SHORT- AND LONG-TERM SIMULATIONS WITH THE BROOKINGS MODEL

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PREDICTIONS with econometric models, even thirty years after Tinbergen's initial attempt, still involve art as well as science. The present version of the Brookings Model is an advance over its predecessors. Yet much remains to be done to improve the specification of certain sectors and to reduce the predictive error of the system as a whole. The equations of the present system, the 1969 BUSEM, are similar to those presented previously in the Fromm-Taubman simulations, but there are a few significant differences.

1 STRUCTURE OF THE MODEL

To begin, the sample period for earlier versions of the model was 1948–60. Thus, it included the waning years of readjustment to World War II and the Korean War experience. Analysis of covariance tests run for the periods 1948–53, 1954–60, and 1948–60 revealed significant shifts in many coefficients between the earlier and later years of these intervals. It was decided to select a sample period germane to the analysis of current economic problems. Therefore, the present version of the model is estimated over the post-Korean War years, 1954–65. The data employed also are taken from different sources: revised na-

tional income and product accounts and later revisions of unpublished statistics.\(^2\)

The theory underlying some of the equations of the model has been modified as well. Consequently, it is not surprising that certain variables in specific functions no longer have statistically significant coefficients, and these variables have been eliminated. In other instances, new variables or better measures of previous ones have been included.

The 1969 version of the model, for which solutions are presented below, contains 230 equations (118 of which are stochastic) and 104 exogenous variables or parameters. Most of the exogenous variables are of minor importance. The model is estimated using ordinary least squares. Two-stage least squares estimates of a somewhat larger and improved version of the model also have been prepared and will be the basis of complete system solutions to be released in 1970.

A description of the difference in specification of the 1969 BUSEM from the 1968 BUSEM follows. Equations for the 1969 and 1968 models are shown in the appendixes of this paper and in the Fromm and Taubman book, respectively.

**CONSUMER DEMAND**

The present consumption functions depart from the earlier versions primarily in that they are estimated on a real per capita rather than on a real absolute basis. The principal explanatory variables are real disposable income per capita and relative prices. A credit dummy variable has been added to the consumption of durables other than automobiles. The autos equation now includes a capital stock of autos variable and a dummy variable (scaled by per capita disposable income) to reflect auto strikes. The two nondurables consumption equations (foods and beverages, and other nondurables) are unchanged, while the liquid assets term has been deleted from the services equation.

Because of compositional shifts in the late 1950's, housing unit
starts have now been disaggregated into three categories: single units,
double units, and three or more units. All of the original variables ap-
pear in the various starts functions, but in different equations. Single
unit starts are dependent on cost and the availability of funds in finan-
cial markets (short-term interest rates are used as a proxy), real dis-
posable income per household, and the real market price of the average
home. (The latter price is also a function of real disposable income per
household.) Lagged single unit starts, together with three-quarter mov-
ing averages (lagged one-quarter) of the other variables give a modified
Koyck lag effect to the impact of the explanatory factors. The same
type of lag distribution is used in the other starts and price equations.

Housing starts of dual units are a function of interest rates, dis-
posable income per household, a time trend and lagged starts. Pre-
sumably, a market price variable might be significant but data on dual
unit prices are not available separately from other multi-unit prices.
Multi-unit starts (three or more units) are mainly dependent on supply
conditions and are strongly influenced by interest rates and housing
unit vacancies. Vacancies also have a significant influence on the mar-
ket price of multiple units.

Due to the above disaggregation, the price-quantity identity that
defines housing unit expenditures is, of course, slightly modified. The
equation for other residential expenditures is unchanged, except now
the coefficient of the price of such outlays is significant and bears the
correct negative sign. Expenditures for new private nonfarm, non-
residential, nonbusiness construction also are included in this sector;
here, the lagged dependent variable has been added as an explanatory
factor.

INVENTORY INVESTMENT

The inventory investment equations for durable and nondurable
manufacturing are nearly identical to those used previously. Real in-
ventory change is a function of real final sales, beginning of period
inventory stocks and unfilled orders, and the previous period's inven-
tory investment. (The lagged real change in unfilled orders also appears in the durables equation.) The one exception is that a change in final sales of nondurable goods has been deleted from the nondurable function.

Trade inventories, because of requirements elsewhere in the model, have been separated into investment in car inventories and in trade inventories other than cars. The latter is made a function of the final sale of goods and the beginning of period stock of such inventories.

By definition, car inventories are held only by the trade sector and not by manufacturers. Therefore, the change in the value of dealer stocks is hypothesized to be dependent on the level and first difference of personal consumption expenditures on automobiles and the value of the stock of cars at the beginning of the period.

For the residual sector, real inventory investment is a function of real final sales, the beginning of period stock, and lagged inventory change. Price changes and interest rate terms have been dropped from this equation.

ORDERS

A few modifications have been made in the orders sector. For durable manufacturing, speculative price changes and lagged final sales terms have been dropped from the real new orders equation. A two-quarter lagged moving average of Department of Defense military prime contract awards has been substituted for current government military expenditures (both variables in real terms). The reciprocal of the rate of capacity utilization has been added to reflect the impact of capacity constraints. The remaining key explanatory variables are real final sales of durables, construction expenditures, and the level of unfilled orders at the beginning of the period.

The level of real unfilled orders in durables manufacturing is given by an identity between the beginning of period level, price changes (the identity is only valid in current dollar terms), real new orders, and real sales. A linear function relating real sales to real output originating is substituted for the sales term in the identity.

FOREIGN TRADE

Due to modifications for nondurables and services, the price of lagged imports, a dummy variable to act as proxies for prices, and export prices.

This is based on Holland, 1967).
INVESTMENT IN NONFARM BUSINESS PLANT AND EQUIPMENT

The approach for nondurables manufacturing, suggested by Gerald Childs, is somewhat different. Here, using inventory decision rules, the real change in unfilled orders is hypothesized to depend on real values of the first difference in new orders, lagged new orders, the lagged level of unfilled orders, inventory stocks, the level and rate of change in the wholesale price index of nondurables, and the reciprocal of capacity utilization in the industry. New orders are then given by an identity similar to that for unfilled orders for durables manufacturing.

FOREIGN TRADE

Due to modifications in the basic data, equations have been estimated for nondurables and services, and for durables imports rather than for finished and unfinished imports. Real nondurables and services expenditures are a function of the price of these imports relative to the price of consumption, as well as real disposable income, lagged imports, and a dummy variable for dock strikes.

The equation for real export expenditures is unchanged except for the additions of a dock strike dummy. Exports are dependent on the volume of world trade and the price of U.S. exports relative to world export prices.

This is based on his *Unfilled Orders and Inventories: A Structural Analysis* (North-Holland, 1967).
There are four tax functions for total Federal, state, and local receipts of personal, excise, corporate profits and social insurance taxes. In each of the equations, as before, a variable which corresponds to the tax base is included. Now, however, given the changes in rates after 1960, profits before taxes are multiplied by the normal corporate rate plus surtax. (The elasticity of this combined variable is less than unity because of the lower rate that applies to low income corporations and because of carry-forward and carry-back averaging of losses.) Similarly, the social insurance equation now includes terms which reflect the contribution rate, the percentage of employees covered, and the maximum individual tax base. There is also a term to reflect employers' contribution rates for unemployment insurance. Finally, dummy variables are utilized to capture the cut in tax liabilities of the 1964 and 1965 personal and excise tax reductions and the 1962 investment tax credit.

Government transfer payments are predicted by the same equations used previously. Transfers of unemployment benefits are a function of the number of persons unemployed and a GNP potential gap valued in current dollars. The remaining categories of government transfers, social security, veterans', and miscellaneous payments, are treated exogenously.

**Production Functions**

Rather than utilize linear employment functions, this version of the model contains a restructuring of the production functions in accord with more recent theoretical developments. Starting with a Cobb-Douglas function, and an inertial adjustment process, Michael McCarthy developed logarithmic equations for man-hour requirements for production workers in the durables manufacturing, nondurables manufacturing, and trade sectors. The explanatory variables are real output originating and real capital stocks. Time trends are included to account for technological change; dummy variables are introduced in the 1960's to reflect apparent shifts in production functions and reductions in manufacturing production labor requirements. Further study is needed to validate these workers is with real output elements.

Logarithmic requirements for the variables. Again, aside from the explanatory variables, technological change is highly serially correlated.

In the previous section, we described the production functions of the form

$$ E = M H / H $$

where

$$ H = \text{average} $$

$$ X^{58} = \text{gross product} $$

In specifying the real product was not output) as an exponent. Unfortunately, the sum of the product and changes in real output originating and real capital stocks. Time trends are included to account for technological change; dummy variables are introduced in the 1960's to reflect apparent shifts in production functions and reductions in manufacturing production labor requirements. Further study is needed to validate these workers is with real output elements.
is needed to validate the justification for use of the latter dummies.

Data are not available on hours worked by nonproduction workers in the manufacturing and trade sectors. Therefore, employment of these workers is made the dependent variable in logarithmic equations with real output originating and lagged employment as the explanatory elements.

Logarithmic functions also are used to explain total man-hour requirements for the contract construction, regulated, and residual sectors. Again, aside from an inertial adjustment process, the principal explanatory variables are real output originating and a time trend for technological change. Because the residuals of these equations were highly serially correlated, Cochrane-Orcutt corrections were applied.

In the previous model, average weekly hours of production workers in the manufacturing and trade sectors and of all workers in the contract construction and regulated sectors were explained by equations of the form:

\[ H = \beta_0 + \beta_1 \frac{\Delta X^{1958}}{X^{1958}} + \beta_2 H_{-1} \]

where

\[ H = \text{average weekly hours} \]
\[ X^{1958} = \text{gross product originating in 1958 dollars} \]

In specifying the present model an attempt was made to include the real product wage per man-hour (wage rates divided by the price of output) as an explanatory variable measuring labor substitution effects. Unfortunately, statistically significant coefficients were not found. One member of the project staff estimated an hour’s equation using the level and change in real output and the level of wage rates as explanatory variables. This produced statistically significant coefficients and the equations were incorporated in the present model. The complete system solutions for the period 1957–65 for hours of all workers are extremely accurate; the root mean square error is only 0.15 hours per week and the mean error is 0.02 hours (on a base of 40 hours per week).

Given the equations for man-hours and average weekly hours, it is then possible to calculate employment by sector from identities of the form \( E = MH/H \).
INDUSTRY PRICES

In the earlier model, prices of output originating in durables and nondurables manufacturing were determined as a function of the level of normal unit labor costs (current wage rates divided by a twelve-quarter average of output per man-hour), the difference between actual and normal unit labor costs and, as an indicator of demand pressures, the deviation of real inventory stocks per dollar of real output from its three-year trend. Wholesale price indexes for these industries then simply were made linear functions of the prices of output originating.

The present model defines normal unit labor costs as a four-quarter average of wage rates divided by normal productivity (the above output per man-hour average). Following Eckstein and Fromm, wholesale prices then were made dependent on normal unit labor costs, actual from normal unit labor cost deviations, capacity utilization, and the prices of materials inputs from other sectors.4

The price of output originating for durables manufacturing then was related (in a linear equation) to the wholesale price index for this sector and input materials prices (the latter has a negative sign). Output originating prices for nondurables manufacturing were better predicted by using a function similar to that for its wholesale prices (without the raw materials term) than by relating them to wholesale prices. (The marginally significant average weekly hours term—ceteris paribus, an inefficiency indicator—probably should be deleted from the equation.)

With the exception that normal unit labor costs have been slightly redefined, equation specifications for the prices of output originating for the remaining sectors—trade, contract construction, regulated, and other—are identical to those used previously. The primary explanatory variables are normal unit labor costs and actual from normal unit labor cost deviations. For the trade sector, a ratio of an inventory-stock-to-output variable, see above, is included. For the regulated sector, normal (and the deviation of actual from normal) unit capital consumption allowances are important additional determinants of prices.


WAGE RATES

The four-quarter average of real wages has been explained by the price index and production capacity. Basically, the unweighted average of unemployment for the quarter, quarter weighted a quarter, and the unemployment rate was used as an indicator of demand pressures. Also, the same coefficients as the post-1946 period were used for the demand for labor equation.

With the exception that normal unit labor costs have been slightly redefined, equation specifications for the prices of output originating for the remaining sectors—trade, contract construction, regulated, and other—are identical to those used previously. The primary explanatory variables are normal unit labor costs and actual from normal unit labor cost deviations. For the trade sector, a ratio of an inventory-stock-to-output variable, see above, is included. For the regulated sector, normal (and the deviation of actual from normal) unit capital consumption allowances are important additional determinants of prices.

The four-quarter percentage change in wage rates previously had been explained by four-quarter percentage changes in the consumer price index and profits per dollar of real output, the reciprocal of an average of unemployment rates, and the dependent variable lagged four quarters. Basically, the same form still applies. The equations have been altered slightly by dropping the profits per unit of output term (which is no longer significant), by taking the reciprocal of a four-quarter, unweighted average of unemployment rates (instead of a five-quarter weighted average), and by adding, as a distributed lag adjustment, the dependent variable lagged one quarter.

Also, the sample period for the present model encompasses the guidepost era from 1962-65, when the government attempted to restrain wage and price movements by moral suasion. Inclusion of guidepost dummy variables in the equations yielded significant negative coefficients for the durables and nondurables manufacturing, regulated, and residual sectors.

The format for relating the final demands and outputs of industry to GNP component demands, and GNP component prices to industry prices, was originally presented in the first volume on the model. There, as in the Fromm-Taubman solutions, coefficients in equations relating final demands to GNP expenditures were constrained to sum to unity. In further analysis, it was hypothesized that changing mixes within the industry and expenditure aggregates would vitiate the homogeneity constraints. The latter approach has been applied in the present model.

Real final demands by industry are related to real GNP comp-


ponent expenditures, which correspond most closely to the output of the industry. For example, for durables manufacturing, the components, in real terms, are inventory change of durables and trade, exports, consumption of durables, producers' durables equipment expenditures, and government purchases of durables. Dummy variables are added in selected periods to account for dock strikes and other unusual phenomena that are imperfectly reflected in the explanatory variables. For sectors other than durables manufacturing, auto-regressive transformations are used to eliminate strong serial correlation of residuals.

As in the past, industry gross product originating is predicted using the input-output relationship:

\[ X_{t}^{58} = D_{t}^{-1}(I - A)^{-1}F_{t}^{58} \]

where

- \( X_{t}^{58} \) is a vector of industry gross product originating in 1958 dollars
- \( D_{t} \) is the inverse of a diagonal matrix of the ratio of real gross output to real gross product originating for each industry
- \( A \) is a fixed coefficient input-output matrix
- \( F_{t}^{58} \) is a vector of industry final demands in 1958 dollars.

Previously, the 1947 input-output matrix had been used for complete model solutions; the 1958 table is employed for the current runs. The \( D \) matrix bears a time subscript because the ratio of gross output to gross product originating in the case of two industries, agriculture and contract construction, has been shifting over the sample period.

In previous solutions, auto-regressive transformations were applied to the output calculations as the next step. These were not done here because final demands are now corrected for serial correlation of residuals prior to the input-output conversion. Also, previously, the sum of real industry gross product originating was constrained to equal real gross national product. A trial calculation indicated that this discrepancy was small (on the order of one to two billion dollars) and the constraint was not imposed. However, it will be applied in future solutions and, if past experience is a guide, should result in improved accuracy.

The conversion of industry prices into \( GNP \) component prices has been refined for the latest directly to the same combined matrix into industry gross product originating as final demands \( (PF) \).

Then the prices of all other \( P_{C,D} \) are derived for relevant industry final demands in the durables matrix, regressive transformations are used to eliminate over-all implicit deflators to correct for these.

An expenditure over-all implicit deflator, \( P_{C} \), is then predicted for total consumption, is then predicted for total consumption of all industries.

FINANCIAL SECTOR

The specifications and structures which were employed in the past changes. First, equation demand deposits and endogenous rather than the principal each of these equations investment variable. Those that remain

\[ \text{F. de Leeuw, "A} \]
been refined for the present solutions. Previously, GNP prices were related directly to industry prices of gross product originating using the same combined matrix as for the conversion of real GNP expenditures into industry gross product originating. Now, industry prices of gross product originating (PX) are first transformed into prices of industry final demands (PF) using

$$PF = (I - A)^{-1} D^{-1} PX$$

Then the prices of GNP components (such as the implicit price deflator for personal consumption expenditures on durables automobiles, $P_{CD4}$) are derived from regressions of these prices on the prices of the relevant industry final demands. For example, $P_{CD4}$ is a function of $PF$ in the durables manufacturing and trade sectors. As previously, auto-regressive transformations are needed for some GNP component prices to correct for serial correlation of residuals.

An expenditure weighted combination of these prices yields the over-all implicit deflator for total personal consumption expenditures, $P_C$. The consumer price index, which appears in the wage rate equations, is then predicted as a linear function of $P_C$.

**FINANCIAL SECTOR**

The specification of the financial sector retains the essential features and structure of de Leeuw's condensed simultaneous submodel, which was employed in previous solutions. There have been a few changes.

First, equations for both currency and demand deposits and for demand deposits alone appear in the model. This makes currency an endogenous rather than exogenous variable (unborrowed reserves remain the principal Federal Reserve exogenous policy instrument). In each of these equations, the lagged disposable income and business investment variables have been dropped as explanatory variables. Those that remain are time deposit yields, government bill rates, disposable income, and the beginning of quarter level of the dependent variable. The functions are homogeneous in wealth, which now is de-
fined as the sum of a twenty-quarter exponentially distributed lag of real \( GNP \) multiplied by the current price of \( GNP \). (Previously, the distributed lag was taken on current dollar \( GNP \).)

The time deposits equation also remains homogeneous in wealth with the primary explanatory variables being time deposit yields, Treasury bill rates, and the prior level of deposits. An alternative first-difference type specification shows a weak influence of disposable income. However, the \( t \)-statistic of this variable was only slightly greater than unity, so the simpler version of the equation was used for the present model solutions.

In de Leeuw's original formulation, banks' demand for free reserves as a percentage of demand and time deposits was made a function of government bill rates, the Federal Reserve discount rate, and short-run percentage changes in deposits less required reserves. For the present model, the equation was renormalized and the bill rate was made the dependent variable. The discount rate and the level and changes in free reserves relative to deposits became the principal explanatory factors of bill rate changes; government deficits (which have a negative sign) as a percentage of wealth also are found to have an effect and, other things being equal, exert upward pressure on short-term money rates.

The term structure equation relating bill rates and long-term bond yields also has been modified along lines suggested by Modigliani and Sutch. The bond yield now is a function of the level and change in bill rates and the prior level of bond yields.

The yield paid on time deposits equation has been altered, too. It is assumed that quarterly changes in the time deposit rate, \( RM_{BDT} \), cover a fraction of the gap between desired and actual rates subject to the Federal Reserve's Regulation Q ceiling limit (\( RM_{BDTM} \)):

\[
\Delta RM_{BDT} = \beta_0 (RM^*_B - RM_{BDT-1}) + \beta_1 RM_{BDTM}
\]

The desired rate \( RM^*_B \) is obtained by maximizing banks' profits on deposits (net of reserve requirements with government bills as the mar-

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ginal investment outlet) less the yield paid on time deposits. Finally, a dummy variable is included to reflect the issuance of certificates of deposit (CD's) in the early 1960's.

NONWAGE INCOME

There has been no change in specification of the nonwage income equations. Government interest payments are a function of levels and changes in government bill rates and the amount of public debt. Dividend payments, following the work of Lintner and Brittain, depend on profits after taxes and capital consumption allowances and lagged dividends. Entrepreneurial income is related to labor compensation and corporate profits in the private sector other than agriculture. Net interest paid by consumers is dependent on a moving average of bond yields multiplied by the sum of personal consumption expenditures on durables and nonfarm residual construction.

CAPITAL CONSUMPTION ALLOWANCES

These equations are identical in form to those in the previous model. Quarterly changes in capital consumption allowances depend on recent investment and on prior allowances and various dummy variables to account for the transitions between the use of different depreciation methods.

LABOR FORCE

The equation for estimating the number of persons in the civilian labor force remains unchanged. The explanatory elements are the number of persons employed, last quarter's level and change in unemployment, and a time trend to approximate the trend toward higher labor force participation rates of working age women.
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

IDENTITIES, FIXED PROPORTIONS, AND MISCELLANEOUS RELATIONSHIPS

Most of these equations comprise the aggregation of the national income and product accounts and have not been modified. A few changes have been occasioned by redefinition of data or better approximations to splits in an aggregate quantity.

For example, previously, real producers' durables equipment investment, \( I_{PD} \), was taken as a fixed proportion of real business investment. Now the split is made a function of time and dummy variables to reflect the impact of the investment tax credit on desired proportions of plant to equipment.

Several additions have been made for the purpose of defining potential GNP and both capacity output and capacity utilization in manufacturing. Potential real GNP and real capacity output is estimated to have grown by 3.5 per cent per year from the third quarter of 1953 through 1965 and by 4 per cent thereafter. The model uses the Wharton capacity utilization rates for durables and nondurables manufacturing as explanatory variables. These, in turn, are related to previous utilization rates and changes in the real actual-to-capacity-output ratios.

