIPLIERS, NO DIAGNOSTIC TABLES
IDAT = FIRST YEAR TO BE COMPUTED, E(G T. 1) 1950
IFIL = FILE NUMBER OF THE FIRST OF N FILES IN WHICH THE ESTIMATES OF THE ENDOGENOUS VARIABLES ARE STORED
TITLE = ALPHANUMERIC DESCRIPTION
PREV = # OF OBS. IN FILE TO BE SKIPPED BEFORE OBS. TO BE READ IN
READ(5, 2001) N, N1, IT, KLAC, KLAG, LRNC, NRM, IDAT, IFIL, PREV,

C READ FILE CARDS FOR ENDOG. VOLS.
C TITLE = TITLE
C READ FILE CARDS(S) FOR ENDOG. VOLS.
IF (IT .GT. 400) GO TO 5000
IF (N .LT. 100) GO TO 5001
IF (N1 .LT. 100) GO TO 5002
IF (LRNC .NE. 1) GO TO 39
30 READ (5, 2004) IFIL(J), J=1, N
C READ FILE CARDS(S) FOR EXOG. VOLS.
35 READ (5, 2004) (IFIL(J), J=1, N)

C Initializes work areas to zero
DO 50 I=1, N
VS(I) = 0.0
V(I) = 0.0
V4(I) = 0.0
Y(I) = 0.0
Y5(I) = 0.0
Y6(I) = 0.0
YT(I) = 0.0
Y6(I) = 0.0

C Initializes work areas to zero
DO 50 I=1, N
VS(I) = 0.0
V(I) = 0.0
V4(I) = 0.0
Y(I) = 0.0
Y5(I) = 0.0
Y6(I) = 0.0
YT(I) = 0.0
Y6(I) = 0.0
89  V0(I) = 0.0
90  VlO(I) = 0.0
91  RUN(I) = 0.0
92  SMEl(I) = 0.0
93  TPFI(I) = 0.0
94  TPFl(I) = 0.0
95  TV(I) = 0.0
96  TPUI(I) = 0.0
97  V2(I) = 0.0
98  VA(I) = 0.0
99  V2(I) = 0.0
100  VB(I) = 0.0
101  VOpF(I) = 0.0
102  VOpF2(I) = 0.0
103  VOpF3(I) = 0.0
104  VALP(I) = 0.0
105  VAPC(I) = 0.0
106  DOG(I) = 0.0
107  RS(I) = 0.0
108  5O VO(I) = 0.0
109  DO 50 I = 23, 38
110  DO 50 J = 1, 16
111  WRITE(I + J, YA)
112  55 CONTINUE
113  DO 60 K = 1, N1
114  XI(K) = 0.0
115  XE(K) = 0.0
116  X2(K) = 0.0
117  X4(K) = 0.0
118  X6(K) = 0.0
119  X8(K) = 0.0
120  X10(K) = 0.0
121  X12(K) = 0.0
122  60 X0(K) = 0.0
123  C ENDOGENOUS VALUES. EXOGENOUS VALUES AND STARTING VALUES ARE
124  C READ BY THE INPUT PROGRAM DATIN
125  C READ STARTING SET OF ENDOGENOUS VARIABLES
126  CALL DATIN(VO, N1, J9, NUMM, ERR, IK, VA, VB, VBl, IPLEN, IFLEX, KCR)
127  WRITE (6, 71)
128  71 FORMAT ('**END0G. STARTING VALUES **')
129  DO 70 J = 1, N1
130  70 WRITE (6, 72) (VO(I), I = 1, N1)
131  C READ EXOGENOUS DATA SET ONLY 1 TIME PERIOD REQUIRED IF NANO = 2
132  IF (NANO = 2) GO TO 140, 140
133  80 KCR = 1
134  CALL DATIN(XO, N1, J9, NUMM, ERR, IK, VA, VB, VBl, IPLEN, IFLEX, KCR)
135  DO 130 KCR = 1, 16
