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Technical Appendix

for the

Bayesian Vector Autoregression Model

of the

U.S. Economy

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CONTENTS

INTRODUCTION

Since the late 1970s, Bayesian vector autoregression (BVAR) models have been used at the Federal Reserve Bank of Minneapolis in conjunction with research and Bank briefings held before FOMC meetings. The monthly BVAR model of the U.S. economy, developed late in 1981, was first used for the pre-FOMC briefing of March 1982. In its original form, the monthly model consisted only of a small core sector with seven variables. By May 1983, the model had expanded to its current size of 47 forecasting variables covering the major sectors of the national economy. The model's 47 variables are distributed among eight economic sectors. The variables of the main sector (core) feed into the other seven sectors: production, labor, financial markets, consumption, government, international trade, and prices. These sectors interact with each other as well: the production sector feeds into labor; labor feeds into government; and financial markets and labor feed into consumption.

The model is programmed in a language called RATS (Regression Analysis of Time Series), and the model's programs are available on request to the Research Department, Federal Reserve Bank, Minneapolis, Minnesota 55480. RATS is available for mainframe computers from TSP International (204 Junipero Serra Boulevard, Stanford, California 94305) and for microcomputers from VAR Econometrics (P.O. Box 19334, Minneapolis, Minnesota 55419-0334).

The primary task in setting up the model is constructing its monthly data base--a process detailed in this technical appendix. A later version of this appendix will describe the processes of estimating the model's 47 equations and generating unconditional forecasts. For an overview of how the model is run, see the flowchart in Annex C.

CONSTRUCTING THE MODEL'S DATA BASE

Constructing the model's monthly data base is by far the most arduous part of running the national model. In order to forecast the 47 time series, we actually draw on roughly 90 series. We do this for two reasons. First, since many of the model's variables are published only as quarterly data, we rely on other related monthly series to estimate their monthly values. (We call this process interpolation.) Second, when nominal versions of some of the model's real variables are released earlier, we deflate them to update the real variables.

The main source of our 90 series is the data base of Interactive Data Corporation (IDC), a division of Chase Econometrics. More recently, we have used Automatic Data Processing (ADP) as an alternative to IDC. The series codes (mnemonics) of the model's data series from both ADP and IDC are listed in Annex B, which also lists basic information about each series.

To construct the data base we first determine the cutoff point for the data series. We then may have to perform different procedures to prepare the data. These procedures include projection, deflation, seasonal adjustment, interpolation, extension of interpolated series, and data transformation. Each is discussed in turn below. For convenience, a sector-by-sector discussion of how we construct each of the 47 series is available in Annex A.

Definition of Beginning and End Dates

In general, we define the beginning of the data series as January 1948 (48:1). However, some of the monthly variables related to the quarterly series and some of the production and financial forecasting variables do not start from 48:1. In the first instance, we project the monthly variables back to 48:1. In the second, we estimate the equations in the production and financial sectors from 58:1 and 59:1, respectively.

We define the cutoff point of the data (ENDDATA) as the month with the most recently available information on the nominal consumption series (services, durable goods, and nondurable goods). If we are in the final 10 days of the current month, ENDDATA is approximately the previous month. If we are in the first 20 days of the current month, ENDDATA is two months earlier. (For example, if we were running the model on June 30, we would define ENDDATA as May; but if we were running the model on June 10, we would define ENDDATA as April.) To determine ENDDATA, it is important to know on exactly which day of the month the nominal consumption series will be released by the Commerce Department.

We define ENDDATA in this way because about 60 percent of real gross national product (GNP) is accounted for by personal consumption expenditures. Since the nominal consumption expenditures are released one month before the real versions, deflating this extra piece of information gives us a good estimate of real GNP for ENDDATA. As a result, the model's actual forecast of real GNP starts from ENDDATA+1.

Projection Through ENDDATA

Once ENDDATA is defined, it is possible that some of the remaining variables (the 44 variables left after subtracting the 3 consumption variables) have one or two lags relative to ENDDATA. In this case, a simple 6-lag univariate autoregression model (UVAR) is used to project the variables that are released monthly. See Table 1 for a list of monthly forecasting series that are projected. If any of the interpolated (quarterly) series does not extend through ENDDATA, the equation relating the monthly variables to the quarterly variable, together with the projected related monthly series and residuals, is used to extend the data through ENDDATA. A 6-lag UVAR is also used to project most of the related monthly variables, although for some related series we use equations involving other time series. For a list of the related monthly series that are projected, see Table 2. (If a nominal series corresponding to a real series has an extra observation, the deflation of the extra information by an appropriate price series takes priority over the projection of the real series using a VAR.)