2 TURNING POINT ANALYSIS

A DISTINCTIVE feature of the Brookings Model, among the others being considered at this Conference, is its size and detail. The model generates dynamic solutions of 230 variables every quarter. There is a rich analysis waiting to be undertaken in the study of many individual variables or groups of variables. Nevertheless, in the light of the Conference format, the principal analysis is conducted in terms of solutions for seventeen standardized variables. (See Table 1.)

The sample period for parameter estimation begins after the Korean War; therefore, the first cycle analyzed is the 1953–54 recession. The 1957–58, and 1960–61 recessions are then considered. Given the need for lagged values, the first solution is for the trough of the recession in the six-quarter simulations before the beginning one, two, a

A way of evaluating root mean square errors from the

(billions of dollars)

<table>
<thead>
<tr>
<th>Short-term Treasury</th>
<th>Long-term Treasury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real nonagricultural GNP deflator (P_{GNP})</td>
<td>Unfilled orders (Q)^a</td>
</tr>
<tr>
<td>Real nonfarm resident personal income (Y)</td>
<td>Corporate profits before GNP in current dollars (G)</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>Consumer expenditures</td>
</tr>
<tr>
<td>Nonfarm inventory</td>
<td>Net foreign balance</td>
</tr>
<tr>
<td>Employment</td>
<td>Employment (EHH)</td>
</tr>
<tr>
<td>Hours worked per</td>
<td>Money wage rate (W)</td>
</tr>
</tbody>
</table>

NOTE: These are square errors of an A way of evaluating root mean square errors from the

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about 2/3 of a point per cent.
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h begins after the
the 1953–54 reces-
the trough of
the recession in the third quarter of 1954. The first of the successive
six-quarter simulations begins in 1954, in the first quarter or two quar-
ters before the trough. The other turning points have simulations be-
ning one, two, and three quarters before the peak or trough.

A way of evaluating performance at peaks and troughs is to com-
are root mean square (RMS) errors at the turning point, near the
turning point, or over the whole six-quarter span with root mean square
errors from the whole sample period (which includes steady growth

<table>
<thead>
<tr>
<th>Variable</th>
<th>Root Mean Square Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term Treasury bill rate (RM.getJSONObject), per cent</td>
<td>0.226</td>
</tr>
<tr>
<td>Long-term Treasury bond yield (RM.getJSONObject), per cent</td>
<td>0.177</td>
</tr>
<tr>
<td>Real nonagricultural gross capital formation (GNS Goblin)</td>
<td>0.946</td>
</tr>
<tr>
<td>GNP deflator (Pb), index, 1958 equals 1.0</td>
<td>0.0072</td>
</tr>
<tr>
<td>Unfilled orders (Qb)</td>
<td>4.155</td>
</tr>
<tr>
<td>Real nonfarm residential construction expenditures (Ib Goblin)</td>
<td>1.006</td>
</tr>
<tr>
<td>Personal income (Yb)</td>
<td>3.384</td>
</tr>
<tr>
<td>Corporate profits before tax (Zb)</td>
<td>3.650</td>
</tr>
<tr>
<td>GNP in current dollars (GNP)</td>
<td>5.841</td>
</tr>
<tr>
<td>GNP in 1958 dollars (GNP Goblin)</td>
<td>4.998</td>
</tr>
<tr>
<td>Unemployment rate (Ru), proportion</td>
<td>0.00622</td>
</tr>
<tr>
<td>Consumer expenditures in 1958 dollars (CB Goblin)</td>
<td>2.429</td>
</tr>
<tr>
<td>Nonfarm inventory investment in 1958 dollars (INV Goblin)</td>
<td>2.653</td>
</tr>
<tr>
<td>Net foreign balance (B)</td>
<td>1.350</td>
</tr>
<tr>
<td>Employment (EH Goblin), millions of persons</td>
<td>0.534</td>
</tr>
<tr>
<td>Hours worked per week (Hf), hours</td>
<td>0.150</td>
</tr>
<tr>
<td>Money wage rate (RW Goblin), dollars per hour</td>
<td>0.0397</td>
</tr>
</tbody>
</table>

Note: These are quite favorable results. GNP solutions with root mean
square errors of approximately $5.0 billion are good for ex post solutions.
Interest rates are estimated with root mean square errors of approximately 20
basis points. Price level errors are approximately $\%_4$ of a point movement
in the index based on 100. Similarly, the error in the unemployment rate, Ru, is
about $\%_3$ of a point in the third decimal place when the rate is expressed as a
per cent.
phases between the lower and the succeeding upper turning points). The longer dynamic simulation from given initial values begins in the first quarter of 1957 and runs through the fourth quarter of 1965. Given the small size of the variable, the root mean square error of real inventory investment is large. Similarly, corporate profits before taxes and the net foreign balance are estimated subject to a fair size error.

Simulations of eleven variables around the five sample-period turning points are depicted in Charts 1—11. In general, the pattern of predicted values follows actual experience reasonably well. However, solutions tend to run within the actual cycles, understating peak and overstating trough values. Furthermore, predicted turning points often occur either too early or too late. These phenomena have been found in other studies. In the following discussion of the individual turning points, emphasis is placed primarily on the accuracy of GNP and real GNP predictions. The reader is encouraged, however, to examine all the charts in conjunction with the text discussion.

THE 1954 TROUGH

Most variables show a substantial negative residual (actual minus computed) at the trough, the third quarter of 1954. In some cases the negative residual is one quarter on either side of the trough. In the case of the unemployment rate, the small negative residual at the trough does not indicate underestimation of amplitude; the residual is much smaller than the root mean square value for RU in Table 1. For the other variables, the root mean square values are both larger and smaller than the reference values; but the residuals almost all have the same sign, supporting the view that when the economy makes a large movement in either direction, model solutions vary with lower amplitude. The nonstochastic solution is often a smooth series compared to the actual data and cuts off extreme peak and trough fluctuations.

On the whole, performance is good at this turning point. The errors in the solution are frequently lower than those in Table 1. Several

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Simulations with Brookings Model

Simulations begin in the quarter of 1965. Given the error of real profits before taxes is a fair size error, five sample-period errors generally tend to be fairly well. However, understating peak and turning points often have been found when individual turning points of GNP and real per capital income are compared to the actual. Table 1. For the residual (actual minus predicted) at the trough. In some cases the residual is much larger and smaller. It all have the same lower amplitude. In some cases the fluctuations. Simulations beginning "p" quarters before starting point. The errors in Table 1. Several and Albert A. Hirsch, "Simulations with Brookings Model," this volume.
CHART 2

$P_{GDP}$
Implicit Price Deflator for Gross National Product
(1958 = 100)
CHART 4

New Private Nonfarm Residential Construction in 1958 Dollars

Simulations beginning "H" Quarters before turning point

- - - - - - 3 Quarters
- - - - - - - 2 Quarters
- - - - - - - - - 1 Quarter
- - - - - - - - - - - Actual
CHART 5

\(\Delta \text{INV}_{1958}\)

Nonfarm Inventory Investment in 1958 Dollars

Simulations beginning "n" Quarters before turning point

- - - - 3 Quarters
- - - - 2 Quarters
- - - - - - - 1 Quarter

Actual

1958 Dollars

Billions of Dollars

1953 1954 1955

1956 1957 1958

1959 1960 1961
Simulations beginning "n" Quarters before turning point

- - - - 3 Quarters
- - - - 2 Quarters
- - - - 1 Quarter
______ Actual

CHART 6

C34

Personal Consumption Expenditures in 1958 Dollars
CHART 7

RU
Unemployment Rate
CHART 8

EHH

Civilian Employment

Simulations beginning "n" Quarters before turning point
- - - 3 Quarters
-- 2 Quarters
-...- 1 Quarter
--- Actual
CHART 9

$RM_{683}$

Short-Term Treasury Bill Rate

Simulations beginning "n" Quarters before turning point

- 3 Quarters
- 2 Quarters
- 1 Quarter
- Actual
CHART 10

RWSS
Hourly Wage Rate Including Supplements

Simulations beginning "n" Quarters before turning point

- - - - - 3 Quarters
- - - - 2 Quarters
- - - - - - - - 1 Quarter

Actual
Chapter 11

Corporate Profits Before Taxes Including Inventory Valuation Adjustment
TABLE 2

1954 Recovery: Root Mean Square Errors, Trough
(billions of dollars)

<table>
<thead>
<tr>
<th></th>
<th>Starting from 1954:1</th>
<th>Starting from 1954:2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Six Quarters</td>
<td>1954:3</td>
</tr>
<tr>
<td>GNP</td>
<td>4.958</td>
<td>-5.058</td>
</tr>
<tr>
<td>GNP58</td>
<td>5.184</td>
<td>-0.738</td>
</tr>
</tbody>
</table>

turning point errors improve when we start up the solution one instead of two quarters before the trough. (See Table 2.)

1957–58 RECESSION

In this case the peak is in the third quarter of 1957 and the trough is in the second quarter of 1958. At the peak, the performance appears to be good. Many cyclical variables have the correct quarter-to-quarter movements, and the root mean square errors are either smaller or not significantly larger than the sample average values either at the peak point or over an entire six-quarter solution period. There is a tendency, however, for underestimation to occur at the peak.

Usually, models such as the present one do better at business cycle troughs than at peaks. (See Table 3.) This does not seem to be the case for the Brookings Model in the 1957–58 recession. Corresponding to the comparatively good performance at the peak, the root mean square errors are mostly larger for the trough calculations, both at the trough point and for the whole six-quarter simulation period.

With the two GNP series, there is consistent underestimation at peaks and overestimation at troughs. The timing and change-of-sign correspondence was good at the troughs in spite of large errors.

THE 1960–61 RECESSION

One of the mildest sets of actual turning points of the economy is the 1960–61 recession. The movement is so slight that it is more difficult to predict this the peak and trough principal series. The in mean that the model are difficult to project set of solutions (19 peak point, a defect to a fall enough, leaving
SIMULATIONS WITH BROOKINGS MODEL

The peak and trough are the most difficult to predict this recession than other postwar downturns. At both the peak and trough, there are discrepancies in the movement of principal series. The inability to deal with 1960–61 does not necessarily mean that the model has serious defects; fluctuations in narrow ranges are difficult to project. Some variables, however, perform well in this set of solutions (1960–61). The GNP series generally misses the turning point, a defect that needs to be corrected. (See Table 4.)

Generally speaking, there are large errors in comparison with root mean square values for the whole sample period. This is true for both measures of GNP at peaks. Behavior near the trough is better. The root mean square errors for GNP in six quarters covering the trough are low and the error for trough quarters are not excessive. At the peak quarters, observations exceed computed values of GNP and GNP58. This again is a failure to reach the complete range of the observed amplitude. At troughs, the reverse result holds, and the model fails to fall enough, leaving negative errors.

**TABLE 3**

1957–58 Recession—Recovery: Root Mean Square Errors (billions of dollars)

<table>
<thead>
<tr>
<th>Peak Starting from 1956:4</th>
<th>Peak Starting from 1957:1</th>
<th>Trough Starting from 1958:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP</td>
<td>6.180</td>
<td>8.904</td>
</tr>
<tr>
<td>GNP58</td>
<td>5.488</td>
<td>5.339</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Peak Starting from 1957:2</th>
<th>Peak Starting from 1957:3</th>
<th>Trough Starting from 1958:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP</td>
<td>6.993</td>
<td>2.781</td>
</tr>
<tr>
<td>GNP58</td>
<td>5.808</td>
<td>5.092</td>
</tr>
</tbody>
</table>
TABLE 4
1960-61 Recession—Recovery: Root Mean Square Errors
(billions of dollars)

<table>
<thead>
<tr>
<th></th>
<th>Peak</th>
<th></th>
<th>Peak</th>
<th></th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Starting from 1959:3</td>
<td>Six Quarters</td>
<td>1960:2</td>
<td>Six Quarters</td>
<td>1960:2</td>
</tr>
<tr>
<td></td>
<td>Trough</td>
<td>Six Quarters</td>
<td>1961:1</td>
<td>Six Quarters</td>
<td>1961:1</td>
</tr>
</tbody>
</table>

3 LONGER-RUN SIMULATIONS

There are two basic ways of generating long-run solutions of the model. One approach is limited to the sample period, with possibly a few post-sample-period observations added. The other approach extrapolates the series entirely beyond the sample. There is no limit, in principle, to the time duration of simulations outside the sample period. First, sample period simulations for thirty-six quarters are examined, starting in the first quarter of 1957 and ending with the fourth quarter of 1965.

The general impression of these thirty-six-quarter dynamic simulations is that computed values track the course of observed values rather closely, especially at the beginning and end of the period. This point is supported by the relatively small residuals shown in Table 1 and Charts 12-15.
olutions of the model. Possibly a few post-
roach extrapolates to a
in principle, to the sample period. First,
are examined, starting in the fourth quarter of
quarter dynamic simul-
of observed values of the period. This is shown in Table 1
Chart 13

\( P_{GDP} \)

Implicit Price Deflator for Gross National Product

- Solution
- Actual

1957 '58 '59 '60 '61 '62 '63 '64 '65

1958 = 100

Billion dollars

1957 '58
CHART 14

\( P_{BUSGAF} \)

Nonagricultural Business Gross Investment

Product

Billion dollars

1957 '58 '59 '60 '61 '62 '63 '64 '65

'53 '54 '55 '56 '57 '58 '59 '60 '61

Actual

Solution
Some larger error
The model picks up the
is mixed. The solution
58 period, but it fails
fecting steady price
whole nine-year period.

The quantitative
the seventeen simulat
in most instances. The
quarterly changes ex

Some strong trends displayed in Charts 3 have the appropriate
addition, real GNP in
projections are one of
c this is not a large error
both business inventories
cyclical swings are
formity is acceptable
but also at the specific
tudes of the peak and

In comparison, these results repres
gave rise to a regular
Also, the older model
occurred in the early pe
simulation, though one-half of those rep
stochastic simulations.

Two methods of the estimates of the peak only by ordinary linear

Although the G

L. Nagar, "Stochastic
Model: Some Further R
Some larger errors occur in the middle ranges of the simulation. The model picks up the trend component very well. Cyclical behavior is mixed. The solution for real GNP, however, does follow the 1957-58 period, but it fails to decline in 1960-61. Current dollar GNP, reflecting steady price inflation, has only one quarterly decline in the whole nine-year period. It misses the peak and trough points.

The quantitative nature of the solution, however, is good. Among the seventeen simulated variables, the quarterly sign change is correct in most instances. The percentage of correct signs estimated for quarterly changes exceeds 75 per cent in all except four cases.

Some strong trend variables and some highly cyclical variables are displayed in Charts 12-15. Real GNP and the GNP deflator both have the appropriate trend growth corresponding to the actual data. In addition, real GNP has some of the appropriate cyclical content. Price projections are one or two points low at the end of the calculation, but this is not a large error. In the case of the capital formation series—both business investment and residential construction—the main cyclical swings are well delineated by the computed values. Conformity is acceptable not only at the reference cycle peaks and troughs, but also at the specific cycle peaks and troughs. In 1959-60, the amplitudes of the peak and trough in residential construction are underestimated, but the timing is approximately correct.

In comparison with the previous version of the Brookings Model, these results represent improvement. Earlier, there were biases that gave rise to a regular discrepancy between estimated and actual GNP. Also, the older model implied more price inflation than actually occurred in the early part of the 1960’s. The absolute errors in the present simulation, though for a different time span, are generally one-third to one-half of those reported by Nagar in his study of stochastic and non-stochastic simulations over the sample period.10

Two methodological points are highlighted by these results: (1) the estimates of the model at the present time have been computed only by ordinary least squares (OLS); (2) some of the estimated structural equations have serially correlated errors.

Although the OLS estimates appear to be functioning very well in

these exercises on complete system performance, other studies have found that least squares bias sometimes appears to be more significant in complete system solutions than in separate equations, and that biases tend to accumulate as simulations are conducted over long time periods.\(^\text{11}\) Consistent estimates of the new Brookings Model will be forthcoming.

In the paper on the OBE Model, and also on the Wharton Model, it was found that auto-regressive transformations of individual equations (to take account of the presence of serial correlation in calculated residuals) brought modest improvement to sample period simulations. That technique was not used for solution of the Brookings Model, but some of the equations were originally estimated with second-order auto-regressive corrections. For a relationship

\[
y_t = \alpha_0 + \alpha_1 x_t + e_t
\]

\[
e_t = \rho_1 e_{t-1} + \rho_2 e_{t-2} + u_t
\]

the estimated form was

\[
(y_t - \hat{r}_1 y_{t-1} - \hat{r}_2 y_{t-2}) = \hat{a}_0 (1 - \hat{r}_1 - \hat{r}_2) + \hat{a}_1 (x_t - \hat{r}_1 x_{t-1} - \hat{r}_2 x_{t-2})
\]

\[
\hat{a}_1 = \text{est } \alpha_1, \quad \hat{r}_i = \text{est } \rho_i
\]

These estimates were made for investment functions, where it was found that second-order corrections were needed in order to eliminate serial correlation of residuals. Although the estimates of \(\alpha_0\) and \(\alpha_1\) should be more efficient by this correction, the transformed equations gave very poor results in the complete system simulations. The alternative of solving the system using

\[
y_t = a_0 + a_1 x_t
\]

admitting serial correlations in residuals was not undertaken. Instead,

\[
y_t = a_0^* + a_1^* x_t
\]

was re-estimated in the presence of serially correlated errors. Although \(a_1^*\) should be less efficient than \(a_1\), the equations with \(a_1^*\) coefficients gave better system solution results than the transformed set using \(a_1\).

other studies have shown more significant variations. And that over long time periods Model will be Wharton Model, with second-order

\[ r_1 x_1 - r_2 x_2 \]

simulations, where it was undertaken. Instead, transformed equations. The alternative to eliminate

errors. Although with \( a_i \) coefficients formed set using \( a_i \). Macroeconometrician, "The Brookings Model is essentially a short-run forecasting model and as such is not designed for simulations over a twenty-five year period. Therefore, certain adjustments, discussed below, were necessary in order to produce a reasonable control solution. The control solution is a hypothetical growth path over the period from the first quarter of 1966 through the fourth quarter of 1990. However, actual values of some of the exogenous variables were used for the first three and one-half years. Also, government spending and employment were adjusted to reflect the possible slowdown of the Vietnam War during 1970.

Shocked simulations were produced by introducing random additive disturbances to the stochastic equations of the model. These disturbances are selected so that they have the same asymptotic variance-covariance properties, of all orders, as the original single equation residuals. The procedure used to generate these shocks is discussed in the paper by Michael D. McCarthy. A slight change from McCarthy's procedure was necessary because residuals from the equation estimates were not available. The residuals were computed over the

\[ G, G^{18}, WSS, WSG, E, DOD_{HPC}, WSS, \]

and \( E \). The components of \( G^{18} \) were adjusted to add up to \( G^{18} \).

\[ ^{18} \text{M. D. McCarthy, "Some Notes on the Generation of Pseudo Structural Errors for Use in Stochastic Simulation Studies," Appendix to "Short-Run Prediction and Long-Run Simulation of the Wharton Model," this volume, pp. 185-191.} \]
sample period using the simulation program, which leads to different results in cases where equations are renormalized. For example, the man-hours equations were estimated in log form but the residuals for the man-hours equations as computed in the simulation program were in man-hours.

The exogenous variables for the twenty-five year simulation were generated mainly by extrapolation along their actual trends over the period from 1954 through 1965. In cases where actual data were used through the second quarter of 1969, the trend was extended from that point. The government sector exogenous variables were lowered in 1970 to simulate the end of the Vietnam War and then raised to their trend levels during 1971. The beginning and ending values along with annual percentage rates of change are shown for the principal exogenous variables in Table 5.

As is mentioned above, certain equations had to be modified in order to arrive at areas.

| TABLE 5 | Exogenous Variables for the Twenty-five Year Simulation |
|---------------------------------|-----------------|-----------------|-----------------|
| Principal Exogenous Assumptions | Annual Rate of Change |
|                                 | 1965:4 | 1990:4 | 1984:4 |
| $G^{56}$                        | 118.4  | 286.6  | 3.6   |
| $G$                             | 143.3  | 694.9  | 6.5   |
| $E_G$                           | 10.26  | 19.86  | 2.7   |
| $WSS_G$                         | 78.5   | 283.9  | 5.3   |
| $V_OA_S_{GF}$                   | 18.6   | 100.1  | 7.0   |
| $V_{FE}$                        | 5.7    | 13.1   | 3.4   |
| $V_{DG}$                        | 11.5   | 47.0   | 5.8   |
| $IBUS_{SP}$                     | 4.6    | 9.6    | 3.0   |
| $WSS_{AA}$                      | 3.6    | 5.2    | 1.5   |
| $E_A$                           | 4.20   | 1.81   | -3.3  |
| $PEX_{SW}$                      | 1.030  | 1.065  | 0.1   |
| $EX_{WS}$                       | 164.8  | 356.5  | 3.1   |
| $PM$                            | 1.047  | 1.537  | 1.5   |
| $INT_{BUS}$                     | 6.9    | 17.70  | 3.8   |
| $INT_{CON}$                     | 11.7   | 26.75  | 3.4   |
| $N^R$                           | 194.73 | 267.67 | 1.3   |
which leads to different d. For example, the but the residuals for lation program were rear simulation were tual trends over the ctual data were used s extended from that es were lowered in then raised to their ng values along with the principal exog- ed to be modified in

<table>
<thead>
<tr>
<th>Annual Rate of Change</th>
<th>3.6</th>
<th>6.5</th>
<th>2.7</th>
<th>5.3</th>
<th>7.0</th>
<th>3.4</th>
<th>5.8</th>
<th>3.0</th>
<th>1.5</th>
<th>-3.3</th>
<th>0.1</th>
<th>3.1</th>
<th>1.5</th>
<th>3.8</th>
<th>3.4</th>
<th>1.3</th>
</tr>
</thead>
</table>

order to arrive at a reasonable growth path over the twenty-five year period. The two sets of functions where modifications were necessary were the tax, man-hours and hours equations. The modified tax functions are presented in Table 6. The personal income tax function was adjusted to approximate actual tax yields from 1966 through the second quarter of 1969. The surcharge was cut in half for the first two quarters of 1970 and then terminated. The tax rate was raised gradually through 1976 and then held constant in order to keep disposable income from growing too rapidly and also to limit government deficits.