136  IF (KCR = 1) GO TO 110
137  DO 120 J = 1, N1
138  100 NANO(I) = X0(I)
139  110 J = J + 1
140  120 WRITE (80, 130) (X0(I), I = 1, N1)
141  130 CONTINUE
142  GO TO 191
143  140 DO 190 KCR = 1, 16
144  CALL DATIN(XO, N1, J9, NUMM, ERR, IK, VA, VB, VBl, IPLEN, IFLEX, KCR)
146 IF(KCR=1) 150,150,170
147 150 DO 160 I=1,NI
148 160 KNDT(I)=X(I)
149 170 J=J+1
150 WRITE(22,J) (X(I),I=1,NI)
151 190 CONTINUE
152 191 CONTINUE
153 210 WRITE(6,3002) TITLE
154 220 WRITE(6,3002) IF(NHND=1) 220,220,230
155 220 KEND2=IT
156 230 GO TO 240
157 240 CALL HEAD(29,NI,KEND2,VAL1,VAL2,IDAT)
158 IF(KLAG) 260,260,250
159 C READ STARTING X LAGS WHERE
160 WRITE (6,249)
161 249 FORMAT(*!,*,"STARTING ENDOGENOUS LAGS")
162 DO 255 J=1,KLAG
163 READ(8,2005) ILX, INX, VVX
164 WRITE(6,2005) ILX, INX, VVX
165 WRITE(320,J) ILX, INX, VVX
166 255 CONTINUE
167 IF (KLAG) 280,280,270
168 C READ STARTING X LAGS WHERE
169 WRITE (6,269)
170 269 FORMAT(*!,*,"STARTING EXOGENOUS LAGS")
171 DO 275 J=1,KLAGX
172 READ(8,2008) ILX, INX, VVX
173 WRITE(6,2005) ILX, INX, VVX
174 275 CONTINUE
175 280 CONTINUE
176 IF (NHND=1) 341,340,341
177 340 CALL DATINYA;NI,3,J9,NNUM,IER1,IK,VA,VAL1,VB,Val2,IPLEN,FLFXT,KCR)
178 IF(KCR=1) 300,300,320
179 IF(KCR=0) 300,300,320
180 DO 310 J=1,N
181 310 YMD(J)=VAL1(J)
182 320 J=J+1
183 WRITE(24,J) (VAL1(I),I=1,N)
184 340 CONTINUE
185 341 CONTINUE
186 IF(NHND=1) 370,370,390
187 370 IC=JC+1
188 380 IC=JC+1
189 390 IS=0
190 LAND=1
191 C READ MULTIPLIER ANALYSIS CONTROL CARD WHERE
192 NCHEXOGENOUS VARIABLE NUMBER USED IN MULTIPLIER ANALYSIS
193 VAL1=FIRST-ROUND VALUE OF SELECTED ENDOGENOUS VARIABLE
194 VAL2=SECOND-ROUND VALUE OF SELECTED ENDOGENOUS VARIABLE
195 READIR(2006) NCHE, VAL1, VAL2
192  370 DD 380 J=1,NI
193  360 XO (1)=XRNDC(J)
194  GO 390 J=1,NI
195  YO (1)=YRNDA(J)
196  390 YA (1)=YRNDA(J)
197  400 CONTINUE
198  410 J=0
199  IF(KLAG) 470,470,420  C
200  420 GO 460 J=1,KLAG
201  READ(32,J) ILL,INC,YVC
202  GO TO (43,435,436,437,438,439,440) ILL
203  431 Y1(INC)=YVC
204  C GO TO 460
205  432 Y2(INC)=YVC
206  GO TO 460
207  433 Y3(INC)=YVC
208  GO TO 460
209  434 Y4(INC)=YVC
210  GO TO 460
211  43S Y5(INC)=YVC
212  GO TO 460