Table 1

Projection of Monthly Forecasting Series

Projected Series	No. of Projections	VAR Type
Federal government budget plus off-budget items	1	Six lags of own and constant
Federal government net receipts	1	Six lags of own and constant
Index of spot market prices, raw industrials	1	Six lags of own and constant
Monetary base (published by St. Louis Fed)	1	Six lags of own and constant
Value of manufacturers' new orders	1	Six lags of own and constant
Value of manufacturers' shipments	1	Six lags of own and constant

Table 2

Projection of Related Monthly Series

Projected Series	No. of Projections	VAR Type
Change in real value of inventories on hand and on order	2	Six lags of own and constant plus three lags of manufacturers' new orders, manufacturing and trade wholesale inventories (The contemporaneous value of wholesale trade is also used if it exists.)
Commercial and industrial loans outstanding	1	Six lags of own and constant
Commodity Credit Corporation (CCC) inventories	2	Six lags of own and constant
Consumer credit outstanding	1	Six lags of own and constant
Exports	1	Six lags of own and constant
Hours, wage and salary workers, nonagricultural establishments	1	Six lags of own and constant plus six lags of total employment and the average weekly hours, manufacturing (The contemporaneous values of the latter two are also used if available.)
Imported oil price	1	Six lags of own and constant
Imports	1	Six lags of own and constant
Net outlays, national defense	1	Six lags of own and constant
Real value of construction put in place, nonresidential	1	Six lags of own and constant
Real value of construction put in place, residential	1	Six lags of own and constant

(cont.)

Table 2, continued

Projected Series	No. of Projections	VAR Type
Real value of manufacturers' new orders, nondefense capital goods	1	Six lags of own and constant
Real value of manufacturing inventories, durable goods	1	Six lags of own and constant plus six lags of real value of retail trade and wholesale trade inventories, durables
Real value of manufacturing inventories, nondurable goods	1	Six lags of own and constant plus six lags of real value of retail trade and wholesale trade inventories, nondurables
Real value of retail trade inventories, durable goods	1	Six lags of own and constant plus six lags of real value of manufacturing and wholesale trade inventories, durables
Real value of retail trade inventories, nondurable goods	1	Six lags of own and constant plus six lags of real value of manufacturing and wholesale trade inventories, nondurables
Real value of wholesale trade inventories, durable goods	1	Six lags of own and constant plus six lags of real value of manufacturing and retail trade inventories, durables (The contemporaneous values of the latter two are also used if they exist.)
Real value of wholesale trade inventories, nondurable goods	1	Six lags of own and constant plus six lags of real value of manufacturing and retail trade inventories, nondurables (The contemporaneous values of the latter two are also used if they exist.)
Value of manufacturers' shipments, nondefense capital goods	1	Six lags of own and constant

Deflation Procedure

Basically, two types of nominal series are deflated in the model. The first type includes nominal series for which the corresponding real versions are not published. We deflate these data series by closely related price series. Table 3 lists the nominal series of this type and the corresponding price series.

The second type of nominal series we deflate includes those series published earlier than their corresponding real versions. The nominal series is used to obtain a good estimate of its real version for the period to be announced (usually ENDDATA). The formula we use for updating the real series is

$$R_t = (N_t P_{t-1} R_{t-1})/(P_t N_{t-1})$$

where R_t is the real series, N_t is the nominal series, and P_t is a related price series. Table 4 lists the second type of nominal series and the corresponding price series.