The corporate profits tax function was adjusted so as to yield an approximately correct value given the actual data over the initial three and one-half years. The suspension of the investment tax credit in the fourth quarter of 1966 and first quarter of 1967 was accounted for by setting the tax credit dummy \((DMY_{ITC})\) to zero. The expected termination of the credit in the third quarter of 1970 was simulated by both a change in \(DMY_{ITC}\) and the corporate tax rate \(TC_{RT}\). The corporate tax surcharge was cut in half in the first quarter of 1970 and terminated in the third quarter.

The indirect business tax function was adjusted, through changes in \(DMY_{TX}\), to approximate actual excise tax collections from the first quarter of 1966 through the second quarter of 1969. The value of \(DMY_{TX}\) was held constant from that point onwards. The contributions for social insurance function was similarly adjusted.

Assumptions about old age and survivors insurance (OASI) contribution rates, and maximum individual wage and salary tax bases, and unemployment insurance contribution rates are taken from Pechman, Aaron and Taussig, and from Pechman, respectively. The percentage of employees covered by OASI was raised over the period from 89 to 93 per cent.

The rate of productivity increase implicit in the production man-hours equations for the manufacturing nondurables, trade, and other sectors was too moderate, so the time trends and constant terms in these equations were appropriately adjusted. The long-term rate of productivity increase in the construction sector was also negligible.

### TABLE 6

**Tax Function Assumptions**
*(by year and quarter, unless otherwise indicated)*

<table>
<thead>
<tr>
<th>Year</th>
<th>1234</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>TP</td>
<td></td>
</tr>
<tr>
<td>0.923</td>
<td>0.950</td>
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<td>1.000</td>
<td>1.000</td>
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<td>1.150</td>
<td>1.150</td>
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<tr>
<td>1.100</td>
<td>1.100</td>
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<tr>
<td>1.060</td>
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<td>1.220</td>
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<table>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>TC</td>
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<tr>
<td>1.000</td>
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<td>0.988</td>
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<td>0.988</td>
<td>0.988</td>
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</table>

### IV.

**TW = -5.84**

- 0.27
+ 0.71

<table>
<thead>
<tr>
<th>Year</th>
<th>1234</th>
</tr>
</thead>
<tbody>
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<td>TC</td>
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<td>0.480</td>
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<tr>
<td>0.539</td>
<td>0.539</td>
</tr>
<tr>
<td>0.543</td>
<td>0.543</td>
</tr>
<tr>
<td>0.518</td>
<td>0.518</td>
</tr>
<tr>
<td>0.493</td>
<td>0.493</td>
</tr>
<tr>
<td>0.493</td>
<td>0.493</td>
</tr>
</tbody>
</table>
### III. Indirect Business Tax

\[ TX = -7.5578 + 2.1879 DMY_{TX} + 0.1014 GNP \]

*(DMY\textsubscript{TX})*

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>-1.37</td>
<td>-1.23</td>
<td>-1.10</td>
<td>-1.42</td>
</tr>
<tr>
<td>1967</td>
<td>-1.37</td>
<td>-1.23</td>
<td>-1.28</td>
<td>-1.14</td>
</tr>
<tr>
<td>1968</td>
<td>-1.46</td>
<td>-1.14</td>
<td>-0.87</td>
<td>-0.69</td>
</tr>
<tr>
<td>1969</td>
<td>-0.70</td>
<td>-0.70</td>
<td>-0.70</td>
<td>-0.70</td>
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<tr>
<td>1990</td>
<td>-0.70</td>
<td>-0.70</td>
<td>-0.70</td>
<td>-0.70</td>
</tr>
</tbody>
</table>

### IV. Contributions for Social Insurance

\[ TW = -5.8424 + 0.1552 (t - 4) + 0.0286 UINS\textsubscript{RT} EHH \]

\[ -0.2765 OASI\textsuperscript{FR-RT} (OASI\textsubscript{RA} EHH - WSS) \]

\[ + 0.7199 OASI\textsuperscript{FR-RT} OASI\textsubscript{RA} EHH + DMY\textsubscript{CR} \]

*(DMY\textsubscript{CR})*

<table>
<thead>
<tr>
<th>Years</th>
<th>OASI\textsuperscript{FR-RT}</th>
<th>OASI\textsubscript{RA}</th>
<th>UINS\textsubscript{RT}</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>1967</td>
<td>0.079</td>
<td>6.6</td>
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<tr>
<td>1968</td>
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<tr>
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<td>0.086</td>
<td>7.8</td>
<td>3.1</td>
</tr>
<tr>
<td>1970</td>
<td>0.087</td>
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<td>3.1</td>
</tr>
<tr>
<td>1971-72</td>
<td>0.094</td>
<td>7.8</td>
<td>3.1</td>
</tr>
<tr>
<td>1973-75</td>
<td>0.103</td>
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<tr>
<td>1976-77</td>
<td>0.104</td>
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<tr>
<td>1978-79</td>
<td>0.105</td>
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<tr>
<td>1980-82</td>
<td>0.107</td>
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<td>3.1</td>
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<tr>
<td>1983-86</td>
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<td>3.1</td>
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<tr>
<td>1987</td>
<td>0.110</td>
<td>7.8</td>
<td>3.1</td>
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<tr>
<td>1988-90</td>
<td>0.111</td>
<td>7.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

*(DMY\textsubscript{CR})*

<table>
<thead>
<tr>
<th>Year</th>
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<th>2</th>
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</thead>
<tbody>
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<td>-0.9</td>
<td>0.1</td>
<td>0.2</td>
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<td>1967</td>
<td>0.1</td>
<td>0.8</td>
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<td>1.3</td>
</tr>
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<td>1968</td>
<td>-0.6</td>
<td>-0.1</td>
<td>0.4</td>
<td>0.9</td>
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<tr>
<td>1969</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1990</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
but was modified only slightly. Productivity was adjusted upward in the overhead employment functions. All the hours functions showed a consistent upward bias and were adjusted to maintain an approximately constant workweek. Productivity figures at the start and end of the twenty-five year control simulation and average annual rates of change are shown in Table 7.

Over the 1966–90 period the control solution exhibited very little fluctuation, especially after 1970. Smooth extrapolation of the exogenous variables most likely caused this steady growth. Fluctuations over the first four years are due largely to the use of some actual exogenous data and to the initial conditions.

Simulation of the slowdown attributable to the end of the Vietnam War and its aftermath resulted in fluctuations in 1970–71. Only a slowdown in growth, and no actual downturn, resulted with the unemployment rate rising to only 4.4 per cent.

Control solution time paths over the full twenty-five year simulation period for $P_{GNP}$, $GNP_{58}$, $I_{BUS_{EAF}}$, and $I_{EAF_{FR}}$ are shown in Charts 16–19, respectively. Values for the seventeen variables considered in this study are presented in Table 8 for the fourth quarters of 1965 and 1990, together with their annual rates of change (where relevant). Fifty stochastic simulations, using the first quarter of 1966 in these simulations, ran the same variance-covariance residuals from the same stochastic simulations plus and $E_{EH}$ product ($GNP_{58}$), the business gross fixed-farm residential constant.
Fifty stochastic simulations were run over the period from the first quarter of 1966 through the fourth quarter of 1990. In computing these simulations, random disturbance terms were introduced having the same variance-covariance and serial correlation properties as the residuals from the sample period equation estimates. While some of the stochastic simulations drifted, the majority fluctuated about the control path. The means of the stochastic simulation values were almost identical to their control solution values. Charts 16–19 show the control solution, a representative stochastic simulation, and the control solution plus and minus two standard errors for real gross national product (\(GNP^{58}\)), the implicit deflator for GNP (\(P_{CNP}\)), real nonfarm business gross fixed investment (\(I_{BUS^{58}}^{AF}\)), and real new private nonfarm residential construction (\(P_{NFR}^{AF}\)).

In order to determine whether the stochastic simulations produced

| TABLE 8 |
| Summary of Control Solution |

<table>
<thead>
<tr>
<th>Variable</th>
<th>1965:4</th>
<th>1990:4</th>
<th>Annual Rate of Change (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R_{MGBE}^{58})</td>
<td>4.160</td>
<td>6.942</td>
<td>–</td>
</tr>
<tr>
<td>(R_{MGBL}^{58})</td>
<td>4.350</td>
<td>5.155</td>
<td>–</td>
</tr>
<tr>
<td>(IBUS^{58}_{EAF})</td>
<td>45.2</td>
<td>141.0</td>
<td>4.7</td>
</tr>
<tr>
<td>(P_{GNP}^{58})</td>
<td>1.115</td>
<td>1.709</td>
<td>1.7</td>
</tr>
<tr>
<td>(O^{58}_{K} )</td>
<td>63.4</td>
<td>114.6</td>
<td>2.4</td>
</tr>
<tr>
<td>(I_{NFR}^{58})</td>
<td>23.3</td>
<td>55.4</td>
<td>3.5</td>
</tr>
<tr>
<td>(Y_{F} )</td>
<td>558.4</td>
<td>2088.0</td>
<td>5.4</td>
</tr>
<tr>
<td>(Z_{B} )</td>
<td>80.3</td>
<td>372.3</td>
<td>6.3</td>
</tr>
<tr>
<td>(GNP )</td>
<td>710.0</td>
<td>2779.8</td>
<td>5.6</td>
</tr>
<tr>
<td>(GNP^{58} )</td>
<td>636.6</td>
<td>1626.9</td>
<td>3.8</td>
</tr>
<tr>
<td>(RU )</td>
<td>0.041</td>
<td>0.039</td>
<td>–</td>
</tr>
<tr>
<td>(C^{58} )</td>
<td>409.2</td>
<td>1075.9</td>
<td>3.9</td>
</tr>
<tr>
<td>(\Delta INV^{58}_{EAF} )</td>
<td>8.1</td>
<td>10.1</td>
<td>–</td>
</tr>
<tr>
<td>(B )</td>
<td>5.7</td>
<td>-0.3</td>
<td>–</td>
</tr>
<tr>
<td>(EHH )</td>
<td>71.81</td>
<td>100.97</td>
<td>1.4</td>
</tr>
<tr>
<td>(H )</td>
<td>39.93</td>
<td>38.59</td>
<td>–</td>
</tr>
<tr>
<td>(RWSS )</td>
<td>5.691</td>
<td>16.283</td>
<td>4.3</td>
</tr>
</tbody>
</table>
CHART 16

GNP^58
Gross National Product in 1958 Dollars

CHART 17

P_{exp}
Implicit Price Deflator for Gross National Product
CHART 17

Implicit Price Deflator for Gross National Product

---

CHART 18

$I_{BUSXMF}$
Nonagricultural Business Gross Investment

Billion 1958 dollars

- Control solution
- Control + 2 standard deviations
- Representative stochastic simulation

CHART 19

$I_{NPXFR}$
New Private Nonfarm Residential Construction in 1958 Dollars

Billion 1958 dollars

- Control solution
- Control + 2 standard deviations
CHART 19

New Private Nonfarm Residential Construction in 1958 Dollars
cyclical movements similar to those observed in historical data, spectral analysis was applied to the fifty series generated for each of these four variables. This required the removal of trends in the series. Denoting the original stochastically generated series as $Y_s$, the control solution as $Y_c$, and $t$ as a time index, the detrended series, $X$, may be represented by

$$X_t = Y_{s,t} - a - bY_{c,t} - ct,$$ for $t = 1966:1, \ldots, 1990:4$

where $a$, $b$ and $c$ are determined by ordinary least squares regressions of $Y_{s,t}$ on $Y_{c,t}$ and $t$. The effectiveness of this detrending procedure was tested by comparing the means and variances of $X_t$ computed over the first and second halves of the period first quarter of 1966 through the fourth through the fourth

CHART 20

*Average Spectra for Fifty Real National Product Series*

[Diagram of Average Spectra for Fifty Real National Product Series]
historical data, spectral
for each of these four
the series. Denoting
, the control solution
X, may be represented

. . . . 1990:4

it squares regressions
detrending procedure
ences of X, computed
first quarter of 1966


duct Series

through the fourth quarter of 1990. In almost all cases, the two sub-
sample means and variances were not significantly different.\textsuperscript{15}

Average spectral densities are shown for each of the four series
in Charts 20–23. Chart 24 shows frequency counts of the most prom-
inent spectral peaks in the fifty series. A Parzen window and a lag
length of 40 were used for all spectral calculations.\textsuperscript{16} All the average

\textsuperscript{15} The t- and F-tests were used to test equality of the means and variances, respec-
tively. Even though an implicit normality assumption was required, especially for the
F-test, no test for normality was made.

\textsuperscript{16} C. W. J. Granger and M. Hatanaka, \textit{Spectral Analysis of Economic Time Series}
CHART 22

Average Spectra for Fifty Nonfarm Business Gross Fixed Investment Series
CHART 23
Average Spectra for Fifty Real New Private Nonfarm Residential Construction Series
spectra have their high and all exhibit minor (less than one year) reflect seasonal fluctuate and exhibits peaks at approximately six quarter cycle is not obvious individual spectra shows series — in six series that (24). Real fixed nonfixed any significant cycles central peaks for real almost all lie in the year cycle lengths as $\hat{p}_{GNP}$, the most prominent year range.

5 CONCLUSION

In the present, 1969 period properties six model tracks trends points and cyclical model portrays the

Judging by root improved complete problem areas basically; and prices. But even values have been rein

Twenty-five year the sample period found that the none on the values chose these, endogenous historical experience
spectra have their highest power at low frequencies (long cycle length) and all exhibit minor cyclical movements at the highest frequencies (less than one year cycle length). These latter movements probably reflect seasonal fluctuations. The average spectra for real GNP also exhibits peaks at approximately four and six quarters. $P_{\text{GNP}}$ tends to exhibit both six quarter and three year cycles. While the three year cycle is not obvious in its average spectra, examination of the individual spectra shows that the cycle occurs in twenty-six of the fifty series—in six series the three year cycle was most prominent (see Chart 24). Real fixed nonfarm business investment ($I_{\text{BBUSEA}}^{\text{a}}$) does not exhibit any significant cycles of intermediate length. The most prominent spectral peaks for real private nonfarm residential construction ($I_{\text{CNFR}}^{\text{a}}$) almost all lie in the five to ten year cycle length range—five to seven year cycle lengths are the most common. For the average spectra of $I_{\text{CNFR}}^{\text{a}}$, the most prominent spectral peak also occurs in the five to seven year range.

5 CONCLUSION

The present, 1969 version of the Brookings Model exhibits sample period properties similar to the earlier Fromm-Taubman version. The model tracks trends quite well. Also, although leads and lags at turning points and cyclical amplitudes are not always predicted accurately, the model portrays the actual cyclical fluctuations.

Judging by root mean square errors, the 1969 version exhibits improved complete system performance over earlier versions. Problem areas basically remain the same, notably inventories, wage rates, and prices. But even here differences between predicted and actual values have been reduced to some extent.

Twenty-five year nonstochastic and stochastic simulations beyond the sample period were run with the model for the first time. It was found that the nonstochastic path of the solution depends primarily on the values chosen for principal exogenous variables but that, given these, endogenous variables take values that accord well with prior historical experience. Although some had trend deviations, stochastic
solutions generally fluctuated about the nonstochastic control. A spectral analysis of these results revealed a general pattern of falling spectral densities from low to high frequencies without much evidence of distinct peaks except in isolated cases of highly cyclical variables. It might be said that the average spectral diagram exhibited the typical spectral shape of economic variables suggested by Granger. Analysis of the frequency distribution of spectral peaks did, however, reveal some short-run cyclical content for many of the variables.

APPENDIX A

CONSUMER DEMAND

\[ C_{\text{DEA}}^{58} \frac{N_R}{N_R} = -0.1378 + 0.2004 \frac{Y_D^{58}}{N_R} - 0.0150 \frac{P_{\text{DEA}}}{P_C} \]

\[ - 0.1499 \left[ \frac{K_{\text{DEA}}^{58}}{N_R} \right]^{-1} + 0.0014DMY_{55} \]

\[ R^2 = 0.986 \quad SE = 0.0028 \quad DW = 0.94 \]

\[ C_S^{58} \frac{N_R}{N_R} = 0.0430 + 0.0913 \frac{Y_D^{58}}{N_R} - 0.0723 \frac{P_{\text{CDM}}}{P_C} \]

\[ - 0.0903 \left[ \frac{K_{\text{CDM}}^{58}}{N_R} \right]^{-1} - 0.5262RU + 0.0214DMY_{55} \]

\[ + 0.0039[DMY_{STR}] \left[ \frac{Y_D^{58}}{N_R} \right] \]

\[ R^2 = 0.893 \quad SE = 0.0053 \quad DW = 1.77 \]

\[ C_{\text{FBP}}^{58} \frac{N_R}{N_R} = 0.4180 + 0.0655 \frac{Y_D^{58}}{N_R} - 0.1332 \frac{P_{\text{FBP}}}{P_C} \]

\[ 17 \text{ Ibid., pp. 55–59.} \]
stochastic control. A
eral pattern of falling
without much evidence
yclical variables. It
exhibited the typical
Granger. Analysis
did, however, reveal
variables.

\[ \hat{R}^2 = 0.923 \quad SE = 0.0032 \quad DW = 0.94 \]

\[ C_{NFB}^{\Delta} = \frac{0.3053 + 0.1451 Y_{FB}^{\Delta} - 0.2636 \frac{P_{CNEFB}}{P_C}}{R^2 - 0.923} \quad SE = 0.0030 \quad DW = 1.92 \]

\[ \hat{R}^2 = 0.989 \quad SE = 0.0030 \quad DW = 0.82 \]

RESIDENTIAL CONSTRUCTION

\[ \Delta U_{AVL_EAF} = -0.0035 - 0.0019[U_{AVL_EAF}]_t \]

\[ + 0.2620[0.25[U_{STSE_A}_1] - 0.50[U_{STSE_A}]_1] \]

\[ + 0.25[U_{STSE_A}]_3 \]

\[ \hat{R}^2 = 0.944 \quad SE = 0.0093 \quad DW = 0.93 \]

\[ U_{VAC_EAF} = U_{VAC_E_A}_1 + \Delta U_{AVL_EAF} - \Delta H_{EAF} \]

\[ U_{STSE_A} = 0.7343 + 0.6413[U_{STSE_A}]_1 \]

\[ - 0.0740 \left( \frac{1}{2} \right) \sum_{i=1}^{3} \left[ RM_{GBS3} \right]_t \quad SE = 0.0030 \quad DW = 1.77 \]

\[ \frac{P_{CNEFB}}{P_C} \]
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

\[ -0.0624 \frac{PM_{ICRD}}{P_{ICRFR}} \]

\( \bar{R}^2 = 0.924 \quad SE = 0.0469 \quad DW = 1.65 \) \( \text{(2.3)} \)

\( \text{(A.9)} \) \( HU_{SSTSEAF}^T = 0.6223[HU_{SSTSEAF}^T]_t - 0.0045 \left( \frac{1}{3} \right) \sum_{i=1}^{3} [RM_{GBS3}]_t \]

\( + 0.0002[\text{time-8}] + 0.0024 \left( \frac{1}{3} \right) \sum_{i=1}^{3} \left[ \frac{Y_d}{P_cHH_{EAF}} \right]_t \)

\( \bar{R}^2 = 0.682 \quad SE = 0.0044 \quad DW = 1.85 \) \( \text{(A.10)} \)

\( \text{(A.15)} \) \( \frac{PM_{ICBD}}{P_{ICNFR}} = \left[ \frac{PM}{P} \right] \)

\( \text{(A.16)} \) \( I_{E}^{gb} \)

\( \text{(A.17)} \) \( I_{C}^{gb} \)

\( \text{(A.18)} \)

\( \text{(A.19)} \)

\( \text{(A.20)} \) \( I_{E}^{gb} = \)

\( \bar{R}^2 = 0.983 \quad SE = 0.0193 \quad DW = 1.74 \)