213  436 Y6(INC)=YVC
214  GO TO 460
215  437 Y7(INC)=YVC
216  GO TO 460
217  438 Y8(INC)=YVC
218  GO TO 460
219  439 Y9(INC)=YVC
220  GO TO 460
221  440 Y0(INC)=YVC
222  460 CONTINUE
223  470 IF(KLAG) 530,530,540  C
224  540 DD 520 J=1,KLAG
225  READ(31,J) ILX,INK,YVX
226  GO TO (48,482,483,484,485,486,487,488,489,490) ILX
227  481 X1(INK)=YVX
228  GO TO 520
229  482 X2(INK)=YVX
230  GO TO 520
231  483 X3(INK)=YVX
232  GO TO 520
233  484 X4(INK)=YVX
234  GO TO 520
235  485 X5(INK)=YVX
236  GO TO 520
237  486 X6(INK)=YVX
238  GO TO 520
239  487 X7(INK)=YVX
240  GO TO 520
241  488 X8(INK)=YVX
242  GO TO 520
243  489 X9(INK)=YVX
244  GO TO 520
245  490 X0(INK)=YVX
246  520 CONTINUE
247  530 J=0
248  IF(NRND-1) 570,570,540
249  540 IF(NRND-1,0) 560,560,590
550 K(INCHG)=VAL2
260 GO TO 570
250 K(INCHG)=VAL1
240 NT=0
230 CONTINUE
220 NT=NT+1
210 DO 610 I=1,N
200 V44(I)=YO(I)
190 CONTINUE
180 DO 600 I=1,N
170 630 Y44(I)=YO(I)
160 CALL CEN(I)
150 PRINT(2,500)*I=I+1
140 CALL SUBROUTINE CEN TO COMPUTE ALL ENDOGENOUS VALUES
130 FOR THE TIME PERIOD
120 660 PRINT(2,500)*I=I+1
110 IF(INTH=1) WRITE(6,646) 644,648,1320
100 650 IF(INTH=500) WRITE(6,655),1330
90 655 WRITE(6,654) YO(I), I=1,N
80 665 CONTINUE
70 670 IF(V44(I)<Y44(I)) GO TO 680
60 680 IF(V44(I)>Y44(I)) GO TO 690
50 690 CONTINUE
40 700 CONTINUE
30 710 CONTINUE
20 720 CONTINUE
10 730 CONTINUE
00 740 CONTINUE
-90 750 CONTINUE
-80 760 CONTINUE
-70 770 CONTINUE
-60 780 CONTINUE
-50 790 CONTINUE
-40 800 CONTINUE
-30 810 CONTINUE
-20 820 CONTINUE
-10 830 CONTINUE
00 840 CONTINUE
10 850 VDIF(l)=Y0(I)
20 860 VAPC(l)=VAPC(I)+((Y44(I)-YO(I))/YA(I))*100.0
30 870 VDIF3(l)=VDIF(l)**2
40 880 SM(l)=SM(l)+((Y44(I)-YO(I))/YA(I))*100.0**2
50 890 SUM(l)=SUM(l)+Y44(I)
60 900 CONTINUE
70 910 VDIP(l)=VAPC(l)*Y44(I)
80 920 VDIF3(l)=VDIF3(l)+((Y44(I)-YO(I))/YA(I))*100.0**2
90 930 IF(Y44(I)<Y0(I)) SM(l)=SM(l)+1
100 940 IF(Y44(I)>Y0(I)) SM(l)=SM(l)+0
110 950 IF(Y44(I)=Y0(I)) SM(l)=SM(l)+0
120 960 IF(Y44(I)<Y0(I)) SM(l)=SM(l)+1
130 970 IF(Y44(I)>Y0(I)) SM(l)=SM(l)+0
140 980 IF(Y44(I)=Y0(I)) SM(l)=SM(l)+0
TPU(1) = TPU(1)+YA(1)*#2
304 DSG(1) = DSG(1)+(YA(1)-Y0(1))*#2
305 NW = PREV