Table 3

Deflation of Type I Nominal Series
(no real version published)

Nominal Series I	Price Series
Change in Commodity Credit Corporation (CCC) investments	GNP deflator
Commercial and industrial loans outstanding	GNP deflator
Monthly exports	Interpolated exports deflator
Monthly general imports	Interpolated imports deflator
Net outlays, national defense	GNP deflator
Value of manufacturers' shipments, nondefense capital goods	Three lags of producer price index, capital equipment

Table 4

Deflation of Type II Nominal Series
(released earlier than real version)

Nominal Series II	Price Series*
Personal consumption expenditures, durable goods	CPI
Personal consumption expenditures, nondurable goods	CPI
Personal consumption expenditures, services	CPI
Retail trade inventories, durable goods	PPI
Retail trade inventories, nondurable goods	PPI
Value of manufacturers' inventories, durable goods	PPI
Value of manufacturers' inventories, nondurable goods	PPI
Wholesale inventories, durable goods	PPI
Wholesale inventories, nondurable goods	PPI

*CPI = Consumer Price Index; PPI = Producer Price Index

Seasonal Adjustment Procedure

In general, we use published seasonally adjusted data in our data base. However, when seasonally adjusted data is unavailable we use our own method of seasonal adjustment. We also use our seasonal adjustment procedure when we consider the source of seasonal adjustment to be unreliable--that is, when we find seasonal peaks in the spectrum of the seasonally adjusted data. We make sure that all data are seasonally adjusted before we perform any data manipulation, such as projection or interpolation.

Our seasonal adjustment procedure is a frequency domain method based on Nerlove (1964) and Geweke (1978). The steps of the procedure are listed below:

(1) To remove the deterministic components from the data, we regress the logged unadjusted data, z_t, on constant, trend, and trend-squared:

$$z_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$$

where e_t represents the residuals. (If the series is a rate of change, we do not use the log transformation.)

(2) To remove the effects of deterministic seasonals if they appear to be significant, we regress the residuals obtained from Step 1 on seasonal dummies and compute the F-test of the hypothesis of zero coefficients for seasonal dummies. We replace the new residuals with the old residuals if the significance level of the F-test is less than 0.05. As a result, the deterministic parts are removed from the unadjusted data.

(3) Assuming that the length of the original data series is N, we center the data (with the deterministic parts removed) in a data series of length T > N. We choose T as a product of small primes which is also divisible

by the number of periods per year for the data. [If $N = 500$ and the data are monthly observations, then $T = 768 = (2^8 \cdot 3)$ is the recommended choice. The data are centered in the new data series when the first observation starts from the 135th and ends in the 634th period. If $N = 150$ and the data are quarterly observations, then $T = 256 = 2^8$ would be a good choice. Here, the data are centered by fitting them between the 54th and 203rd periods of the new data series. For further explanation about how to choose T, see the spectral analysis section of the RATS manual (1984).]

(4) We extend the centered data, say R_t, about $(T-N)/2$ periods forwards and backwards by using the following univariate vector autoregressions (UVARs):

$$R_t = \alpha_1 R_{t-1} + \alpha_2 R_{t-2} + \alpha_3 R_{t-3} + \alpha_4 R_{t-4} + \alpha_5 R_{t-5} + \alpha_6 R_{t-6} + \alpha_7 R_{t-11} + \alpha_8 R_{t-12} + \alpha_9 R_{t-13} + r_t$$

for monthly series and

$$R_t = \alpha_1 R_{t-1} + \alpha_2 R_{t-2} + \alpha_3 R_{t-3} + \alpha_4 R_{t-4} + \alpha_5 R_{t-5} + \alpha_6 R_{t-6} + r_t'$$

for quarterly series. Here r_t and r_t' represent the errors. To extend the data backwards, the time index should be reversed first before using these UVARs.

(5) We taper the extended series, R_t. (A <u>taper</u> scales the ends of the data so that they merge smoothly with the zeros on either side.) The tapered series y_t is defined by $y(t) = [b(t)R_t]$ where

$$b(t) = \begin{cases} t/m & 1 \leq t \leq m \\ 1 & m+1 \leq t \leq T-m \\ \frac{(T-t+1)}{m} & T-m+1 \leq t \leq T \end{cases}$$

and where $m = \{[(T-N)/2] - 2n\}$ and n is the number of periods per year--that is, the taper begins two years before and two years after the actual residuals.