\( \text{(A.11)} \)

\( HU_{SSTSEAF}^T = HU_{SSTSEAF}^T + HU_{SSTSEAF}^T \)

\( \text{(A.12)} \)

\( HU_{SSTSEAF}^T = HU_{SSTSEAF}^T + HU_{SSTSEAF}^T \)

\( \text{(A.13)} \) \( \frac{PM_{ICRD}}{P_{ICNFR}} = 1.1205 + 0.7296 \left[ \frac{PM_{ICRD}}{P_{ICNFR}} \right]_t \)

\( + 0.3559 \left( \frac{1}{3} \right) \sum_{i=1}^{3} \left[ \frac{Y_d}{P_cHH_{EAF}} \right]_t \)

\( \bar{R}^2 = 0.918 \quad SE = 0.1730 \quad DW = 2.82 \)

\( \text{(A.14)} \) \( \frac{PM_{ICRD}}{P_{ICNFR}} = 4.3574 + 0.6390 \left[ \frac{PM_{ICRD}}{P_{ICNFR}} \right]_t \)
\[ (A.15) \quad \frac{PM_{ICBD}}{PICNFR} = \left[ \frac{PM_{ICBD}}{PICNFR} (HU_{STSEAF}^1) + \frac{PM_{ICBD}}{PICNFR} (HU_{STSEAF}^2) \right] - \frac{1}{HU_{STSEAF}} \]

\[ (A.16) \quad I_{CNFR}^{EAF} = 0.41 \left[ \frac{PM_{ICBD}}{PICNFR} HU_{STSEAF}^1 \right] + 0.49 \left[ \frac{PM_{ICBD}}{PICNFR} HU_{STSEAF}^2 \right] + 0.10 \left[ \frac{PM_{ICBD}}{PICNFR} HU_{STSEAF}^2 \right] \]

\[ (A.17) \quad I_{CNFR}^{EAF} = 2.6589 + 0.1773[HU_{AVG, EAF}]^{-1} \]

\[ (A.18) \quad I_{CNFR}^{EAF'} = I_{CNFR}^{EAF} + I_{CNFR}^{EAF'} \]

\[ (A.19) \quad I_{CNFR}^{EAF} = (DMY_{18}) I_{CNFR}^{EAF} \]

\[ (A.20) \quad I_{YD} = -2.2879 + 0.4240 \left( \frac{1}{8} \sum_{i=1}^{8} \left[ \frac{Y_D}{(P_C)(HH_{EAF})} \right] \right) + 0.8148[I_{YD}^{EAF}]^{-1} \]

\[ \tilde{R}^2 = 0.976 \quad SE = 0.0913 \quad DW = 1.77 \]
(A.21) $\Delta INV_{M}^{\alpha} = -0.8912 + 0.0613[SF_{M}^{\beta} + GNP_{M}^{\delta}]$
\hspace{1cm} (0.3) \hspace{1cm} (1.9) \\
\hspace{1cm} - 0.2922[INV_{M}^{\beta}]_{-1} + 0.2846[INV_{M}^{\beta}]_{-1}$
\hspace{1cm} (1.7) \hspace{1cm} (2.7) \\
\hspace{1cm} + 0.1090[O_{M}^{\alpha}]_{-1} + 0.0427[O_{M}^{\alpha}]_{-1}$
\hspace{1cm} (4.8) \hspace{1cm} (1.9) \\
$R^2 = 0.725$ \hspace{0.5cm} $SE = 1.2391$ \hspace{0.5cm} $DW = 1.93$

(A.22) $\Delta INV_{NX}^{\alpha} = -0.2809 + 0.0747[SF_{NX}^{\beta} - 0.5350[INV_{NX}^{\beta}]_{-1}$
\hspace{1cm} (0.1) \hspace{1cm} (2.7) \hspace{1cm} (2.2) \\
\hspace{1cm} + 0.2480[INV_{NX}^{\beta}]_{-1} + 0.7117[O_{NX}^{\alpha}]_{-1}$
\hspace{1cm} (2.1) \hspace{1cm} (3.0) \\
$R^2 = 0.310$ \hspace{0.5cm} $SE = 0.7103$ \hspace{0.5cm} $DW = 1.94$

(A.23) $\Delta [INV_{F}^{\beta} - INV_{CAR}^{\beta}] = -5.659 + 0.0750[SF_{F}^{\beta} - \frac{WS_{G}}{P_{G}} - C_{S}^{\beta}]$
\hspace{1cm} (2.9) \hspace{1cm} (2.7) \\
\hspace{1cm} - 0.4559[INV_{F}^{\beta} - INV_{CAR}^{\beta}]_{-1}$
\hspace{1cm} (2.2) \\
$R^2 = 0.182$ \hspace{0.5cm} $SE = 1.3300$ \hspace{0.5cm} $DW = 1.69$

(A.24) $\Delta INV_{CAR}^{\delta} = 0.9420 + 0.3642[SF_{CAR}^{\beta} - 0.1649[C_{BAR}^{\delta}]_{-1}$
\hspace{1cm} (1.0) \hspace{1cm} (4.3) \hspace{1cm} (1.6) \\
\hspace{1cm} - 1.019[INV_{CAR}^{\beta}]_{-1}$
\hspace{1cm} (2.8) \\
$R^2 = 0.366$ \hspace{0.5cm} $SE = 0.8516$ \hspace{0.5cm} $DW = 1.93$

(A.25) $\Delta INV_{D_{t}}^{\alpha} = -0.6917 + 0.0071[SF_{D_{t}}^{\beta} - \frac{WS_{G}}{P_{G}}]$
\hspace{1cm} (2.0) \hspace{1cm} (2.5) \\
\hspace{1cm} - 0.3209[INV_{D_{t}}^{\beta}]_{-1} + 0.4485[INV_{D_{t}}^{\beta}]_{-1}$
\hspace{1cm} (2.0) \hspace{1cm} (4.0) \\
$R^2 = 0.435$ \hspace{0.5cm} $SE = 0.2616$ \hspace{0.5cm} $DW = 2.20$
SIMULATIONS WITH BROOKINGS MODEL

\[ INV_j^{\Delta} = \frac{1}{4} \Delta INV_j^{\Delta} + [INV_j^{\Delta}]_{-1} \]
\[ j = MD, MN, T-CAR, CAR, O^o4 \]

ORDERS

\[ O_{MD}^{\Delta} = 264.692 + 0.9950[S F_j^{\Delta} + G N P_j^{\Delta}] \]
\[ + 4.0568 \sum \frac{D O D_{NP j}}{P_{GR}} - 160.57 \left( \frac{1}{J C A P_{MD}} \right) \]
\[ - 1.0381 [O_{MD}^{\Delta}]_{-1} \]
\[ (6.2) \quad (10.1) \]
\[ R^2 = 0.936 \quad SE = 7.5083 \quad DW = 0.96 \]

\[ O_{MN}^{\Delta} = 4 \left[ O_{MN}^{\Delta} - [O_{MN}^{\Delta}]_{-1} \left( \frac{W P I_{MN}}{W P I_{MN}} \right) \right] + 2.5650 X_{MN}^{\Delta} \]
\[ - 0.6959 \Delta INV_{MN}^{\Delta} + 0.3478 \text{[time-4]} + 7.1606 \]
\[ (A.28) \]

\[ O_{MD}^{\Delta} = [O_{MD}^{\Delta}]_{-1} \left( \frac{W P I_{MD}}{W P I_{MD}} \right) + 0.25 O_{MD}^{\Delta} \]
\[ - 0.25 \left[ 37.1023 + 1.8387 X_{MD}^{\Delta} \right] \]
\[ (A.29) \]

\[ \Delta O_{MN}^{\Delta} = 17.4029 + 0.0255 \Delta O_{MN}^{\Delta} + 0.0106 [O_{MN}^{\Delta}]_{-1} \]
\[ + 3.0671 [W P I_{MN}]_{-1} - 9.9576 \left( \frac{W P I_{MN}}{W P I_{MN}} \right) \]
\[ (1.3) \quad (2.3) \]
\[ R^2 = 0.557 \quad SE = 0.1360 \quad DW = 2.10 \]
(A.31) $I_{BUSMD}^{H} = -19.8370 + 7.7521[DMY_{23} - DMY_{22}]$

\[= 19.8370 + 10.3800 - 0.1567 t \times DMY_{22} \pm (5.1) (2.0) \]

\[+ [0.2300 - 0.110 (DMY_{23} - DMY_{22})] \sum_{i=0}^{2} A_i [X_{MB}^{H}]_{i-2} \pm (6.5) (2.3) \]

\[- 0.366 \sum_{i=0}^{7} A_i [RM_{GIBL}]_{i-2} + 10.4768 \begin{bmatrix} X_{MB}^{H} \\ X_{KMB}^{H} \end{bmatrix} \pm (5.3) \]

\[R^2 = 0.817 \quad SE = 0.5051 \quad DW = 0.56 \]

(A.33) $I_{BUSR}^{H} = \begin{bmatrix} X_{MB}^{H} \\ X_{KMB}^{H} \end{bmatrix} = \begin{bmatrix} 3.9778 \\ -11.2909 \end{bmatrix} [DMY_{23} - DMY_{22}]$

\[= 3.9778 - 11.2909 [DMY_{23} - DMY_{22}] \pm (3.3) (5.9) \]

\[+ [9.6082 - 0.1369 t] DMY_{22} \pm (1.5) (1.5) \]

\[+ [0.3332 + 0.1641 (DMY_{23} - DMY_{22})] \sum_{i=0}^{7} A_i [X_{MB}^{H}]_{i-2} \pm (9.1) (5.3) \]

\[- 1.4847 \sum_{i=0}^{7} A_i [RM_{GIBL}]_{i-2} - 0.3533 [K_{E}^{H}]_{i-1} \pm (7.2) (5.8) \]

\[R^2 = 0.931 \quad SE = 0.2068 \quad DW = 1.10 \]

(A.37) $EX^{H} = 1$
\[ Y_{22} \] = 7.1978 + 0.0672 \sum_{i=0}^{7} A_i [X^{58}_{MD}]_{i-2} \\
\quad - 1.4991 \sum_{i=0}^{7} A_i [RM_{GBL}]_{i-2} + 21.4221 \left[ \frac{X^{58}_{MD}}{X^{58}_{KMD}} \right]_{-1} \\
\quad - 0.7015 [K^{38}_{N}]_{-1} + 0.0971 \left( \frac{1}{2} \sum_{i=1}^{2} [X^{58}_{MD}]_{i-1} \right) \\
\quad R^2 = 0.930 \quad SE = 0.3189 \quad DW = 0.85

Foreign Trade

\[ M_N^{38} + M_F^{38} = 4.9227 - 5.0961 \frac{PM_{XSs}}{P_C} + 0.0229 Y^{38}_{D} \]
\quad + 0.5508 [M_N^{38} + M_F^{38}]_{-1} + 0.5789 DMY_{DKSTR} \\
\quad R^2 = 0.983 \quad SE = 0.3521 \quad DW = 1.91

\[ M_D^{38} = 1.9971 + 0.569 X^{58}_{MD} - 3.5042 \frac{PM_{NB}}{PX_{MD}} + 0.4622 [M_D^{38}]_{-1} \\
\quad + 0.3438 DMY_{DKSTR} + 0.5395 DMY_{STLWTZ} \\
\quad R^2 = 0.987 \quad SE = 0.1966 \quad DW = 1.95

\[ EX^{38} = 19.9535 - 20.5046 \frac{P_{EX}}{P_{EXW}} + 0.6204 [EX^{38}]_{-1} \]
\quad R^2 = 0.998 \quad SE = 0.0172 \quad DW = 1.95
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\[ + 0.1303[EX^{58} - EX^{58}] + 1.3051 \Delta M_{DKSTR1} \]

\[ (4.7) \quad (4.6) \]

\[ \hat{R}^2 = 0.972 \quad SE = 0.9543 \quad DW = 2.13 \]

GOVERNMENT TAXES AND TRANSFER PAYMENTS

(A.38) \[ TP = -14.5008 + 13.7186 \Delta M_{TP} + 0.1613 Y_p \]

\[ (12.3) \quad (1.7) \quad (51.7) \]

\[ - 0.0392[\Delta M_{TP} Y_p] \]

\[ (2.5) \]

\[ \hat{R}^2 = 0.989 \quad SE = 1.0715 \quad DW = 1.08 \]

(A.39) \[ TX = -7.5578 + 2.1879 \Delta M_{TX} + 0.1014 GNP \]

\[ (15.9) \quad (11.3) \quad (100.4) \]

\[ \hat{R}^2 = 0.997 \quad SE = 0.5355 \quad DW = 1.10 \]

(A.40) \[ TC = 0.9303 - 0.6567 \Delta M_{TC} + 0.8360[TC_{RT} Z_{RT}] \]

\[ (2.5) \quad (4.1) \quad (54.5) \]

\[ \hat{R}^2 = 0.993 \quad SE = 0.3176 \quad DW = 0.45 \]

(A.41) \[ TW = -5.8424 + 0.1552[t - 4] \]

\[ (8.7) \quad (11.0) \]

\[ + 0.7199[OASI_{RT} OASI_{PR} OASI_{RB}] EHH \]

\[ (20.1) \]

\[ - 0.2765[OASI_{RT} OASI_{PR} OASI_{RB}] EHH - WSS \]

\[ (8.0) \]

\[ + 0.0286 UN S_{RT}[EHH] \]

\[ (7.2) \]

\[ \hat{R}^2 = 0.999 \quad SE = 0.2233 \quad DW = 0.71 \]

(A.42) \[ V_{USCF} = -1.3555 + 0.9403 U + 0.0127[GNP_{58} - GNP_{58}] P_{GNO} \]

\[ (5.4) \quad (8.7) \quad (2.6) \]

\[ \hat{R}^2 = 0.930 \quad SE = 0.2379 \quad DW = 1.04 \]
SIMULATIONS WITH BROOKINGS MODEL

(4.33) \[ V_c = V_{EHI} + V_{OASIF} + V_{VET} + V_{DG}. \]

**PRODUCTION FUNCTIONS**

(4.4) \[ \Delta \ln MH_{PM} = 0.3246 + 0.7085 \ln X_{0}^{MP} \]
\[ - 0.1426 \ln [K_{M/MP}] - \ln X_{0}^{MP} \]
\[ - 0.3963 \ln [MH_{PM}] - \ln X_{0}^{MP} \]
\[ - 0.2749 \ln [X_{10}^{MP}] \]
\[ - 0.0050[\tau - 8] - 0.8675 \ln [MH_{PM}] - \ln X_{0}^{MP} \]
\[ + DMY_4[3.8371 - 0.1102(\tau - 8)] \]
\[ + 0.0007881(\tau - 8)^2 \]
\[ \bar{R}^2 = 0.941 \quad SE = 0.0078 \quad DW = 1.52 \]

(4.5) \[ \Delta \ln MH_{PM} = 0.5880 + 0.7264 \ln X_{10}^{MP} - 0.3283 \ln [K_{M/MP}] - \ln X_{0}^{MP} \]
\[ - 0.0050[\tau - 8] - 0.8675 \ln [MH_{PM}] - \ln X_{0}^{MP} \]
\[ + DMY_4[3.8371 - 0.1102(\tau - 8)] \]
\[ + 0.0007881(\tau - 8)^2 \]
\[ \bar{R}^2 = 0.861 \quad SE = 0.0052 \quad DW = 1.61 \]

(4.6) \[ \ln MH_{PT} = 0.2195 + 0.1780 \ln X_{p}^{GP} + 0.1659 \ln [X_{10}^{GP}] \]
\[ - 0.0050[\tau - 8] - 0.8675 \ln [MH_{PM}] - \ln X_{0}^{MP} \]
\[ + DMY_4[3.8371 - 0.1102(\tau - 8)] \]
\[ + 0.0007881(\tau - 8)^2 \]
\[ \bar{R}^2 = 0.861 \quad SE = 0.0052 \quad DW = 1.61 \]
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

\[-0.0022t + 0.4412 \ln [MH_{nt}] - 1\]  
\((4.8)\) \((4.5)\)

\[\hat{R}^2 = 0.984\] \[SE = 0.0040\] \[DW = 2.19\] \[\rho_1 = 0.594\]

(A.47) \[\ln MH_c = -1.0240 + 0.6899 \ln X_t^{38} - 0.00044t\]  
\((3.5)\) \((5.2)\) \((1.1)\)

+ 0.3848 \ln [MH_c] - 1 \n\((3.5)\)

\[\hat{R}^2 = 0.899\] \[SE = 0.0185\] \[DW = 1.90\] \[\rho_1 = 0.2574\]

(A.48) \[\ln MH_r = -0.4213 + 0.4172 \ln X_t^{38} + 0.1157 \ln [X_t^{38}] - 1\]  
\((1.5)\) \((10.5)\) \((1.9)\)

\[\hat{R}^2 = 0.982\] \[SE = 0.0092\] \[DW = 2.46\] \[\rho_1 = 0.7326\]

(A.49) \[\ln MH_0 = -0.7940 + 0.4788 \ln X_t^{38} + 0.1260 \ln [X_t^{38}] - 1\]  
\((3.0)\) \((4.9)\) \((0.9)\)

\[\hat{R}^2 = 0.999\] \[SE = 0.0028\] \[DW = 1.80\] \[\rho_1 = 0.4653\]

(A.50) \[\ln E_{n, ud} = -0.1553 + 0.0461 \ln X_t^{38} + 0.9495 \ln [E_{n, ud}] - 1\]  
\((3.3)\) \((3.7)\) \((41.3)\)

\[\hat{R}^2 = 0.993\] \[SE = 0.0084\] \[DW = 0.36\]

(A.51) \[\ln E_{n, ms} = -0.1363 + 0.0473 \ln X_t^{38} + 0.9046 \ln [E_{n, ms}] - 1\]  
\((4.2)\) \((4.5)\) \((43.3)\)

\[\hat{R}^2 = 0.998\] \[SE = 0.0026\] \[DW = 1.85\]

(A.52) \[\ln E_{n, r} = -0.6613 + 0.2262 \ln X_t^{38} + 0.0011t\]  
\((5.2)\) \((6.6)\) \((2.5)\)

\[\hat{R}^2 = 0.999\] \[SE = 0.0028\] \[DW = 1.80\] \[\rho_1 = 0.4653\]
SIMULATIONS WITH BROOKINGS MODEL • 265

\[ 2.19 \quad \rho_1 = 0.5940 \]

\[ 0.00044t \]

\( (1.1) \)

\[ 1.90 \quad \rho_1 = 0.2574 \]

\[ 1157 \ln \left[ X_{R}^{m} \right]_{-1} \]

\( (1.9) \)

\[ \beta_{1} \]

\[ 2.46 \quad \rho_1 = 0.7326 \]

\[ 1260 \ln \left[ X_{O}^{m} \right]_{-1} \]

\( (1.9) \)

\[ \beta_{1} \]

\[ 1.80 \quad \rho_1 = 0.4653 \]

\[ 495 \ln \left[ E_{O,MD} \right]_{-1} \]

\( (1.3) \)

\[ 0.084 \quad DW = 0.36 \]

\[ 0.046 \ln \left[ E_{O,MD} \right]_{-1} \]

\( (3.3) \)

\[ 0.026 \quad DW = 1.85 \]

\[ 0.0011t \]

\( (2.5) \)

\[ + 0.5801 \ln \left[ E_{O,MD} \right]_{-1} \]

\( (8.1) \)

\[ \tilde{R}^2 = 0.998 \quad SE = 0.0053 \quad DW = 2.12 \]

\[ H_{P,MD} = 37.5601 + 0.0744X_{R}^{m} + 0.0416 \Delta X_{R}^{m} \]

\( (125.8) \quad (14.0) \quad (3.3) \)

\[ - 1.0769RW_{SS,MD} \]

\( (7.5) \)

\[ \tilde{R}^2 = 0.859 \quad SE = 0.2770 \quad DW = 0.96 \]

\[ H_{PMN} = 37.6692 + 0.1319X_{O}^{m} + 0.1190 \Delta X_{O}^{m} \]

\( (178.7) \quad (10.3) \quad (3.8) \)

\[ - 2.4588RW_{SS,PMN} \]

\( (8.8) \)

\[ \tilde{R}^2 = 0.803 \quad SE = 0.185 \quad DW = 1.13 \]

\[ H_{P} = 42.8931 + 0.0170X_{R}^{m} + 0.0108 \Delta X_{R}^{m} - 2.5898RW_{SS,P} \]

\( (379.5) \quad (2.5) \quad (0.6) \quad (9.7) \)

\[ \tilde{R}^2 = 0.965 \quad SE = 0.1069 \quad DW = 0.79 \]

\[ H_{C} = 36.0767 + 0.0764X_{C}^{m} + 0.2181 \Delta X_{C}^{m} - 0.2527RW_{SS,C} \]

\( (30.1) \quad (1.0) \quad (1.5) \quad (1.3) \)

\[ \tilde{R}^2 = 0.053 \quad SE = 0.3891 \quad DW = 1.50 \]

\[ H_{R} = 39.7580 + 0.0816X_{R}^{m} + 0.0657 \Delta X_{R}^{m} - 0.8953RW_{SS,R} \]