306 IF (((NW > 20) .OR. (NW .GT. 50)) GO TO 8800
307 Y00C(1) = 0.0
308 Y0IF(1) = 0.0
309 Y0IF(1) = 0.0
310 YS(1) = 0.0
311 DSG(1) = 0.0
312 TUG(1) = 0.0
313 8800 CONTINUE
314 IF (HT <= 90) 820,820,910
315 Y00 = ((Y00(1)-Y00(1))/Y00(1)) = 100.0 - (((Y00(1)-Y00(1))/Y00(1)) = 100.0)
316 TP(1) = TP(1)+((Y00(1)-YS(1))-(Y00(1)-YS(1))*#2
317 TUG(1) = TUG(1)+((Y00(1)-YS(1)) = #2
318 IF ((T = EQ. 901 .AND. (HT .LE. 561)) TUG(1) = 0.0
319 920 CONTINUE
320 830 CONTINUE
321 IF (HT) 860,840,860
322 840 IF (HT) 870,870,920
323 WRITE(27*) JI0(1),J10(1),J10(1)
324 WRITE(23*) JI0(1),J10(1),J10(1)
325 WRITE(26*) JI0(1),J10(1),J10(1)
326 820 CONTINUE
327 900 CONTINUE
328 860 IF (HT) 910
329 C UPDATE LAGGED VALUES FOR THE NEXT TIME PERIOD
330 880 DO 890 I=1,N
331 Y00(1) = Y00(1)
332 Y00(1) = Y00(1)
333 V00(1) = V00(1)
334 V00(1) = V00(1)
335 Y00(1) = V00(1)
336 V00(1) = V00(1)
337 Y00(1) = Y00(1)
338 V00(1) = V00(1)
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341 V00(1) = V00(1)
342 V00(1) = V00(1)
343 V00(1) = V00(1)
344 890 CONTINUE
345 DO 900 I=1,N
346 X10(1) = X10(1)
347 X00(1) = X00(1)
348 X00(1) = X00(1)
349 X00(1) = X00(1)
350 X00(1) = X00(1)
351 X00(1) = X00(1)
352 X00(1) = X00(1)
353 X00(1) = X00(1)
354 X00(1) = X00(1)
355 X00(1) = X00(1)
356 900 CONTINUE
357 IF (HT = 90) 960,960,910
358 910 IF (HT = 90) 1070,1070,980
359 920 NR = HT
360 READ(24*) NR, YA(1),J=1,N
361  READ(26*MR) (X0(I),I=1,N)
362  IF(I88) 980,950,960
363  950 IF(NT-1) 960,960,1010
364  960 WRITE(6,3003) TITLE
365  IF(NRNO-1) 970,970,1030
366  970 GO TO 990
367  980 IF(NT-1) 990,990,1010
368  990 IF(NRNO-1) 1000,1000,1030
369  1000 WRITE(6,3005)
370  1010 IF(NRNO-1) 1020,1020,1030
371  1020 WRITE(6,3002) ITY,INT
372  1030 IF(NRNO-1) 1040,1040,1060
373  1040 IF(NRNO-1) 1050,1050,1070
374  1050 XR(NCHG)=VAL1
375  1060 GO TO 990
376  1070 IF(NRNO-1) 1080,1080,1090
377  1080 IF(NRNO-1) 1090,1090,1100
378  1090 CONTINUE
379  1100 ITY=1
380  1110 WRITE(6,3008)
381  1120 IDAT=
382  1130 CALL HEADR(27, N,KEND,VA,V0,IDAT)
383  1140 WRITE(IDAT)
384  1150 GO TO 1130
385  1160 CONTINUE
386  1170 WRITE(IDAT)
387  1180 CONTINUE
388  1190 CONTINUE
389  1200 WRITE(6,3009)