(6) The Fourier transform of the tapered series is computed by

$$F(\lambda_j) = \sum_{t=1}^{T} y_t e^{-i(t-1)\lambda_j}$$

where $\lambda_j = (2\pi j/T)$ and $j = 0,\ldots,(T-1)$. Then the Fourier transform is multiplied by a deseasonalized set of weights--that is, a series with dips at the seasonal frequencies and with ones elsewhere. The weights we use are defined by $w(\lambda_j) = 1 - 0.9e^{in\lambda_j}$ where $j = 0,\ldots,(T-1)$ and n is the number of periods per year. This process of multiplying the Fourier transform by these weights is called prewhitening:

$$X(\lambda_j) = w(\lambda_j)F(\lambda_j)$$

for $j = 0,\ldots,(T-1)$. If we divide instead of multiply, the process is called recoloring. Both tapering (Step 5) and prewhitening are designed to improve the estimate of the spectrum (see Priestly 1981, p. 556).

(7) The periodogram is obtained by multiplying the prewhitened Fourier coefficients by their conjugates, $\overline{x}(\lambda_j)$, and scaling the products by $2\pi s$, where $s = \sum_{t=1}^{T} b^2(t)$. Thus, $P(\lambda_j) = (1/2\pi s)x(\lambda_j)\overline{x}(\lambda_j)$ is the j^{th} periodogram coefficient.

(8) The spectrum, $S(\lambda_j)$, is computed by smoothing the periodogram using a flat window of length 11 and a mask. (A mask is simply a dummy series

with entries of 0 or 1; the masked observations are marked with zeros.) This masks the infinite frequency and possibly the seasonal frequencies if the seasonal dummies were removed in Step 2. [For more details, see the spectral analysis section of the RATS manual (1984).]

(9) Both the periodogram and spectrum are recolored:

$$P'(\lambda_j) = P(\lambda_j)/w(\lambda_j)\overline{w}(\lambda_j)$$

$$S'(\lambda_j) = S(\lambda_j)/w(\lambda_j)\overline{w}(\lambda_j)$$

where $\overline{w}(\lambda_j)$ is the conjugate of $w(\lambda_j)$.

(10) The estimate of the nonseasonal spectrum, say $S''(\lambda_j)$, is obtained by interpolating across the seasonal peaks of the recolored seasonal spectrum with a quadratic curve. This is done by regressing a number of periodogram ordinates (usually 8 ordinates for a monthly series and 6 for a quarterly series) on each side of the seasonal band on constant, trend, and trend-squared. (The <u>seasonal band</u> is considered to be those ordinates roughly 10 ordinates on either side of the seasonal peak.) We then use the estimated equation to interpolate across the seasonal band.