\( (541.7) \quad (13.5) \quad (4.0) \quad (9.6) \)

\[ \tilde{R}^2 = 0.915 \quad SE = 0.0760 \quad DW = 1.85 \]

\[ MH_{ij} = (40)(0.052)E_{ij} \quad j = MD, MN, T \]

\[ (A.53) \]

\[ MH_{i} = MH_{ij} + MH_{ij} \quad j = MD, MN, T \]

\[ (A.54) \]
(A.60) \[ E_{P_j} = \frac{MH_{P_j}}{(0.052)H_{P_j}} \]
\[ j = MD, MN, T \]

(A.61) \[ E_j = \frac{MH_j}{(0.052)H_j} \]
\[ j = C, R, O \]

PRICES AND WAGE RATES

(A.62) \[ ULC^i_j = \frac{1}{4} \sum_{i=0}^{1} [RWSS]_{-i} \]
\[ j = MD, MN, T, C, R, O \]

(A.63) \[ ULC_j = \frac{WSS_j}{X_j^{SS}} \]
\[ j = MD, MN, T, C, R, O \]

(A.64) \[ WPI_{MD} = -0.1632 + 0.6688[ULC_{MD} - ULC_{MD}] \]
\[ (5.2) \quad (7.5) \]
\[ + 1.1594ULC_{MD} + 0.2314 J_{CAP_{MD}} + 0.1393 PR_{MD} \]
\[ (38.7) \quad (7.0) \quad (3.6) \]
\[ \hat{R}^2 = 0.982 \quad SE = 0.0074 \quad DW = 0.61 \]

(A.70)

(A.71)

(A.72) \[ PX_r = 0.2 \]
\[ (6) \]

(A.73) \[ WPI_{MN} = -0.0228 + 0.6818[ULC_{MN} - ULC_{MN}] \]
\[ (0.3) \quad (4.9) \]
\[ + 0.6844ULC_{MN} + 0.3118 J_{CAP_{MN}} + 0.2995 PR_{MN} \]
\[ (18.3) \quad (6.6) \quad (9.8) \]
\[ \hat{R}^2 = 0.917 \quad SE = 0.0048 \quad DW = 0.77 \]
SIMULATIONS WITH BROOKINGS MODEL • 267

(A.66) \[ PX_{MD} = 0.0443 + 1.0987 WPI_{MD} - 0.1507 PR_{MD} \]
\[ (1.2) \quad (40.2) \quad (4.9) \]
\[ R^2 = 0.972 \quad SE = 0.0103 \quad SW = 1.85 \]

(A.67) \[ PX_{MN} = -0.7470 + 0.9675 [ULC_{MN} - ULC_{MN}'] \]
\[ (3.6) \quad (3.7) \]
\[ + 1.7518 ULC_{MN} + 0.2225 J_{CAP, MN} + 0.0108 H_{PMN} \]
\[ (25.1) \quad (2.1) \quad (1.6) \]
\[ R^2 = 0.947 \quad SE = 0.0087 \quad DW = 0.71 \]

(A.68) \[ PX_T = 0.1809 + 0.9021 [ULC_T - ULC_T'] + 1.4527 ULC_T' \]
\[ (6.5) \quad (3.4) \quad (28.7) \]
\[ - 0.4160 \left[ \frac{INV^{18}_R}{X^{18}_R} - \frac{1}{12} \sum_{i=0}^{11} \left( \frac{INV^{18}_R}{X^{18}_R} \right)_{-1} \right] \]
\[ (1.7) \]
\[ R^2 = 0.953 \quad SE = 0.0104 \quad DW = 0.94 \]

(A.69) \[ PX_C = 0.1046 + 1.4501 [ULC_C - ULC_C'] + 1.2301 ULC_C' \]
\[ (11.2) \quad (24.7) \quad (99.3) \]
\[ R^2 = 0.997 \quad SE = 0.0076 \quad DW = 0.39 \]

(A.70) \[ UCCA^R_R = \frac{1}{12} \sum_{i=0}^{11} \left( \frac{CCA_R}{X^{18}_R} \right)_{-1} \]

(A.71) \[ UCCA_R = \frac{CCA_R}{X^{18}_R} \]

(A.72) \[ PX_R = 0.2699 + 0.8097 [ULC_R - ULC_R'] + 0.7517 ULC_R' \]
\[ (6.7) \quad (7.2) \quad (10.2) \]
\[ + 1.5635 [UCCA_R - UCCA_R'] + 2.3607 UCCA_R' \]
\[ (5.8) \quad (27.4) \]
\[ R^2 = 0.972 \quad SE = 0.0064 \quad DW = 1.03 \]
(A.73) \[ PX_0 = 0.1483 + 1.2332[U LC_0 - U LC_0^0] + 2.3036U LC_0^0 \]
\[
\begin{align*}
\text{R}^2 &= 0.997 \\
SE &= 0.0046 \\
DW &= 0.62
\end{align*}
\]

(A.74)
\[
\frac{[RWSS_{MD} - RWSS_{MD-4}]}{RWSS_{MD-4}} = 0.0124 + 0.00073 \frac{4}{\sum_{i=0}^{4} [RU]_{-i}} - 0.0069DMY_{GP}
\]
\[
\begin{align*}
R^2 &= 0.649 \\
SE &= 0.0084 \\
DW &= 1.21
\end{align*}
\]

(A.75)
\[
\frac{[RWSS_{MN} - RWSS_{MN-4}]}{RWSS_{MN-4}} = 0.0084 + 0.0012 \frac{4}{\sum_{i=0}^{4} [RU]_{-i}} - 0.0055DMY_{GP}
\]
\[
\begin{align*}
R^2 &= 0.898 \\
SE &= 0.0039 \\
DW &= 2.41
\end{align*}
\]
\[
\begin{align*}
\text{(A.76)} & \quad \frac{\text{RWSS}_T - \text{RWSS}_{T-4}}{\text{RWSS}_{T-4}} = 0.0040 + 0.0016 \frac{1}{\text{RU}} - 0.0011 \text{DMY}_{CP} \\
& \quad + 0.5628 \frac{1}{4} \sum_{i=0}^{3} \left[ \frac{\text{CPI} - \text{CPI}_{-i}}{\text{CPI}_{-i}} \right]_{-i} \\
& \quad - 0.4628 \frac{\text{RWSS}_{T-4} - \text{RWSS}_{T-8}}{\text{RWSS}_{T-8}} \\
& \quad + 0.4239 \frac{\text{RWSS}_{T-1} - \text{RWSS}_{T-5}}{\text{RWSS}_{T-5}} \\
\tilde{R}^2 & = 0.794 \quad \text{SE} = 0.0049 \quad \text{DW} = 1.77
\end{align*}
\]

\[
\begin{align*}
\text{(A.77)} & \quad \frac{\text{RWSS}_C - \text{RWSS}_{C-4}}{\text{RWSS}_{C-4}} = 0.0277 - 0.0020 \text{DMY}_{GP} \\
& \quad + 0.9016 \frac{1}{4} \sum_{i=0}^{3} \left[ \frac{\text{CPI} - \text{CPI}_{-i}}{\text{CPI}_{-i}} \right]_{-i} \\
& \quad - 0.3480 \frac{\text{RWSS}_{C-4} - \text{RWSS}_{C-8}}{\text{RWSS}_{C-8}} \\
& \quad + 0.4060 \frac{\text{RWSS}_{C-1} - \text{RWSS}_{C-5}}{\text{RWSS}_{C-5}} \\
\tilde{R}^2 & = 0.511 \quad \text{SE} = 0.0164 \quad \text{DW} = 2.15
\end{align*}
\]

\[
\begin{align*}
\text{(A.78)} & \quad \frac{\text{RWSS}_R - \text{RWSS}_{R-8}}{\text{RWSS}_{R-4}} = 0.0283 \\
& \quad + 0.0008 \frac{1}{\text{RU}} - 0.0097 \text{DMY}_{GP} \\
& \quad + 0.5999 \frac{1}{4} \sum_{i=0}^{3} \left[ \frac{\text{CPI} - \text{CPI}_{-i}}{\text{CPI}_{-i}} \right]_{-i} \\
\tilde{R}^2 & = 0.632 \quad \text{SE} = 0.0152 \quad \text{DW} = 2.41
\end{align*}
\]
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

\[
-0.5782 \left( \frac{RWSS_{R-1} - RWSS_{R-3}}{RWSS_{R-3}} \right) \\
+ 0.4718 \left( \frac{RWSS_{R-1} - RWSS_{R-3}}{RWSS_{R-3}} \right)
\]

\[
\tilde{R}^2 = 0.731 \quad SE = 0.0055 \quad DW = 2.03
\]

\[
(A.79) \quad \frac{RWSS_0 - RWSS_{0-4}}{RWSS_{0-4}} = 0.0071
\]

\[
+ 0.0014 \left( \frac{1}{RU} - 0.0049DMYGP \right)
\]

\[
+ 0.2674 \left( \frac{1}{4} \sum_{i=0}^{3} \left( \frac{CPI - CPI_{-i}}{CPI_{-i}} \right) \right) - 1
\]

\[
- 0.3346 \left( \frac{RWSS_{0-1} - RWSS_{0-8}}{RWSS_{0-8}} \right)
\]

\[
+ 0.3914 \left( \frac{RWSS_{0-1} - RWSS_{0-5}}{RWSS_{0-5}} \right)
\]

\[
\tilde{R}^2 = 0.587 \quad SE = 0.0068 \quad DW = 1.45
\]

**FINAL DEMAND AND GROSS PRODUCT ORIGINATING**

\[
(A.80) \quad F_{y0} = -29.1841 + 1.2973\Delta INV_{y0} + 0.4711\Delta INV_{y3}
\]

\[
(4.3) \quad (7.2) \quad (2.0)
\]

\[
+ 0.6235EX^{28} + 0.8437[C_0^{28} + I_{02E}]
\]

\[
(2.3) \quad (9.2)
\]

\[
+ 1.3531G_{00}^{58} + 9.6516DMY_{24} - 2.8153DMY_{25}
\]

\[
(4.8) \quad (7.2) \quad (2.5)
\]

\[
- 1.3382DMY_{DISTRI}
\]

\[
(1.5)
\]

\[
\tilde{R}^2 = 0.979 \quad SE = 2.1390 \quad DW = 1.26
\]
SIMULATIONS WITH BROOKINGS MODEL

(A.81) \[ F_{MN}^{98} = -11.8126 + 0.6936[C_{SF}^{98} + C_{SEF}^{98} + G_{R}^{98}] \]
\[ + 0.2670[DNV_{F}^{98} - DINV_{CAR}^{98}] + 0.5848DINV_{MN}^{98} \]
\[ \bar{R}^{2} = 0.985 \quad SE = 1.6287 \quad DW = 1.62 \quad \rho_{1} = 0.6534 \]

(A.82) \[ F_{C}^{98} = -17.0536 + 0.2087C_{DA}^{98} + 0.4179C_{DE}^{98} \]
\[ + 0.4726C_{SF}^{98} + 0.5676C_{SEFB}^{98} \]
\[ \bar{R}^{2} = 0.998 \quad SE = 0.5325 \quad DW = 1.93 \quad \rho_{1} = 0.3960 \]

(A.83) \[ F_{C}^{98} = -0.9315 + 2.0547[I_{SFR}^{98} + I_{SR}^{98} + I_{R}^{98} + G_{R}^{98}] \]
\[ \bar{R}^{2} = 0.970 \quad SE = 0.7993 \quad DW = 0.8365 \quad \rho_{1} = 0.9603 \]

(A.84) \[ F_{R}^{98} = -7.9821 + 0.2624C_{S}^{98} + 0.1316G_{C}^{98} \]
\[ \bar{R}^{2} = 0.988 \quad SE = 0.6182 \quad DW = 1.92 \quad \rho_{1} = 0.6930 \]

(A.85) \[ F_{0}^{98} = 14.9166 + 0.7141C_{S}^{98} + 0.0545G_{C}^{98} \]
\[ \bar{R}^{2} = 0.997 \quad SE = 0.9096 \quad DW = 1.69 \quad \rho_{1} = 0.9900 \]
OUTPUT CONVERSION

\[
\begin{align*}
\text{(A.86)} & \quad X_A^{\text{th}} = \begin{bmatrix} 1.46397 & 0.04525 & 0.02645 & 0.03357 \\ 0.02976 & 1.01411 & 0.02154 & 0.05480 \\ 0.07616 & 0.12910 & 1.03212 & 0.04237 \\ 0.06969 & 0.09119 & 0.06838 & 1.15032 \\ 0.19137 & 0.16668 & 0.19038 & 0.16624 \\ 0.07864 & 0.55824 & 0.06445 & 0.09801 \\ 0.25868 & 0.15821 & 0.08993 & 0.10977 \\ 0.00811 & 0.01037 & 0.02080 & 0.07036 
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.87)} & \quad X_C^{\text{th}} = \begin{bmatrix} 0.05342 & 0.05061 \\ 0.05363 & 0.01562 \\ 0.04555 & 0.07743 \\ 0.07312 & 0.09810 \\ 1.21264 & 0.15223 \\ 0.14863 & 1.61022 \\ 0.14432 & 0.16316 \\ 0.01795 & 0.01142
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.88)} & \quad X_T^{\text{th}} = \begin{bmatrix} 0.02645 & 0.03357 \\ 0.02154 & 0.05480 \\ 0.04237 \\ 1.15032 \\ 0.16624 \\ 0.09801 \\ 0.10977 \\ 0.07036
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.89)} & \quad X_R^{\text{th}} = \begin{bmatrix} 0.05342 & 0.05061 \\ 0.05363 & 0.01562 \\ 0.04555 & 0.07743 \\ 0.07312 & 0.09810 \\ 1.21264 & 0.15223 \\ 0.14863 & 1.61022 \\ 0.14432 & 0.16316 \\ 0.01795 & 0.01142
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.90)} & \quad X_{DO}^{\text{th}} = \begin{bmatrix} 0.05342 & 0.05061 \\ 0.05363 & 0.01562 \\ 0.04555 & 0.07743 \\ 0.07312 & 0.09810 \\ 1.21264 & 0.15223 \\ 0.14863 & 1.61022 \\ 0.14432 & 0.16316 \\ 0.01795 & 0.01142
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.91)} & \quad X_{MD}^{\text{th}} = \begin{bmatrix} 0.02645 & 0.03357 \\ 0.02154 & 0.05480 \\ 0.04237 \\ 1.15032 \\ 0.16624 \\ 0.09801 \\ 0.10977 \\ 0.07036
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.92)} & \quad X_{MX}^{\text{th}} = \begin{bmatrix} 0.05342 & 0.05061 \\ 0.05363 & 0.01562 \\ 0.04555 & 0.07743 \\ 0.07312 & 0.09810 \\ 1.21264 & 0.15223 \\ 0.14863 & 1.61022 \\ 0.14432 & 0.16316 \\ 0.01795 & 0.01142
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.93)} & \quad X_{DE}^{\text{th}} = \begin{bmatrix} 0.05342 & 0.05061 \\ 0.05363 & 0.01562 \\ 0.04555 & 0.07743 \\ 0.07312 & 0.09810 \\ 1.21264 & 0.15223 \\ 0.14863 & 1.61022 \\ 0.14432 & 0.16316 \\ 0.01795 & 0.01142
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{(A.94)} & \quad X_A^{\text{th}} = \frac{1}{d_A} \hat{X}_A^{\text{th}} \\
\text{(A.95)} & \quad X_C^{\text{th}} = \frac{1}{d_C} \hat{X}_C^{\text{th}} \\
\text{(A.96)} & \quad X_T^{\text{th}} = \frac{1}{1.281} \hat{X}_T^{\text{th}} \\
\text{(A.97)} & \quad X_R^{\text{th}} = \frac{1}{1.604} \hat{X}_R^{\text{th}} \\
\text{(A.98)} & \quad X_{DO}^{\text{th}} \\
\text{(A.99)} & \quad X_{MD}^{\text{th}} \\
\text{(A.100)} & \quad X_{MX}^{\text{th}} \\
\text{(A.101)} & \quad X_{DE}^{\text{th}}
\end{align*}
\]

PRICE CONVERSION

\[
\begin{align*}
\text{(A.102)} & \quad \begin{bmatrix} PF_A \\ PF_C \\ PF_T \\ PF_R \\ PF_O \\ PF_{MD} \\ PF_{MN} \\ PF_{CE} \end{bmatrix} = \begin{bmatrix} 1.46397 & 0.04525 & 0.02645 & 0.03357 \\ 0.02976 & 1.01411 & 0.02154 & 0.05480 \\ 0.07616 & 0.12910 & 1.03212 & 0.04237 \\ 0.06969 & 0.09119 & 0.06838 & 1.15032 \\ 0.19137 & 0.16668 & 0.19038 & 0.16624 \\ 0.07864 & 0.55824 & 0.06445 & 0.09801 \\ 0.25868 & 0.15821 & 0.08993 & 0.10977 \\ 0.00811 & 0.01037 & 0.02080 & 0.07036 
\end{bmatrix}
\end{align*}
\]

where \( T \) superscript stands for the transpose operator.
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\[
\begin{align*}
X_{dp}^{oa} &= \frac{1}{1.589} X_{dp}^{op} \\
X_{dN}^{oa} &= \frac{1}{2.354} X_{dN}^{op} \\
X_{dN}^{oa} &= \frac{1}{3.255} X_{dN}^{op} \\
X_{dE}^{oa} &= \frac{1}{1.741} X_{dE}^{op}
\end{align*}
\]

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<td>037</td>
<td>0.02080</td>
<td>0.07036</td>
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</table>

transpose operator.
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

(A.110) \[ P_{CDA} = 0.1394 + 0.6925PF_{MD} + 0.1480PF_T \]
\[ (0.9) \quad (4.2) \quad (0.7) \]
\[ \bar{R}^2 = 0.954 \quad SE = 0.0143 \quad DW = 1.98 \quad \rho_t = 0.8316 \]

(A.111) \[ P_{CDEA} = \left[ 0.0522 + 0.9472 \left( \frac{P_{CDE}}{P_{CDA}} \right) \right] P_{CDA} \]

(A.112) \[ P_{CNEF} = 0.1779 + 0.5023PF_{MN} + 0.3254PF_T \]
\[ (8.5) \quad (5.2) \quad (3.9) \]
\[ \bar{R}^2 = 0.981 \quad SE = 0.0058 \quad DW = 0.69 \]

(A.113) \[ P_{CNFB} = 0.8301PF_{MN} + 0.1710PF_T \]
\[ (9.8) \quad (2.0) \]
\[ \bar{R}^2 = 0.983 \quad SE = 0.0059 \quad DW = 1.85 \quad \rho_t = 0.9504 \]

(A.114) \[ P_{CS} = 0.9667PF_o + 0.0456PF_R \]
\[ (20.6) \quad (1.0) \]
\[ \bar{R}^2 = 0.999 \quad SE = 0.0030 \quad DW = 2.06 \quad \rho_t = 0.9504 \]

(A.115) \[ P_{IBUS} = -0.1400 + 0.9733PF_{MD} + 0.1673PF_C \]
\[ (5.7) \quad (16.8) \quad (4.2) \]
\[ \bar{R}^2 = 0.985 \quad SE = 0.0095 \quad DW = 1.44 \]

(A.116) \[ P_{ICNFR} = 0.2059 + 0.8074PF_C \]
\[ (8.9) \quad (35.6) \]
\[ \bar{R}^2 = 0.963 \quad SE = 0.0147 \quad DW = 0.35 \]

(A.117) \[ P_{EX} = 0.5719 + 0.3353PF_{MD} + 0.0943PF_{MN} \]
\[ (5.4) \quad (2.7) \quad (0.5) \]
\[ \bar{R}^2 = 0.920 \quad SE = 0.0085 \quad DW = 1.55 \quad \rho_t = 0.8118 \]

(A.118) \[ P_g = -0.3385 + 0.2667PF_{MD} + 0.3462PF_{MN} \]
\[ (3.4) \quad (2.8) \quad (1.9) \]
\[ + 0.1430PF_C + 0.0951 \frac{WSS_{E}}{E_{G}} \]
\[ (1.4) \quad (7.0) \]
\[ \bar{R}^2 = 0.997 \quad SE = 0.0060 \quad DW = 1.52 \quad \rho_t = 0.9009 \]

FINANCIAL SECTOR

(A.119) \[ P_{GFI} \]

(A.120) \[ P_{C} = \left[ \sum \right] \]

(A.121) \[ RES_{r} = \]

(A.122) \[ W_{LB} \]

(A.123) \[ DEF_{r} = \]

(A.124) \[ CURR + WLL_{TB} \]
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\( P_{CF} = \left[ 0.0587 + 0.940 \left( \frac{P_{CF}}{P_G} \right) \right] P_C \) 

(A.119)

\[ P_C = \left[ \sum_j P_C C_j \right] \] 

(j = DA, DEA, NFB, NEFB, S) 

(A.120)

\[ \Delta CPI = -0.0003 + 1.0626 \Delta P_C \] 

(0.6) (8.8)