390  1210 CALL HEADR(27, N,KEND,VA,V0,IDAT)
391  1220 WRITE(IDAT)
392  1230 GO TO 1130
393  1240 CONTINUE
394  1250 CONTINUE
395  1260 CONTINUE
396  1270 WRITE(IDAT)
397  1280 CALL HEADR(26, N,KEND,VA,0,10A)
398  1290 CONTINUE
399  1300 IF(SW) 1310,1220,1190
400  1310 LN0=LN0+1
401  1320 GO TO 370
402  1330 CALL HEADR(26, N,KEND,VA,10A)
403  1340 IDAT=
404  1350 DO 1210 J=1,N
405  1360 READ(26*J) (PACC(I),I=1,N)
406  1370 READ(29J) (YOU(I),I=1,N)
407  1380 DO 1205 I=1,N
408  1390 PAC(I)=PAC(I)-YOU(I)
410  1400 CONTINUE
411  1410 WRITE(25*J) (PAC(I),I=1,N)
412  1420 CONTINUE
413  1430 WRITE(6,3011)
414  1440 IDAT=
415  1450 WRITE(6,3010) (NCHG,VAL1,NCHG,VAL8)
416  1460 CALL HEADR(26, N,KEND,VA,10A)
417  1470 IF(NRNO-1) 1280,1280,1200
418  1480 CONTINUE
419  1490 IF(NRNO-1) 1340,1320,1340
420  1500 CONTINUE
C CALCULATE SYSTEM NONPARAMETRIC MEASURES
421 DD 1270 I=1,N
422 IF (TU(I)) I=1240,1850,1240
423 1240 TU(I)=SORT(TP(I))/TU(I))
424 GO TO 1240
425 1250 TU(I)=0.0
426 1260 YAPC(I)=YAPC(I)/IT
427 YDIF1(I)=YDIF1(I)/IT
428 YDIF3(I)=SORT(YDIF3(I)/IT)
429 ZE = (((TP(I))/IT) - ((SUM(I)/IT)+8))/(((TP(I))/IT)-
430 (SUM(I)/IT))
431 IF (ZS < 0.0) GO TO 1270
432 YB(I) = 999999.
433 GO TO 9970
434 9270 CONTINUE
435 9280 CONTINUE
436 IF (I.EQ. 20) AND (N < 60) V(i) = 0.0
437 DS0 = DS0/I/IT
438 RMS(I) = SORT(DS0)
439 DS0(I)=SORT(DS0)/SORT(TP(I))
440 1270 CONTINUE
441 WRITE(6,3013)
442 WRITE(6,3016)
443 WRITE(6,3018)(VA(I),YAPC(I),YDIF2(I),YDIF3(I),V(I),TU(I),
444 9 DS0(I), RMS(I)), I=1,N
445 1280 CONTINUE
446 IF(IFIL.O) 7720,7720,7000
447 7000 CONTINUE
448 DO 7719 K=1,N
449 DO 7714 K=1,IT
450 READ (87*) (YV0(I),I=1,N)
451 7714 CONTINUE
452 WRITE(IOP*IFIL) I,IT,YV,ZE,(YV(I),I=1,IT)
453 7715 IFIL=IFIL+1
454 7720 CONTINUE
455 7720 CONTINUE
456 GO TO 1340
457 1290 IF(NT-1) 1300,1330,1300
458 1300 KEND= NT-1
459 GO TO 1320
460 1320 WRITE(6,3007)
461 CALL HEADR(20, N,KEND,VA, VB, IDAT)
462 WRITE(6,3016)
463 KEND=16
464 IDAT=IDAT+NT-1
465 WRITE(6,3017) IDAT
466 IDAT=1
467 CALL HEADR(30, N,KEND,VA, VB, IDAT)
468 1340 CONTINUE
C C READ END-OF-JOB CARD
469 READ(18,207) ITEST
470 IF( (IEST=9999) OR (IEST=9999) ) GO TO 1350