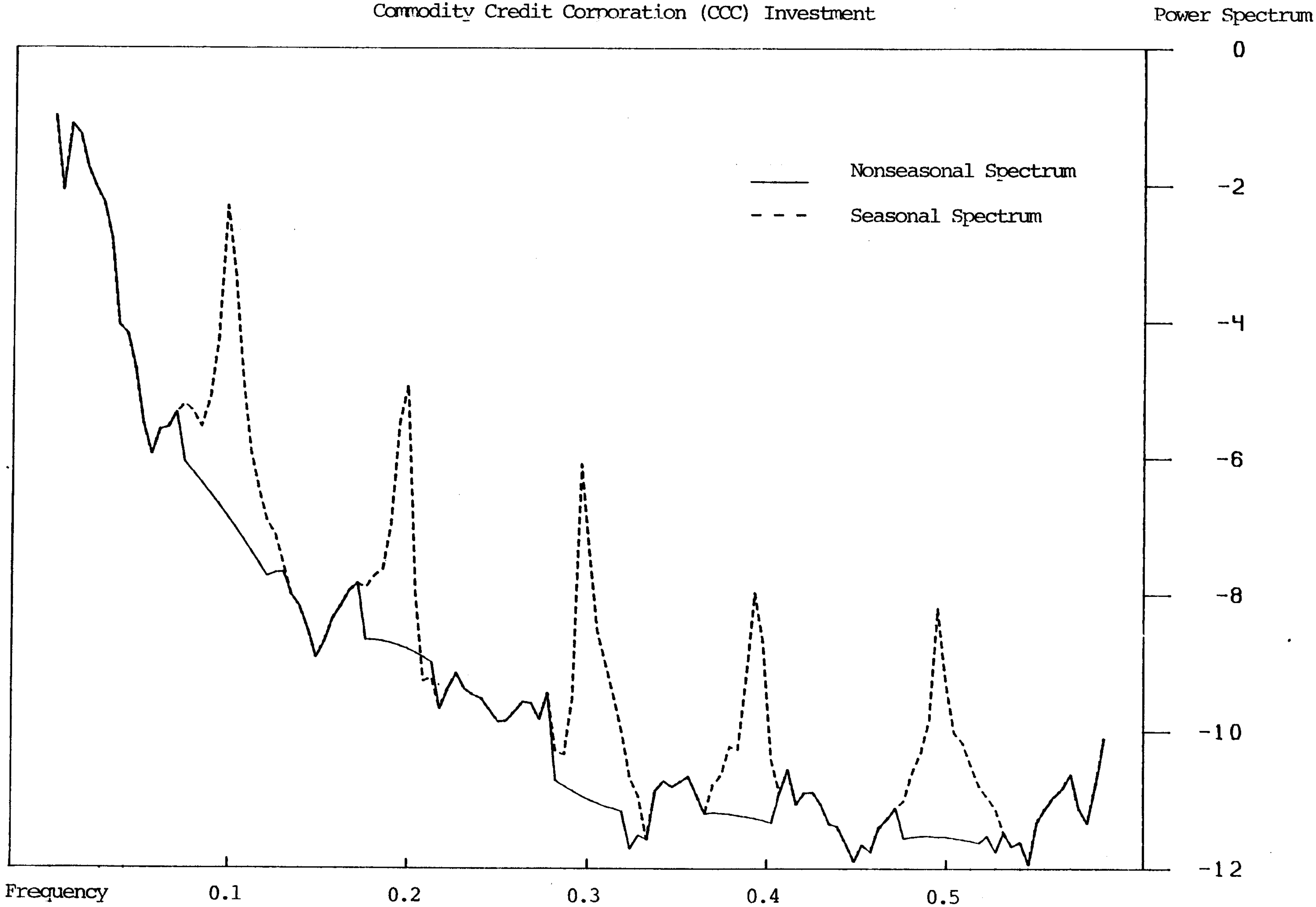
(11) We compute the ratio of the seasonal spectrum over the nonseasonal spectrum across the seasonal bands. (In Figure 1, the two spectra are plotted.) For any j = 0,...,(T-1), the ratio of the nonseasonal spectrum, $S''(\lambda_j)$, to the spectrum, $S'(\lambda_j)$, is defined by

$$R(\lambda_j) = \begin{cases} \dfrac{S''(\lambda_j)}{S'(\lambda_j)} & \text{if } \lambda_j \text{ belongs to one of the seasonal bands } \underline{\text{and}} \\ & S''(\lambda_j) < S'(\lambda_j). \\ 1 & \text{if otherwise.} \end{cases}$$

Figure 1

Seasonal Versus Nonseasonal Spectrum

Commodity Credit Corporation (CCC) Investment



(12) The Fourier transform of the extended series is adjusted by multiplying by the ratio of Step 11:

$$F'(\lambda_j) = F(\lambda_j)R(\lambda_j)$$

for $j = 0,\ldots,(T-1)$.

(13) The seasonally adjusted series, $\hat{z}_t$, is obtained by inversing the adjusted Fourier transform and adding the constant, trend, and trend-squared back:

$$\hat{z}_t = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\beta}_2 t^2 + \sum_{j=0}^{T-1} F'(\lambda_j)e^{+i(t-1)\lambda_j}.$$