\( R^2 = 0.620 \) \( SE = 0.0022 \) \( DW = 2.61 \)

FINANCIAL SECTOR

(A.122) 

\( RES_F = RES_{NB} - RES_R \)

(A.123) 

\[ RES_R = \left[ \frac{DD_{MB}}{DD_{CB}} \right] RRR_D [DD + DD_{GR}]_{CB} + \left[ \frac{DT_{MB}}{DT_{CB}} \right] RRR_T DT_{CB} \]

(A.124) 

\( W L T H^{58} = 0.114 \sum_{i=1}^{20} (0.9)^{-1} [G N P^{58}]_{-1} \)

(A.125) 

\( W L T H = [P_{GRP}]_{-1} W L T H^{58} \)

(A.126) 

\[ DEF_G = TP + TX + TC + TW - G - V_G \]

\[ - SUB_G - INT_G - V_{FORCG} \]

(A.127) 

\[ \frac{CURR + DD}{W L T H} = -0.0232 + 0.8703 \left[ \frac{CURR + DD}{W L T H} \right]_{-1} \]

\[ - 0.0039 RM_{BDT} - 0.0026 RM_{GBS} \]

\[ + 0.1047 \frac{Y_D}{W L T H} \] 

(1.2) (30.7) (2.8) (6.6) (3.4)

\( R^2 = 0.998 \) \( SE = 0.0016 \) \( DW = 1.18 \)
(A.128) \[ \frac{DD}{WLTH} = -0.0124 + 0.8522 \left[ \frac{DD}{WLTH} \right]_{-1} \]
\[ - 0.0039RM_{BDF} - 0.0023RM_{GBS3} \]
\[ + 0.0845 \frac{Y_D}{WLTH} \]
\[ R^2 = 0.997 \quad SE = 0.0014 \quad DW = 1.19 \]

\[ \text{NONWAGE INCOME} \]

(A.132) \[ RM_{BDF} \]

\[ \text{RM}_{FBE} = -0.4580 + 0.0860[RM_{GBS3}]_{-1} + 1.0050RM_{FBE} \]
\[ - 78.1320 \left[ \frac{RES}{(DD + DT)} \right]_{-1} \]
\[ - 167.9075 \left[ \frac{RES - RES_{F-1}}{(DD + DT)} \right]_{-1} \]
\[ - 3.9087 \frac{DEF_i}{WLTH} \]
\[ R^2 = 0.942 \quad SE = 0.2195 \quad DW = 1.46 \]

(A.133) \[ \Delta INTEGR = -0 \]

\[ \Delta Y_{ENT_EAF} = 0.172 \]
\[ (2.5) \]

(A.134) \[ \Delta DIV = -0 \]

\[ \text{RM}_{FBE} = 0.1933 + 0.2035RM_{GBS3} - 0.1890[RM_{GBS3}]_{-1} \]
\[ + 0.9431[RM_{GBL}]_{-1} \]
\[ R^2 = 0.966 \quad SE = 0.0958 \quad DW = 2.19 \]

(A.135) \[ \Delta INT_{BUS} = \]
\( RM_{BDT} = 0.2261 + 0.9052[RM_{BDT}]_{-1} \) 
\( + 0.0351[(1 - RRRDD)(.65) \) 
\( + (1 - RRRDD)]RM_{GBS3} \) 
\( - 1.1181 \frac{DT}{DD + DT} \) 
\( + 0.1405\overline{DMY}_{CD} + 0.0882RM_{BDTM} \) 
\( R^2 = 0.990 \ SE = 0.0742 \ DW = 1.49 \)

**NONWAGE INCOME**

\( \Delta INT_G = 0.0515 + 0.0152[RM_{GBS3}]\Delta BF_{PUB} \) 
\( + 0.0008(BF_{PUB})\Delta RM_{GBS3} \) 
\( R^2 = 0.293 \ SE = 0.1240 \ DW = 1.62 \)

\( \Delta DIV = -0.0045 + 0.0671[Z_A + CCA_{CORP}] - 0.2511[DIV]_{-1} \) 
\( R^2 = 0.514 \ SE = 0.2000 \ DW = 2.70 \)

\( \Delta Y_{ENTCAF} = 0.1727 + 0.0245\sum_j WSS_j + 0.0752\sum_j Z_{Hj} \) 
\( j = MD, MN, T, C, R, O \) 
\( R^2 = 0.409 \ SE = 0.3000 \ DW = 1.48 \)

\( \Delta INT_{BUSO} = -0.0763 + 0.00059 \sum_{i=0}^{1} [RM_{GBL}(C_D + I_{CNFR})]_{-1} \) 
\( R^2 = 0.268 \ SE = 0.1390 \ DW = 1.43 \)
CAPITAL CONSUMPTION ALLOWANCES

(A.137)  \[ \Delta CCA_{MD} = 0.1157 + 0.0318 \left[ \frac{1}{2} \sum_{i=0}^{1} (I_{BUSEMD})_{-1} - CCA_{MD-1} \right] + 0.1053DMY_{22} + 0.1059DMY_{23} \]

(A.138)  \[ \Delta CCA_{MN} = 0.1146 + 0.0328 \left[ \frac{1}{2} \sum_{i=0}^{1} (I_{BUSEMN})_{-1} - CCA_{MN-1} \right] + 0.0722DMY_{22} + 0.0827DMY_{23} \]

(A.139)  \[ \Delta CCA_{R} = 0.0807 + 0.0170 \left[ \frac{1}{2} \sum_{i=0}^{1} (I_{BUSER})_{-1} - CCA_{R-1} \right] + 0.1231DMY_{22} + 0.0474DMY_{23} + 0.0698DMY_{24} \]

(A.140)  \[ \Delta CCA_{OM} = 0.3031 + 0.0183 \left[ \frac{1}{2} \sum_{i=0}^{1} (I_{BUSEOM})_{-1} - CCA_{OM-1} \right] + 0.0681 \sum_{i=0}^{1} (I_{BUSEOM})_{-1} + 0.1144DMY_{23} \]

LABOR FORCE

(A.141)  \[ L = 15.371 + 0.740EHH + 0.520[U]_{-1} + 0.594\Delta[U]_{-1} + 0.064t \]
\[ (3.6) \quad (14.3) \quad (7.4) \quad (7.0) \quad (5.1) \]
\[ \bar{R}^2 = 0.997 \quad SE = 0.1890 \quad DW = 1.57 \]

(A.142)  \[ EHH = E_{AT} + E_{PM} + E_{OM} + E_{PT} + E_{OT} + E_{C} + E_{R} + E_{O} + E_{O} + \epsilon_{e} \]

(A.143)  \[ U = L - EHH \]

(A.144)  \[ RU = \frac{U}{L} \]
IDENTITIES AND FIXED PROPORTIONS

Gross national product or expenditures.

(A.145) \( GNP^{58} = SF^{58} + \Delta INV^{58} \)

(A.146) \( SF^{58} = C^{58} + I_{EAF}^{58} + I_{D}^{58} + I_{BAF}^{58} + I_{MS}^{58} \)

\( + EX^{58} - M^{58} + G^{58} + \epsilon_{IBUS}\)

(A.147) \( C^{58} = C_{DA}^{58} + C_{DEA}^{58} + C_{NFB}^{58} + C_{NEFB}^{58} + C_{S}^{58} \)

A.148) \( C_{D}^{58} = C_{DA}^{58} + C_{DEA}^{58} \)

(A.149) \( \Delta INV_{EAF}^{58} = \Delta INV_{MD}^{58} + \Delta INV_{MN}^{58} + \Delta INV_{P}^{58} + \Delta INV_{D}^{58} \)

(A.150) \( \Delta INV^{58} = \Delta INV_{EAF}^{58} + \Delta INV_{AF}^{58} \)

(A.151) \( I_{BUS}^{58} = I_{BFUAF}^{58} + I_{BUSEMD}^{58} + I_{BUSEMN}^{58} + I_{BUSEM}^{58} \)

(A.152) \( M^{58} = [M_{S}^{58} + M_{S}^{58}] + M_{D}^{58} \)

(A.153) \( I_{DE}^{58} = [0.6047 + 0.0007t - 0.6943DMY_{1C}]

+ 0.0067DMY_{1C} \times [I_{BFU}^{58} + \epsilon_{IBUS}] \)

+ 11.0393DMY_{1C} + 0.7895 \)

(A.154) \( P_{CER}^{58} = [I_{BFU}^{58} + \epsilon_{IBUS}] - I_{FDE}^{58} \)

(A.155) \( [I_{BFUAF}^{58} + I_{BFU}] = I_{BFUAF}^{58} + I_{BFU} \)

(A.156) \( \epsilon_{IBUS} = I_{BFUAF}^{58} - I_{FDE}^{58} \)

(A.157) \( I_{BFUAF}^{58} = I_{BFUAF}^{58} + I_{BFUAF}^{58} \)

(A.158) \( GNP^{58} = I_{BFUAF}^{58} + G^{58} + G^{58} + G^{58} \)

(A.159) \( C_{D} = [P_{BFUAF}^{58}C_{DA}] + [P_{CDE}C_{D}] \)

(A.160) \( EX^{58} = (0.4189 - 0.00111t)EX^{58} \)

(A.161) \( SF_{D}^{58} = C_{D}^{58} + I_{FDE}^{58} + G^{58} + EX^{58} - M_{D}^{58} \)

(A.162) \( EX^{58} = (0.3897 - 0.0008t)EX^{58} \)

(A.163) \( M_{D}^{58} = (0.5422 - 0.0002t)(M_{S}^{58} + M_{S}^{58}) \)

(A.164) \( SF_{F}^{58} = C_{NFB}^{58} + C_{NEFB}^{58} + G^{58} + EX^{58} - M_{F}^{58} \)
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

(A.165) \( I_{BUSJ} = [P_{BUSJ}][I_{BUSJ}] \)

\( j = MD, MN, R, O \ast 2, AF \)

(A.166) \( \Delta INV = [PM_AF][\Delta INV] + [WPI_M][\Delta INV] \)

\( + [WPI_M][\Delta INV] + [0.5462WPI_M] \)

\( + 0.3722WPI_M + 0.0816P_{MAF}[\Delta INV] \)

\( + \varepsilon_{\Delta INV} \)

(A.167) \( I_{CO} = [PICNFR][I_{CO}] + \varepsilon_{I_{CO}} \)

(A.168) \( I_{CNFR} = [PICNFR][I_{CNFR}] \)

(A.169) \( I_{FIXER} = \sum I_{BUSJ} + [P_{BUSJ}][I_{BUSJ}] + \varepsilon_{BUS} + I_{CO} \)

\( j = MD, MN, R, O \ast 2, AF \)

(A.170) \( I_{BUS_A} = I_{BUS} - I_{BUS_AF} \)

(A.171) \( GNP = [P_C][C] + I_{CNFR} + \Delta INV + I_{FIXER} \)

\( + [P_{EX}][EX] - [P_{MAF}][M] + G + I_{CAF} \)

(A.172) \( P_{GNP} = GNP \)

(A.173) \( M = [M^A + M^B] + M^S \)

Relations among gross national product, national income, personal income and disposable personal income.

(A.174) \( Y_N = GNP - CCA - TX - V_{BUS} - STAT + SUBG \)

(A.175) \( CCA = \sum I_{CCA} + \varepsilon_{CCA} \)

\( j = A, MD, MN, R, O \ast 6 \)

(A.176) \( CCA_{CORP} = 0.6086CCA \)

(A.177) \( Z_B = Y_N - WSS - Y_{ENT} - Y_{REN} - INT_{BUS} + WALD \)

(A.178) \( WSS = \sum WSS_j + \varepsilon_{WSS} \)

\( j = A, G, W, MD, MN, T, C, R, O \)
(A.179) \[ WSS_j = [RWSS_j][MH] \]
\[ j = MD, MN, T, C, R, O \]

(A.180) \[ INT_{BUS} = \sum_j INT_{BUS_j} \]
\[ j = A, C, T, R, O, MD, MN, W \]

(A.181) \[ Z_{BU} = Z_B - IVA_{CORP} \]

(A.182) \[ Z_{AU} = Z_{BU} - TC \]

(A.183) \[ Z_A = Z_{AU} + IVA_{CORP} \]

(A.184) \[ RE = Z_{AU} - DIV \]

(A.185) \[ Y_P = Y_N - RE - TC - IVA_{CORP} - TW - WALD \]
\[ + V_G + INT_G + V_{BUS} + INT_{CON} \]

(A.186) \[ Y_D = Y_P - TP \]

(A.187) \[ Y_D^{\phi} = Y_D/P_C \]

(A.188) \[ T = TP + TC + TX + TW \]

Miscellaneous relationships.

(A.189) \[ X_j^{\phi} = [X_j^{\phi}]_{1953.2} \left[ 1.0 + \frac{r^1}{4} \right]^{r-34} \]
\[ j = MD, MN, R, O \times 6 \]
\[ r = 0.035 \text{ in } 1953:3-1965:4 \]
\[ r = 0.040 \text{ in } 1966:1-1990:4 \]

(A.190) \[ K_{MD}^{\phi} = K_{MD-1}^{\phi} + 0.25[I_{BUSMD}^{\phi} - 0.638K_{MD-1}^{\phi}] \]

(A.191) \[ K_{MN}^{\phi} = K_{MN-1}^{\phi} + 0.25[I_{BUSMN}^{\phi} - 0.118K_{MN-1}^{\phi}] \]

(A.192) \[ K_R^{\phi} = K_{R-1}^{\phi} + 0.25[I_{BUSR}^{\phi} - 0.778K_{R-1}^{\phi}] \]

(A.193) \[ K_{O}^{\phi} = K_{O-1}^{\phi} + 0.25[I_{BUSO}^{\phi} - 0.1575K_{O-1}^{\phi}] \]

(A.194) \[ GNP_R^{\phi} = [GNP_R^{\phi}]_{1953.2} \left[ 1.0 + \frac{r^1}{4} \right]^{r-34} \]
\[ r = 0.035 \text{ in } 1953:3-1965:4 \]
\[ r = 0.040 \text{ in } 1966:1-1990:4 \]
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

(A.195) \[ J_{CAP_{MD}} = 0.000673 + 0.99[J_{CAP_{MD}}]_{-1} + 1.0461 \left( \frac{X_{50}^{MD}}{X_{50}^{MD}} - 0.99 \left( \frac{X_{50}^{MD}}{X_{50}^{MD}} \right)_{-1} \right) \]

(A.196) \[ J_{CAP_{MN}} = 0.00176 + .9682[J_{CAP_{MN}}]_{-1} + .9012 \left( \frac{X_{50}^{MN}}{X_{50}^{MN}} - 0.9682 \left( \frac{X_{50}^{MN}}{X_{50}^{MN}} \right)_{-1} \right) \]

(A.197) \[ K_{CDEA}^{58} = 0.25C_{DEA}^{58} + .92784[K_{CDEA}]_{-1} \]

(A.198) \[ K_{CBA}^{58} = 0.25C_{BA}^{58} + .925[K_{CDEA}]_{-1} \]

(A.199) \[ X_{50}^{58} = X_{50}^{MD} + X_{50}^{MN} \]

(A.200) \[ O_{50}^{58} = O_{50}^{MD} + O_{50}^{MN} \]

(A.201) \[ B^{58} = EX^{58} - M^{58} \]

(A.202) \[ H = \left[ H_{FMD}E_{FMD} + H_{FMN}E_{FMN} + H_{E}E_{E} \right] + H_{Fr}E_{Fr} + H_{C}E_{C} + H_{E}E_{E} \]

(A.203) \[ RWSS = \frac{[WSS - WSS_A - WSS_C]}{[EHH - E_A - E_C]} \]

LIST OF VARIABLES AND DEFINITIONS

MONETARY variables are in billions of dollars, seasonally adjusted. Monetary stock variables are, unless otherwise indicated, end-of-period; and monetary flow variables, including changes in stocks between ends of periods, are at annual rates. In the definitions, the variables are generally defined as if they are in current dollars. In the equations, the distinction is made between current and constant 1958 dollars. Variables in the latter units are superscripted 58. Other modifiers of the variables are:

1. Sector subscripts. These refer only to producing sectors and government; those that appear in the system of equations presented here are as follows:

   1. Sector subscripts. These refer only to producing sectors and government; those that appear in the system of equations presented here are as follows:
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Agriculture, forestry, and fisheries
Farming
Contract construction
Nonfarm business
Federal government (used only as a subscript for government expenditure variables)
Government and government enterprises
Government enterprises
Federal government
State and local government
Manufacturing
Durables manufacturing
Nondurables manufacturing
Residual industries: mining; finance, insurance, and real estate; and services
Mining, wholesale and retail, services, finance, and contract construction
All industries except manufacturing, wholesale and retail trade, and farming
Wholesale and retail trade and contract construction plus residual industries (mining; finance, insurance, and real estate; and services)
Regulated industries: railroad and nonrail transportation, communications, and public utilities
Wholesale and retail trade

2. Other subscripts are defined with the variables to which they apply. The variables in alphabetical order are:

Almon weights for investment equations

<table>
<thead>
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<th>Subscript</th>
<th>Description</th>
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<tr>
<td>$A_i$</td>
<td>Net exports of goods and services</td>
</tr>
<tr>
<td>$BF_{pub}$</td>
<td>Marketable Federal debt held outside the Federal Reserve and U.S. government agencies and trust funds, average during quarter</td>
</tr>
</tbody>
</table>
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

C  Personal consumption expenditures on goods and services

CCA  Capital consumption allowances

CD  Personal consumption expenditures on durable goods

CDA  Personal consumption expenditures on new and net used automobiles

CDEA  Personal consumption expenditures on durable goods other than automobiles

CNFB  Personal consumption expenditures on nondurable goods other than food and beverages

CNS  Personal consumption expenditures on food and beverages

CPI  Consumer price index, 1958 = 1.00

CS  Personal consumption expenditures on services including imputations

CURR  Currency in the hands of the nonbank public, average during quarter

d  Ratio of gross output to output originating

DDBC  Private demand deposit liabilities of commercial banks less interbank deposits, cash items in process of collection, and Federal Reserve float, average during quarter

DDGCB  Federal government demand deposits at commercial banks, average during quarter

DDMB  Demand deposits subject to reserve requirements at Federal Reserve System member banks, average during quarter

DEFG  Government surplus or deficit on income and product accounts

DIV  Dividends

DMY1  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY2  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1963.1, 1.0 thereafter

DMY3  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1963.3, 1.0 thereafter

DMY15  Dummy variable to convert from Bureau of the Census value of new private nonfarm residential

DMY21  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY22  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY23  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY24  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY25  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY26  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY27  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY28  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY29  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY30  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYCD  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYDKSTR  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYDKSTR1  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYGP  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYITC  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMYSTLWT  Dummy variable representing a productivity shift, 0.0 in 1954.1 through 1960.1, 1.0 thereafter

DMY15  Dummy variable to convert from Bureau of the Census value of new private nonfarm residential
buildings put in place to GNP expenditures on private residential nonfarm new construction, both in 1958 dollars.

- $D_{MY21}$: Dummy variable representing the investment boom in 1955, 1.0 in 1955.1 through 1955.4, 0.0 elsewhere.
- $D_{MY22}$: Dummy variable representing a change in the investment tax credit, 1.0 in 1962.1 through 1962.4, 0.0 elsewhere.
- $D_{MY23}$: Dummy variable representing the investment tax credit, 0.0 in 1954.1 through 1961.4, 1.0 elsewhere.
- $D_{MY24}$: Dummy variable, 0.0 in 1954.1 through 1960.1, 1.0 thereafter.
- $D_{MY25}$: Dummy variable representing the 1955 easing of consumer credit, 1.0 in 1955.1 through 1955.4, 0.0 elsewhere.
- $D_{MYCB}$: Dummy variable representing the establishment of the market for certificates of deposit, 0.0 in 1954.1 through 1960.4, .82 in 1961, 1.0 in 1962, .96 in 1963, .74 in 1964, and 1.0 thereafter.
- $D_{MY_DVS}$: Dummy variable representing longshoremen's strikes and incorporating anticipatory and make-up effects, −1.0 in 1954.1, 1.0 in 1954.2, 1.0 in 1956.3, −1.0 in 1956.4, 0.5 in 1957.1, 1.0 in 1959.3, −1.5 in 1959.4, 0.5 in 1960.1, 0.5 in 1962.3, −0.5 in 1962.4, −1.0 in 1963.1, 0.5 in 1963.2, −1.0 in 1965.1, 1.0 in 1965.2, 0.0 elsewhere.
- $D_{MYGP}$: Dummy variable representing the wage guide posts, 0.0 in 1954.1 through 1961.4, 1.0 in 1962.1 through 1965.4.
- $D_{MYITC}$: Dummy variable representing the investment tax credit, 0.0 from 1954.1 through 1961.4, 1.0 in 1962.1 through 1965.4.
- $D_{MYSTLW}$: Dummy variable representing anticipation of steel strikes occurring after foreign producers became competitive in the U.S. market, 1.0 in 1959.2, 2.0
in 1959.3, 2.0 in 1959.4, 1.0 in 1965.1, and 0.0 elsewhere

- DMYSTR: Dummy variable representing strikes in the automobile industry and incorporating make-up effects, -1.0 in 1958.4, 1.0 in 1959.1, -1.0 in 1961.3, -1.0 in 1961.4, -1.0 in 1967.3, -1.0 in 1967.4, 1.0 in 1968.1, 0.0 elsewhere

- DMYTP: Dummy variable representing the 1964 tax cut, 0.0 in 1954.1 through 1963.4, 1.0 in 1964.1 through 1965.4

- DMYTX: Dummy variable representing a change in the excise tax rate, 0.0 in 1954.1 through 1960.1, 1.0 in 1960.2 through 1965.4

- DODMPCA: Department of Defense military prime contract awards for work performed in the U.S.