471 1350 WRITE(6,3016)
472 2001 FORMAT(I2,J2,J12,J14,J14,J9A4,J9X)
473 2004 FORMAT(2012)
474 2005 FORMAT(5X.12.13,F10.4)
475 2006 FORMAT(12.2F10.8)
SUBROUTINE Datin(X,N,IFMT,J9,NNUM,IERR,IK,VA,VBl,VB1,VB2,VB3)
INTEGER I,IFLEX(IOO)
REAL X(|),Y(S),VA(J),VBl(J),VB1(J,400)
INTEGER PREV
COMMON Y0(),Y1(),V2(),Y3(),Y4(),Y5(),Y9(),Y6(),Y7(),Y9(),V10()
COMMON X0(),X1(),X2(),X3(),X4(),X8(),X9(),X10(),X11(),X12(),X13(),X14(),X15(),X16(),X17(),X18(),X19(),X20(),X21(),X22(),X23(),X24(),X25(),X26(),X27(),X28(),X29(),X30(),X31(),X32(),X33(),X34(),X35(),X36(),X37(),X38(),X39(),X40(),X41(),X42(),X43(),X44(),X45(),X46(),X47(),X48(),X49(),X50(),X51(),X52(),X53(),X54(),X55(),X56(),X57(),X58(),X59(),X60(),X61(),X62(),X63(),X64(),X65(),X66(),X67(),X68(),X69(),X70(),X71(),X72(),X73(),X74(),X75(),X76(),X77(),X78(),X79(),X80(),X81(),X82(),X83(),X84(),X85(),X86(),X87(),X88(),X89(),X90(),X91(),X92(),X93(),X94(),X95(),X96(),X97(),X98(),X99(),X100()
COMMON YAPC(),VALP(),YRNO(),XRND(),YRND(),Y10()
COMMON YOUT(),TM()}
COMMON ITN.IX, I
COMMON ITN,PREV
GO TO (1,2,3,4IFMT
READ LABELS FOR ENDOG, VBLS,
1 READ (5,2004)(VA(I),VB(I),I=1,N)
READ(6,2000) (X(I),I=1,N)
2000 FORMAT (10(A4,A4))
RETURN
2 CONTINUE
IF (KCR.NE.GT.1) GO TO 11
DO 10 J=1,N
10 READ (J9,IFLEN#J#; NN# V#(J#); ;) JD J=1,N
IP (PREV .NE. 0) GO TO 29
DO 11 I=1,L
11 I=1,N
11 I=1,L
11 I=1,L
11 I=1,L
CONTINUE
IF (KCR.NE.1) GO TO 19
DO 20 J=1,N
20 X(J) = Z(J,K)
RETURN
3 CONTINUE
IF (KCR.NE.1) GO TO 15
DO 30 J=1,N
30 READ (J9,IFLEN#J#; NN# V#(J#); ;) JD J=1,N
IP (PREV .NE. 0) GO TO 39
DO 38 I=1,L
38 I=1,L
38 I=1,L
38 I=1,L
38 I=1,L
CONTINUE
IF (KCR.NE.1) GO TO 13
DO 40 J=1,N
40 X(J) = Y(J)
RETURN
C FORMAT 2000 IS FOR ENDOGENOUS VARIABLES AND STARTING VALUES
END
SUBROUTINE CEME11
INTEGER PREV
COMMON V0(70),Y1(70),Y2(70),Y3(70),Y4(70),Y5(70),Y6(70),Y7(70),
1 Y8(70),Y9(70),Y10(70)
COMMON X0(100),X1(100),X2(100),X3(100),X4(100),X5(100),X6(100),
1 X7(100),X8(100),X9(100),X10(100)
COMMON Y0(70),Y1(70),Y2(70),Y3(70),Y4(70),Y5(70),Y6(70),Y7(70),
1 Y8(70),Y9(70),Y10(70)
COMMON Y0(70),Y1(70),Y2(70),Y3(70),Y4(70),Y5(70),Y6(70),Y7(70),
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