- DTCB: Time deposits at all commercial banks other than those due to domestic commercial banks and the U.S. government, average during quarter

- DTMB: Time deposits at Federal Reserve System member banks other than those due to domestic commercial banks and the U.S. government, average during quarter

- EHH: Employment, as reported in the household survey, millions of persons, average during quarter

- E0: Employment of nonproduction workers, as reported in the payroll survey, millions of persons, average during quarter

- Ep: Employment of production workers, as reported in the payroll survey, millions of persons, average during quarter

- EX: U.S. exports of goods and services

- EXD: U.S. exports of durable goods

- EXN: U.S. exports of nondurable goods

- EXW: World exports excluding U.S. exports

- ECCA: Capital consumption allowances epsilon: the difference between capital consumption allowances in the national income accounts and the sum of the same
In 1965, and 0.0

strikes in the aut-
ing make-up effects, -1.0 in 1961.3, -1.0
.0 in 1967.4, 1.0 in

the 1964 tax cut, 0.0
in 1964.1 through

care in the excise
1960.1, 1.0 in 1960.2

ary prime contract
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al banks other than
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domestic commercial
ent, average during
ne household survey, 
ning quarter
ers, as reported
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workers, average

omponents
xports
 epsilon: the differ-
on allowances in the
the sum of the same

cancept by industry from quarterly interpolations of
annual data (on an establishment basis)

\( \epsilon_{INV} \)
Inventory investment epsilon: the difference between
current dollar inventory investment in the
gross national product accounts and the sum of real
inventory investment inflated

\( \epsilon_E \)
Employment epsilon: the difference between em-
ployment estimates based on the Bureau of Labor
Statistics' household survey, from which unemploy-
ment estimates are derived, and the sum of employ-
ment by industry from BLS's establishment survey

\( \epsilon_{BUS} \)
Business investment epsilon: the difference between
the sum of expenditures on producers' durable equip-
ment and business construction expenditures as
reported in the GNP accounts and the sum of such
investment by industry

\( \epsilon_{ICO} \)
The difference between the current dollar balance of
new private nonfarm, nonresidential, nonbusiness
construction put in place and the real value of such
construction, inflated by the implicit price deflator
for nonfarm residential construction

\( F \)
Estimated final demand

\( G \)
Government purchases of goods and services

\( G_{CD} \)
Government purchases of durable goods

\( G_{CN} \)
Government purchases of nondurable goods

\( G_{CS} \)
Government purchases of services

\( G_{IC} \)
Government expenditures on new construction

\( GNP \)
Gross national product

\( GNP_{IC} \)
Construction component of gross national product

\( GNP_k \)
Potential gross national product

\( H \)
Average weekly hours of all workers, hours

\( HH \)
Number of households, millions

\( H_p \)
Average weekly hours of production or nonsuper-
visory workers, hours

\( HU_{AVL} \)
Number of housing units available, millions

\( HU_{SFS} \)
Number of single-family housing units started, millions
ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR

$HU_{3TS}$ Number of two-family housing units started, millions

$HU_{3TS}$ Number of multiple-family housing units started, millions

$HU_{VAC}$ Vacant available housing units, millions

$I_{BUS}$ Business gross investment in plant and equipment

$I_C$ New construction component of gross private domestic investment

$I_{CER}$ Gross private domestic investment in nonresidential structures

$I_{CNFR}$ New private nonfarm residential construction, $GNP$ basis

$I_{CNFREH}$ Value of new private nonfarm residential construction excluding housing units put in place (additions and alterations plus nonhousekeeping buildings)

$I_{CNFRH}$ Value of new private nonfarm housing units put in place

$I_{CNFR}^*$ Value of new private nonfarm residential buildings put in place, Bureau of the Census basis

$I_{CO}$ Value of new private nonfarm, nonresidential, non-business construction put in place, billions of dollars

$I_{CPL}$ Business construction

$I_{CRAF}$ New farm residential construction

$I_{FIXER}$ Gross private domestic investment in nonresidential structures and producers' durable equipment

$INT_{BUS}$ Personal interest income paid by business

$INT_{CON}$ Personal interest income paid by consumers

$INT_G$ Personal interest income paid by government

$INV$ The stock of business inventories

$INV_{CAR}$ Dealers' automobile inventories

$I_{PDE}$ Investment in producers' durable equipment

$IVA$ Corporate and unincorporated enterprises' inventory valuation adjustment

$K$ Stock of business fixed capital

$K_{CDA}$ Stock of consumers' automobiles

$K_{CDEA}$ Stock of consumers' durable goods other than automobiles

$L$ Civilian labor force, millions of persons
SIMULATIONS WITH BROOKINGS MODEL • 289

- Imports of goods and services
- Imports of durable goods
- Imports of nondurable goods
- Imports of services
- Total man-hours, billions per year
- Man-hours of nonproduction workers, billions per year
- Man-hours of production or nonsupervisory workers, billions per year
- Total resident population, millions of persons, average during quarter
- Manufacturers' net new orders
- Salary base for determining payments to the Old-Age, Survivors, and Disability Insurance program (OASDI), thousands of dollars
- Percentage of employees covered by the OASDI program
- Percentage of base salary paid into OASDI, sum of employees' and employers' contributions
- Manufacturers' unfilled orders
- Implicit price deflator for personal consumption expenditures, 1958 = 1.0
- Implicit price deflator for personal consumption expenditures on new and used automobiles, 1958 = 1.0
- Implicit price deflator for personal consumption expenditures on durable goods other than new and used automobiles, 1958 = 1.0
- Implicit price deflator for personal consumption expenditures on nondurable goods other than food and beverages, 1958 = 1.0
- Implicit price deflator for personal consumption expenditures on foods and beverages, 1958 = 1.0
- Implicit price deflator for exports of goods and services, 1958 = 1.0
- Unit value index of world exports excluding U.S. components, 1958 = 1.0
Implicit price deflators for the final demand sectors, 1958 = 1.0

Implicit price deflator for total government purchases of goods and services, 1958 = 1.0

Implicit price deflator for Federal government purchases of goods and services, 1958 = 1.0

Implicit price deflator for gross national product, 1958 = 1.0

Implicit price deflator for business gross investment in plant and equipment, 1958 = 1.0

Implicit price deflator for new private nonfarm residential construction, 1958 = 1.0

Implicit price deflator for gross product originating, 1958 = 1.0

Undistributed corporate profits

Free reserves of Federal Reserve member banks, average during quarter

Nonborrowed reserves of Federal Reserve member banks, average during quarter

Required reserves of Federal Reserve member banks, average during quarter

Yield on commercial bank time deposits, per cent

Maximum rate payable on time deposits under Regulation Q

Federal Reserve Bank of New York discount rate, average during quarter, per cent

Yield on U.S. government securities maturing or

Implicit price deflator for imports

Implicit price deflator for value of cash receipts from farm marketing and CCC loans plus value of farm products consumed directly in farm households

Average cost per unit of private housing starts, thousands of dollars

Implicit price deflator for imports of nondurable goods and services, 1958 = 1.0

Index of prices of raw materials in manufacturing, 1958 = 1.0

Implicit price deflator for gross product originating, 1958 = 1.0

Undistributed corporate profits

Free reserves of Federal Reserve member banks, average during quarter

Nonborrowed reserves of Federal Reserve member banks, average during quarter

Required reserves of Federal Reserve member banks, average during quarter

Yield on commercial bank time deposits, per cent

Maximum rate payable on time deposits under Regulation Q

Federal Reserve Bank of New York discount rate, average during quarter, per cent

Yield on U.S. government securities maturing or
callable in ten years or more, average during quarter, per cent

\(RM_{B3}\) Market yield on three-month U.S. Treasury bills, average during quarter, per cent

\(RRR_D\) Effective required reserves ratio for demand deposits at Federal Reserve member banks, average during quarter

\(RRR_T\) Effective required reserves ratio for time deposits at Federal Reserve member banks, average during quarter

\(RU\) Rate of unemployment

\(RWSS\) Compensation of employees per man-hour including supplements, dollars

\(SF\) Final sales, gross national product less change in inventories

\(SF_D\) Final sales of durable goods

\(SF_N\) Final sales of nondurable goods

\(STAT\) Statistical discrepancy in the reconciliation of gross national product with national income

\(SUB\) Subsidies less current surplus of government enterprises

\(t\) Time trend where 1946:1 = 1 and 1954:1 = 37

\(T\) Government receipts

\(TC\) Corporate profits tax liability

\(TCRT\) Corporate profits tax rate

\(TP\) Personal tax and nontax receipts (or payments)

\(TW\) Contributions for social insurance

\(TX\) Indirect business tax and nontax accruals

\(U\) Unemployed in the civilian labor force

\(UCCA\) Unit capital consumption allowances (capital consumption allowances per unit of real gross product originating), dollars per dollar of real product

\(UCCA^N\) Normal unit capital consumption allowances

\(UINS^T\) The unemployment insurance tax rate

\(ULC\) Unit labor cost (compensation of employees per unit of gross product originating), dollars per dollar of real product
DISCUSSION

RALPH B. BR...U.S. TREASURY DEP...

The Brookings inst...ercent for over ten...one of all, seems to...error sector orig...aint least a dozen for a...model is down to...ad government...tax functions then...surprising in light of...Brookings. One of...two rates and tax...rate, of course, with state and local...for estimating personal income. Co...of the Internal Revenue...andy variable as an excise tax rates. Co...of corporate profit presumably). An a...endogeneity of one equation: state

Another area the labor force. Co plaining participation equation making unemployment, an...ecometeric demographic fact...
DISCUSSION

RALPH B. BRISTOL, JR.
U.S. TREASURY DEPARTMENT

The Brookings Model, née the SSRC Model, has now been in existence for over ten years, which is a long enough period of time to establish some trends. For one thing, the model, formerly the biggest one of all, seems to get a little smaller at each appearance. The government sector originally contained some thirty-odd equations, with at least a dozen for state and local receipts and expenditures. Now the model is down to one transfer and four tax equations, and state and local government receipts have vanished entirely. Furthermore, the tax functions themselves look pretty scruffy, which is particularly surprising in light of all the tax research that has been conducted at Brookings. One of the boasts of the original model was that it used tax rates and tax bases, but the present model uses neither. The tax rate, of course, has little meaning if we combine federal receipts with state and local receipts. The tax base or income variable used for estimating personal taxes is the national income accounts variable, including inventory. Personal income. This variable includes transfer payments and excludes personal contributions for social insurance, just the opposite of the Internal Revenue Service definition of taxable income. Indirect taxes are a straight percentage of GNP, minus a constant, with a dummy variable apparently intended to reflect changes in federal excise tax rates. Corporate tax liabilities are regressed on the product of corporate profits and “the tax rate” (federal plus state and local, presumably). An advantage claimed for the original model was the endogeneity of many government expenditures. Now we have just one equation: state unemployment insurance payments.

Another area of shrinkage in the model involves the estimation of the labor force. Originally there were thirty or forty equations explaining participation rates and even marriage rates. Now we have one equation making the labor force a function of employment, lagged unemployment, and a time trend. While it may be unreasonable to expect an econometric model to predict the marriage rate, I do think that demographic factors should have some influence on the labor force.
Another trend that I think I observe in the model is an increased willingness to use dummy variables. This is the way the investment credit is handled, for example. I am rather surprised that the credit is estimated to reduce corporate taxes by only $0.7 billion. That is a lot lower than Treasury estimates. The impact of the investment credit on business expenditures shows up as three additive and multiplicative dummy terms. Other variables determining business investment are the long-term interest rate on government bonds and capacity utilization or capital stock or both, depending on the sector being examined. Some of Dale Jorgenson's pioneering work on investment functions was done in connection with this model, and I question whether the present formulations are an advance over his work.

Dummy variables used for personal tax changes yield curious results. The 1964 tax cut is represented by a dummy that serves both as a constant term and as a multiplier of personal income. I have two observations to make on this procedure. First, only two-thirds of the tax cut was effective in 1964; the rest came in 1965. Second, even at 1965 income levels, the implied estimate of the tax cut is only $7 billion, about three-fourths of the Treasury estimate.

Perhaps the ultimate in dummy variables is shown in the equation for consumer expenditure on durables excluding automobiles, where a dummy variable is included even though its coefficient is less than its standard error!

Another difference between this and earlier versions of the model is the sample period. Formerly, the equations were fit to 1948–60, but the authors state that analysis of covariance tests indicated significant shifts in many coefficients between 1948–53 and 1954–60, so the present model was fit to 1954–65 “to select a sample period germane to the analysis of current economic problems” (page 201). This seems to me a mistaken procedure. Granted that the Korean War period was one of great instability, with horrifying effects on correlation coefficients and standard errors, I think we should hesitate before restricting ourselves to more homogeneous observations. Limiting the sample period to 1954–65, for example, means that we have no observations in which unemployment was below 4 per cent! Is this sample really “germane to the analysis of current economic problems”? I am not surprised that statistically significant shifts occurred in the period after 1953. The economy entered a turning point but it reached its peak until it reached its peak until it reached its peak until it reached its peak until it reached its peak...
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economy entered a period of stagnation from which it did not emerge until it reached its potential again in 1966. Is this the experience most germane to an analysis of the current inflationary situation? In light of the relative homogeneity of the sample period, it seems a shame the authors did not make use of observations after 1965. In addition to different unemployment levels and price movements, we have experienced large swings in residential construction since 1965 and reached the end of the strong upward trend in nonresidential construction in the fourth quarter of 1965. I would be willing to bet that the model failed to pick up either of these last two phenomena.

Turning to applications of the model, there are three analyses in the present paper, the simulation of five National Bureau “turning points”; a sample period simulation covering 1957-65; and a post-sample, twenty-five-year simulation extending from 1966 to 1990.

The format of this conference provided no criteria for the performance of models at turning points, so it is difficult, if not impossible, to evaluate them. For example, is it better to forecast the precise timing of a turning point but badly miss the numerical magnitude, or to be close to the correct magnitude even if the direction of movement is wrong? Past disagreements between econometricians and adherents of the indicators approach have been based on just this distinction. The econometric model builder has concerned himself with minimizing squared residuals, be they dollars, unemployment percentages, or interest rates. The sign of the derivative of a variable with respect to time does not really matter to him, and a change in this sign is important only if it affects the error of the equation or model. Given this approach, it is hardly surprising that most econometric models move much more smoothly than the economy, lagging behind turning points, underestimating amplitudes (both high and low), but “on the average” being not far off.

A “business cycles indicator” researcher, on the contrary, is concerned with dating and forecasting turning points. Less interested in the magnitude of a series than in the sign of its first difference, he deals with indexes of economic performance that are aggregated differently from those of econometric models (e.g., diffusion indexes). It is, therefore, hardly surprising that forecasts based on this approach tend to be qualitative, focusing on the probability that a turning point
will or will not occur. The quantitative aspects of such a forecast tend to be adjectival ("vigorous," "weak") rather than numerical.

We cannot label either of these approaches the "correct" one. If we are at, or think we are at, a turning point, a leading indicator's analysis may be of more interest to us; otherwise, we may prefer to focus on the output of an econometric model. As long as the two approaches remain as different from one another as they are at present, the one to which we turn depends on what information we have at hand and what questions we are asking.

In line with this, the Brookings Model simulations turn out to have root mean square errors that are larger for turning points than for non-turning point periods, but not very much larger. While the magnitude of the variables is forecast rather well, the turning points are not, and the peaks and troughs are underestimated.

The "longer-run simulations" cover the last three-fourths of the sample period. Charts 12—15 indicate that the model tracked real GNP and business investment rather well for the post-1960 expansion, but did not perform very well during the earlier, less stable years. The price estimates appear subject to severe serial correlation errors, and the residential construction simulation does not seem particularly good. Attempts to simulate the 1966 "credit crunch," which was outside the period of fit, might have been instructive.

For the purposes of the twenty-five-year simulation (1966—90), certain adjustments were necessary in tax rates and productivity equations. Specifically, after expiration of the surcharge, the personal tax rate was increased each quarter until 1976, then held constant. The authors state that this was done "in order to keep disposable income from growing too rapidly and also to limit government deficits." This result is certainly different from most long-run projections, which typically show the necessity of periodic tax cuts to reduce what used to be referred to as "fiscal drag." The model's low personal tax elasticity, combined with the assumed rising government share of current dollar GNP, changes projections of "fiscal dividends" to "fiscal deficits," and certainly warrants further discussion by the authors.

The authors also felt it necessary to alter some of the time trends in the production man-hour equations in order to raise productivity increases to what they considered more "reasonable" levels. Since the productivity equation dummy variables should really be considered the result of the variable behavior after 1970 is considerably more volatile." In fact, the strong cycles that led 1980's.

In conclusion, I both a producer and years attempting to building models. As often appalled at economic policy issues years: the 1964 tax cut, the 1980's depression. To be hone major impact on policy. One's model showed tary policy to avoid a way to go. If I have cause I was speaking as a producer, I will the paper: "Predict after Tinbergen's in
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gle" levels. Since the
productivity equations seem to be influenced mainly by various "shift"
dummy variables during the sample period, I wonder if productivity
should really be considered an endogenous variable in this model.

The control solution produced very smooth paths to 1990, presumably the result of smooth extrapolation of the exogenous variables.
None of the variables in Charts 16–19 seems to display any cyclical
behavior after 1970 in the control solution, although there seems to be
considerably more variation in the "representative stochastic simula-
tion." In fact, the residential construction series (Chart 19) exhibits
strong cycles that look as if they would become explosive in the late
1980's.

In conclusion, let me say that I approach econometric models as
both a producer and a consumer. As a producer who has spent some
years attempting to develop improved forecasts, I am filled with hu-
mility for my own efforts and admiration for the success of others in
building models. As a consumer of models, who is supposed to pro-
vide technical assistance to policymakers in the government, I am
often appalled at how inappropriate models can be. Consider the eco-
nomic policy issues that agitated the government during the last ten
years: the investment credit and its suspension and revocation, the
1964 tax cut, the 1965 excise cuts, and the 1968 surcharge with its ex-
tensions. To be honest, I think the only time econometric models had a
major impact on policy decisions came in 1968. At that time, every-
one's model showed that the Federal Reserve should ease up on mone-
tary policy to avoid a recession in 1969. I am afraid we still have quite a
way to go. If I have seemed critical of the Brookings Model, it is be-
because I was speaking as a consumer of econometric models. Speaking
as a producer, I will confess that I agree with the opening sentence of
the paper: "Predictions with econometric models, even thirty years
after Tinbergen's initial attempt, still involve art as well as science."
The paper by Fromm, Klein, and Schink (hereafter FKS) is the fourth version of the Brookings Model to appear in print. Version I, the set of equations presented in the individual chapters of the 1965 Brookings volume [7], has been extensively criticized [16] but never solved nor simulated. Version II was the abbreviated version presented at the end of the 1965 volume, which was solved but never simulated. The equations of version III are presented by Fromm and Taubman in an appendix of [13] and have been used to derive dynamic policy multipliers, but the transition from version II to version III has never been rigorously justified and the equations of the latter are presented in [13] denuded of all measures of goodness of fit or other statistical information.

Version IV replaces version III, as version III replaced version II, with scarcely a word of explanation. Old variables are dropped and new ones appear, with goodness of fit or a "structural change" during the sample period as virtually the only criteria for replacement offered in the cursory explanation by FKS. During the span of roughly six years since the articles in the original Brookings volume were written, almost no published or unpublished articles have been written to justify either theoretically or econometrically the changes made from version to version. In contrast with the MIT-FRB and Wharton Models, which are both supported by a considerable body of theoretical and econometric literature, the Brookings Model has been transformed so many times since its inception that it is now a model almost devoid of theory, with equations altered and dummy variables added wherever necessary to maximize the model's ability to produce a control solution that accurately tracks GNP during the sample period.1 In version IV many variables are included in the results even if their coefficient with "t" reactions. As the specifications of successive versions, the secular simulations, yet an important justification as large as Brookings, fixed as the model shrinks. In light of these developments, theoretical or statistical that the model project.

A natural point of revisions" suggested it. To what extent have corrected in the new version any important weakness in the previous version? Representations of the or are some of the rest assumptions made in the 

I. THE MODEL

Final Expenditure Eq is disaggregated into flexible accelerator in ness of the model in si the lagged stock of at the auto equation as w [9][16] noted that in to consume implied lower than the average. Version IV appears marginal propensity cause long-run policy
variables are included in the equations and thus influence the simulation results even if their coefficients are not significant (there are thirty-six coefficients with "t" ratios below 2.0 in the first seventy-nine equations). As the specification of the model becomes more arbitrary in successive versions, the less one is likely to trust its policy multipliers or secular simulations, yet richness of simulation detail has always been an important justification for the continuation of research on a model as large as Brookings. And even the details are gradually being sacrificed as the model shrinks in overall size between successive versions. In light of these developments, which continually reduce the model's margin of disaggregation over competing models with no offsetting theoretical or statistical innovations, one is left with the impression that the model project has lost its sense of direction.

A natural point of departure for these comments is the "menu of revisions" suggested in my recent critical review [15] of version III. To what extent have the major weaknesses of that version been corrected in the new version IV used for the present simulations? Are any important weaknesses introduced in version IV that were absent in the previous version? Do the simulation results appear to be accurate representations of the cyclical and secular features of the real world, or are some of the results of questionable validity due to the particular assumptions made in specifying the model?

I. THE MODEL

Final Expenditure Equations. As in previous versions, consumption is disaggregated into five components. In version III the absence of a flexible accelerator in the auto equation contributed to the sluggishness of the model in simulations. This defect has now been cured, since the lagged stock of automobiles appears with a negative coefficient in the auto equation as well as that for nonauto durables. Previous critics [9] [16] noted that in earlier versions the long-run marginal propensity to consume implied by the five equations taken together was much lower than the average postwar propensity to consume of about .92. Version IV appears to err in the opposite direction, with a long-run marginal propensity to consume of 1.175. This high propensity will cause long-run policy multipliers to be misleadingly high when these
TABLE 1
Propensity to Consume

<table>
<thead>
<tr>
<th></th>
<th>Brookings Marginal Propensity to Consume</th>
<th>Actual Average Propensity to Consume, 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Impact (1)</td>
<td>Long-Run (2)</td>
</tr>
<tr>
<td>Autos</td>
<td>.2204</td>
<td>.1322</td>
</tr>
<tr>
<td>Nonauto durables</td>
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<td>.0700</td>
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<tr>
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<td>.0710</td>
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<tr>
<td>Other nondurables</td>
<td>.1451</td>
<td>.1755</td>
</tr>
<tr>
<td>Services</td>
<td>.0529</td>
<td>.7260</td>
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<tr>
<td></td>
<td>.5752</td>
<td>1.1747</td>
</tr>
</tbody>
</table>

Source by column: Columns 1 and 2—Calculated from equations (A.1)–(A.5), (A.197), and (A.198) in appendix to FKS paper; Column 3—Survey of Current Business (April 1970), Table 11, p. 9.

are eventually calculated for version IV, and it is responsible for the increase in the ratio of real consumption to GNP in the 1965–90 simulations presented in the FKS paper. Table 1 suggests that the equation for services is the primary culprit responsible for the excessively high long-run marginal propensity to consume.

The present set of consumption equations, as in previous versions, fails to allow for any direct influence of monetary policy on consumption. Thus monetary policy multipliers calculated for the Brookings Model are likely to be smaller than those for the MIT-FRB Model, where total consumption is a function of real wealth (which is influenced by monetary policy via stock prices) and where durables consumption depends on interest rates. And we might expect overpredictions of GNP in simulations.

The residential demand for housing is less volatile than the demand would also be if rates and the expected growth in the housing that lags on interest rates and stock prices. The Brookings Model is likely to track better the supply of credit, on the other hand.

Although econometric evidence is preferable to anecdotes, direct monetary influence on consumption is supported by frequent reports in the financial press in 1969–70 of reduced consumption of luxury goods, attributed to the drop in stock prices. One also notes the marked decline in the average propensity to consume between the first and last halves of 1966, and the first and last halves of 1969, both of which were years characterized by much slower rates of growth of monetary aggregates in the last half than in the first half.
## SIMULATIONS WITH BROOKINGS MODEL

The residential construction equations suffer from a failure to distinguish between the separate influence of monetary factors on the demand for housing and the supply of credit for housing. One would expect demand to be a function of the mortgage rate, which is much less volatile than the Treasury bill used by Brookings. (Housing demand would also be expected to depend on household formations, tax rates and the expected rate of capital gains.) The supply of housing credit, on the other hand, depends on the gap between short-term market interest rates and deposit rates at banks and savings institutions. The Brookings Model would probably underpredict housing expenditures for periods like 1967 and the last half of 1968, when the Treasury bill rate was relatively high compared to the 1954-65 sample period but the supply of credit to the housing market was ample because deposit rates were high relative to the Treasury bill rate. Another weakness, which the housing equations have in common with many others, is that lags on interest rates and other variables are fixed arbitrarily rather than estimated statistically by the numerous methods now available.

The change in inventories causes difficulties in all models, but the Brookings equations do an unusually poor job of fitting the sample period in all sectors but manufacturing durables. This is unfortunate, since inventory change has been the main contributor to the timing pattern of postwar recessions, and models which explain inventories badly are likely to track badly in simulations of recession. Because of the difficulty of explaining inventory change, it is suggested below that the ability to track final sales rather than GNP should be the criterion for judging dynamic simulations of alternative models.

The investment equations were extremely weak in version III, but version IV is even worse. The new equations repeat the earlier error of representing the cost of capital with a nominal rather than a real interest rate. The previous arbitrary “spiked” lag distributions (in which virtually all of the influence of a change in output and interest rates occurs in the fifth quarter after the change, rather than being spread out over several quarters) have been replaced by a smooth distributed lag pattern. But these new lag weights should have been estimated by the Almon technique separately for the output and interest rate variables in each of the four sectors. Instead, however, the au-

### Table: Actual Average Propensity to Consume, 1969

| Column 3—Survey of Responsible for the in the 1965–90 simu-
| Actual Average Propensity to Consume, 1969 |
|----------------------|----------------------|
|                      |                      |
| .0786                | .0640                |
| .1910                | .1964                |
| .3890                | .9190                |
thors have used a single set of weights for output and interest rates in each sector, and these weights were not estimated for the Brookings sectors, variables, or sample period but were simply copied from weights estimated by Shirley Almon for a different variable (the lag of expenditures behind appropriations), a different sector (all of manufacturing) and a different sample period (1954–61). Why create a disaggregated model if a single inappropriate lag pattern is going to be imposed on all sectors?

The extension of the end of the sample period of version IV from 1960 to 1965 forces the authors to deal with the investment tax credit and liberalized depreciation allowances introduced in 1962. The approach is a completely ad hoc use of dummy variables and stands in contrast to numerous recent articles [3][4][17][18], one of which was written by an author of the FKS paper, that attempt to base the treatment of investment incentives on theoretical considerations. And the effect of the dummy variables is very peculiar. They raise the constant and reduce the output elasticity of investment in durable manufacturing, but lower the constant and raise the elasticity in nondurables and lower the constant and leave the elasticity unaffected in the regulated sector. The most dubious feature of the equations is the result that, ceteris paribus, investment incentives reduced real investment spending between 1961 and 1963 by about $7 billion. Very little confidence should be placed in the long-run simulations calculated with these equations.

Other equations. In general, the equations outside of the final expenditures sector are not as weak as other models and require less extended comment that the expenditure equations. The production functions warrant attention, since they determine how rapidly productivity will grow in the twenty-five-year simulations. The durables manufacturing equation calls for an unreasonably erratic fluctuations in the annual rate before 1963.1 and 0.9 decreasing returns is evidence of faster inflation. The long-run labor supply reduces hours per worker in nominal wages by 2.5 hours per period and will overestimate the effect of increased returns in the regulated sector.

In the twenty-five years, a remarkably low 1.7 and 3.9 per cent unemployment is implied in other econometric models.

In the price equation, the ratio of profits to wages is influenced by the arbitrary assumption of a unitary elasticity of product prices. The resultant labor cost is between 3.8 per cent and 5.3 per cent.

These assumptions are with a "more reasonable"
SIMULATIONS WITH BROOKINGS MODEL • 303

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uring equation calls for reexamination, since its steady-state version
has an unreasonably high degree of increasing returns (1.26) and er-
ratic fluctuations in the rate of disembodied technical change (a zero
annual rate before 1960:1, a 4.6 per cent annual rate between 1960:2
and 1963:1, and 0.9 per cent annual rate thereafter). The degree of in-
creasing returns is even stronger in nondurables (1.65).

The hours equations introduce a novel theory of money illusion in
the long-run labor supply curve. An increase in the nominal wage rate
reduces hours per week, no matter how rapidly prices are rising. An in-
crease in nominal wages of $1.00 due entirely to inflation would reduce
hours by 2.5 hours per man per week. The coefficients in these equa-
tions are influenced by the slow rate of inflation during the sample
period and will overestimate the secular decline in hours during periods
of faster inflation.

In the twenty-five-year simulation the price-wage sector generates
a remarkably low 1.7 per cent steady-state annual rate of inflation at a
3.9 per cent unemployment rate, a much lower rate of inflation than is
implied in other econometric work (for my own simulation results see
[14]). In the price equation the elasticity of prices to changes in unit
labor cost is between 1.27 and 1.75, implying an increasing secular
ratio of profits to wages. If corporations are so aggressive in raising the
profit share, why is the rate of inflation so slow in the long-run simula-
tions? The coefficients in the wage equation suggest implausibly docile
behavior by workers. The wage equations of the old version III imply
a plausible annual rate of wage increase of 6.7 per cent at a steady 4
per cent unemployment rate [15, Table 2], but in version IV workers
have become more timid. The steady-state rate of increase of wages
can be calculated for a 4 per cent unemployment rate on the assump-
tion of a unitary elasticity of product prices to changes in unit labor
cost, a rate of productivity growth of 3.0 per cent per annum in each
sector, and an increase in consumer prices at the same rate as in prod-
uct prices.5 The resulting figures are extremely low: 6.0 per cent in
durables, 3.8 per cent in nondurables, 3.4 per cent in trade, 4.8 per

5These assumptions are the same as those used in [16] and [15, Table 2], except for
the arbitrary assumption of a unitary elasticity of prices to changes in unit labor cost,
which is introduced here to judge the coefficients of the wage equations in combination
with a "more reasonable" set of price equations than those in version IV.
cent in regulated, 3.6 per cent in the residual sector, and approximately zero in contract construction. These low estimates in version IV compared to version III may be due to the exclusion from the sample period of any years with an unemployment rate below 4.0 per cent, to the ending of the sample period in 1965:4 before the falling unemployment rate of 1964–65 had much time to influence wage rates, and perhaps to the arbitrary lag distributions. These weak equations also ignore the recent emphasis in the literature on price expectations and disguised unemployment as determinants of wage rates (e.g., [12] [20]).

An improvement in the financial sector of version IV compared to version III is the elimination of the investment variable in the demand for money equation, the coefficient of which in earlier versions was negative and caused the model to generate misleading policy multipliers (see [15]). But the model will still predict that a cut in personal tax revenues will increase interest rates more than an equal increase in government expenditures, due to the use in the demand for money equations of disposable income rather than some broader income concept. Finally, an extremely important flaw in the financial sector is the failure to incorporate any influence on interest rates of changes in the expected price level. In 1968 and 1969 an increase in the rate of expected inflation was a major factor causing a rapid rise in nominal interest rates, and by ignoring inflationary expectations the Brookings Model in a prediction experiment would presumably have underpredicted nominal interest rates. As noted above, the model makes no distinction between the nominal interest rates that enter the demand for money function and the real interest rates that should influence the demand for commodities.

2. THE SIMULATIONS

Turning points. On what criteria should we judge the turning point simulations? A one- or two-quarter error in predicting the exact timing of peaks and troughs is not serious if the order of magnitude of the boom or recession is tracked accurately. And the FKS criterion of comparing six-quarter simulation errors around turning points with errors in a nine-year sample by this criterion is the model at turning points. Whether a policy made forecasting postwar an incorrect policy policy troughs shown in C. stance, the trough up to be 5 per cent instead is overestimated by 1958:2. These fore- those like Secretary and fiscal policy. Once simulations that make the la- out, a task not atten- ment error is only at the 1958 trough, for per cent of real GNP an underestimate of Since the unemployment percentage points, a not by the expendi- ductivity-hours-parti- (Chart 8) relative ticipation equation supply equations in improved, model by Okun's law equation for a given estimate.

Considering the 1958 and 1961 trou
rors in a nine-year simulation is uninformative, since a good performance by this criterion might be due to the shorter time span of the turning point simulations rather than a relatively accurate performance of the model at turning points. Instead, I would ask of these simulations whether a policy maker having confidence in the model and using it for forecasting postwar recessions would have been misled into making an incorrect policy decision. The simulations of the 1958 and 1961 troughs shown in Charts 1-11 are pessimistic on this score. For instance, the trough unemployment rate in 1958:2 (Chart 7) is estimated to be 5 per cent instead of 7 per cent, and the rate of inflation (Chart 2) is overestimated by almost 1 per cent per annum between 1957:2 and 1958:2. These forecasts would have thus supported the arguments of those like Secretary Humphrey who stood against a stimulative monetary and fiscal policy during the Eisenhower recessions.

Once simulation errors have been judged to be serious, the equations that make the largest contributions to the errors should be sought out, a task not attempted by FKS. One first notes that the unemployment error is only about half due to the error in tracking real GNP. At the 1958 trough, for instance, the overestimate of real GNP is about 3 per cent of real GNP, which by application of Okun's law should cause an underestimate of the unemployment rate by one percentage point. Since the unemployment rate is actually underestimated by about two percentage points, about half of the unemployment error is contributed not by the expenditure equations but on the supply side by the productivity-hours-participation equations. The small employment errors (Chart 8) relative to the unemployment errors suggest that the participation equation is an important source of the trouble. Until the supply equations in this and other large-scale econometric models are improved, model builders would be well advised to rely on a simple Okun's law equation to minimize errors in estimating unemployment for a given estimate of real GNP.

Considering the large underestimates of unemployment in the 1958 and 1961 troughs, the overestimate of wage and price changes is
surprisingly small. The slight response of wage changes to unemploy-
ment errors is consistent with comments on the wage equations made
above, and with the impossibly low rates of inflation generated by the
model in the twenty-five-year secular simulation.

Turning now to the real GNP errors at troughs, these appear to be
about half due to incorrect predictions of inventory change. The model
seems to generate a flat and smooth, rather than cyclical, pattern of in-
ventory change in all postwar recessions (Chart 5), and it would be
interesting to know whether the same is true of the residuals in the
underlying inventory equations. The model does a much better job of
tracking real final sales than real GNP and large-scale models will
make a much better impression on readers of simulation reports if in-
creased emphasis is placed on the ability to track final sales. Of the
components of final sales, residential construction is tracked very
closely, and the nonresidential investment predictions behave quite
well except at the 1960 peak. Consumption contributes most (in abso-
lute, not relative terms) to final sales errors, due to the model’s inability
to predict a drop in the propensity to consume in 1958 and a marked in-
crease in 1960. These results cannot fail to give support to the monetarist argument that velocity is relatively more stable than the Key-
nesian multiplier.

1957–65 simulation. The $5.0 billion root mean square error in
tracking real GNP during a nine-year simulation between 1957:1 and
1965:4 appears quite impressive. By contrast the MIT-FRB Model in
a similar simulation for 1958:1 through 1967:2 generates a $7.0 billion
error [2]. But the lustre of the Brookings achievement dims somewhat
when we consider the heavy dependence of the results on dummy vari-
ables. Excluding all strike and tax rate dummies, the remaining dummy
variables change values in eight of the thirty-six quarters included in
the simulation. The dummy variables in the investment equations,
which change in 1962:1 and 1963:1 are particularly important in keep-
ing the model on target in the 1961–65 period.

But even without dummy variables most models fitted to the post-
Korea era do well in simulations of 1961–65, simply because most of
the variance of expenditure components between 1954 and 1965 oc-
curs during 1961–1965, so that these years play a dominant role in de-
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section with the puzzling statement: "The Brookings Model is essentially
a short-run forecasting model and as such is not designed for simula-
tion over a twenty-five-year period." Whatever its original intent,
however, the model has never been used as a forecasting device (to my
knowledge no ex ante forecasts have ever been released), partly be-
cause the large size of the model inhibits the maintenance of an up-to-
date data file. Thus the only possible justification for the Brookings
Model is that its large scale yields superior representation of the true
structure of the economy than smaller models. If so, a secular simula-
ton the Brookings Model
should have a comparative advantage.
One is tempted to apply a microscope to the graphs of the 1966–
69 portion of the 1966–90 simulation values depicted in Charts 16–
19 to test the model’s ability to track outside of its sample period.
Lacking a microscope, I shall eschew comment on this aspect of the
simulations, except to remark that the Brookings Model exhibits the
universal failing—common to all large-scale econometric models which
misspecify the channels by which monetary policy influences real
spending—of predicting an economic slowdown in late 1968 and speed-
up in the last half of 1969.
Given the extrapolations of steady growth in government spend-
ing, it is not surprising that the economy is relatively stable after 1972.
Tax rates are manipulated to maintain the economy at full employment,
so we would expect a stabler economy than occurred with the highly
unstable full-employment surplus of 1953–69. As one looks down the
list of exogenous variables, however, it is apparent that Hamlet is miss-
ing. Nowhere do FKS mention the assumption made about the secular
behavior of unborrowed reserves, the major exogenous monetary vari-
able, although I am told privately that a constant growth rate was as-
sumed. The assumed stability of monetary growth compared to the in-
stability of 1953–69 makes a contribution to the steadiness of the eco-

termining the coefficients in the underlying expenditure equations. A
much more challenging test would have been an extension to 1966–69,
an experiment in which the Wharton Model goes completely off the
rails [10].
The long-term 1966–90 simulations. The authors introduce this sec-
section with the puzzling statement: "The Brookings Model is essentially
a short-run forecasting model and as such is not designed for simula-
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Model is that its large scale yields superior representation of the true
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tion is one of the few experiments in which the Brookings Model
should have a comparative advantage.
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stability of 1953–69 makes a contribution to the steadiness of the eco-
nomics advance of 1970–90, even in a model like Brookings where money plays a marginal role.

In their discussion of exogenous assumptions, the authors state that tax rates are raised steadily through 1976 "to keep disposable income from growing too rapidly." At first glance this appears to conflict with the widespread assumption that steady economic growth yields a "fiscal dividend" that allows a reduction in tax rates. But in this secular simulation the fiscal dividend is negative, since an assumption of a roughly constant ratio of real government spending to real GNP combined with a rising relative price of government requires an increase in the G/GNP ratio in current dollars from 20.2 per cent in 1965:4 to 25.0 per cent in 1990:4, and revenues must also increase the same relative amount to maintain a balanced full-employment budget. This increase in tax revenues could be attained over a twenty-five-year period with income-elasticity of tax revenues of only 1.16, but the Brookings tax equations understate the income elasticity of the U.S. tax system, forcing an increase in the "dummy" coefficients in the tax equations.8

Do the secular rates of growth in Table 8 tell us anything about what is likely to occur in the real world? Virtually all of the results can be traced to some of the peculiar features of the model, described in Part I above. For instance, the ratio of profits to GNP (both in current prices) increases from the already high level of .113 in 1965:4 to .134 in 1990:4 (as compared to .101 in the prosperous year of 1968). This is caused by the unreasonably high elasticity of changes in prices to changes in unit labor cost in the price equations. The low rate of wage increase and low rate of inflation originate in a very weak set of wage equations. The increase in the ratio of consumption to GNP is due to the long-run marginal propensity to consume of greater than 1.0 in the consumption equations. A surprising result is the rapid increase in the ratio of business nonresidential investment to GNP in light of the predicted increase in interest rates. An increase in this ratio would imply a reversal of the secular decline in the capital-output ratio which has continued in the United States since 1919. In fact the behavior of this ratio tells us more about the effect of dummy variables in the investment equations than it tells us about the real world.

8 The ad hoc adjustment that FKS apply to the hours and productivity equations confirm the critical comments made above about the supply sector of the model.
All in all, version IV of the Brookings Model does not appear to be a net improvement over previous versions. Its improved performance in sample-period simulations rests on a shortening of the sample period, the widespread adoption of dummy variables, and ad hoc techniques for specifying equations to maximize simulation performance and goodness of fit. The long-run implications of the resulting equations are questionable in many cases, but the creation of a plausible set of long-run implications is a basic test which must be passed by any model, and this is particularly true of a model like Brookings, which is so unwieldy that it has never been used to fulfill its primary purpose of short-term forecasting. My unhappy conclusion is that, rather than attempt to move on to another version, the Brookings Model builders should merge the best features of their equations into the MIT-FRB Model, which in my judgment is the only large-scale model robust enough to withstand the onslaught of the St. Louis monetarists on either the simulation or forecasting front.

REFERENCES


ECONOMETRIC MODELS OF CYCLICAL BEHAVIOR


INTRODUCTION

1.1 BACKGROUND

In a pioneering study, Frank L. Adelman [main endogenous variables] econometric model by forms of hypothetical stochastic simulation; (2) shocks superimpose on quantities; and (3) shocks introduced are different solutions was rich in valuable variables to the earlier data; each also contains economic trends beyond the sample: one hundred years of interest in learning cyclical movements States economy. Type I shocks did