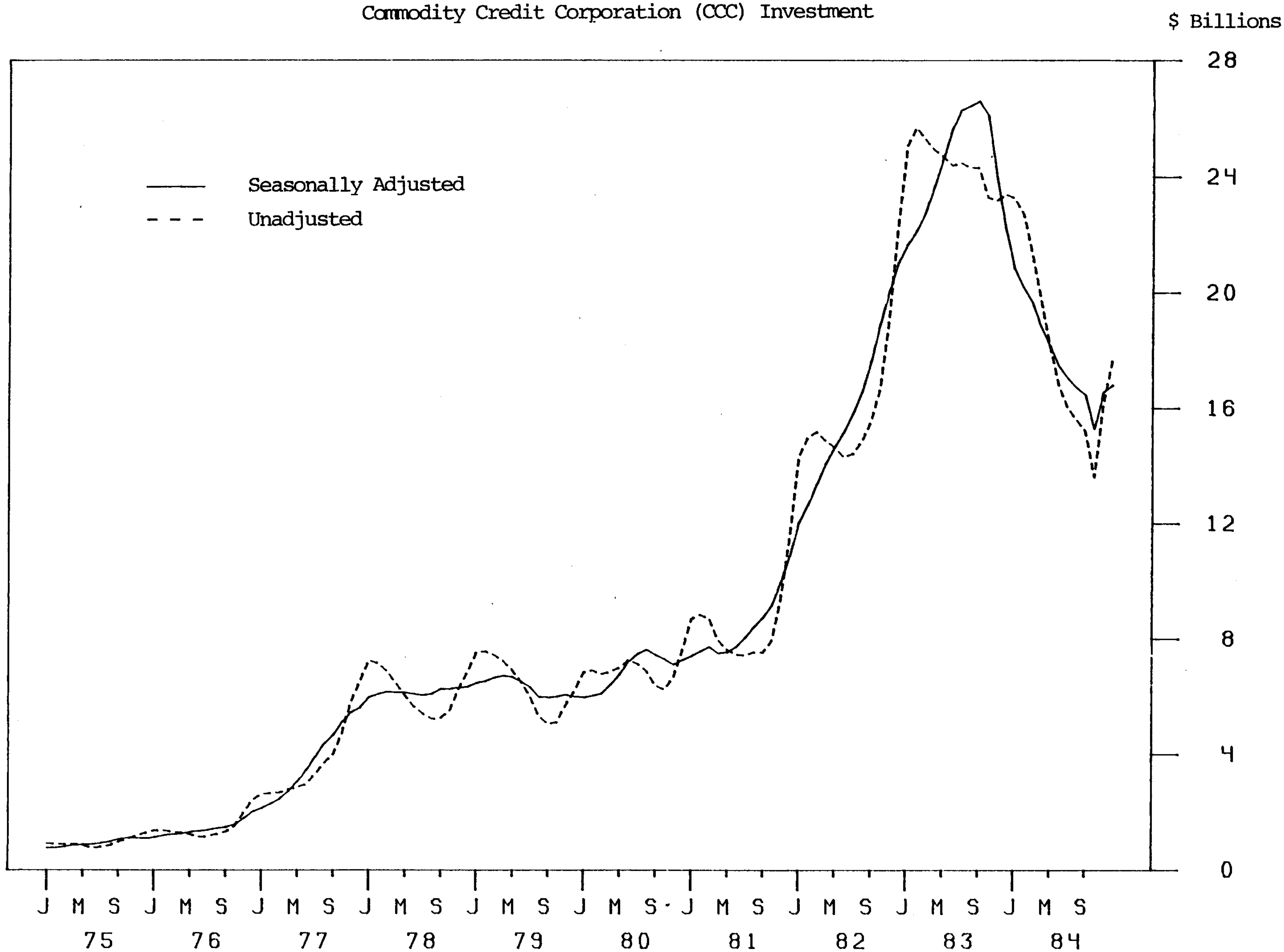
The data series seasonally adjusted by Steps 1-13 are listed below:

- Commodity Credit Corporation (CCC) investment
- Consumer credit outstanding
- Consumer price index, all urban consumers
- Consumer price index, energy
- Federal government budget plus off-budget items
- Federal government net receipts
- Index of spot market prices, raw industrials
- Net outlays, national defense
- Producer price index, all commodities
- Producer price index, capital equipment.

For an example comparing seasonally adjusted versus unadjusted data for a series, see Figure 2.

Figure 2

Seasonally Adjusted Versus Unadjusted Series:
Commodity Credit Corporation (CCC) Investment



Interpolation Procedure

Because many of the model's variables are only published as quarterly data, we use related monthly series to obtain their monthly versions. This process, called interpolation, is the estimation of unobserved monthly values, say y_t, from a quarterly series using some related monthly series, say x_t, by the relation

$$y_t = x_t \beta + u_t.$$

The constraints are that the average of the three monthly estimates for each quarter ought to equal the observed value for the quarter.

In order to estimate this relationship, we use up to three different procedures to interpolate each series. We start with the Litterman (1983) procedure, which assumes the error process, u_t, follows a random walk

$$u_t = u_{t-1} + e_t$$

where e_t is a first-order Markov process,

$$e_t = \alpha e_{t-1} + v_t,$$

and v_t is white noise. Litterman (1983) shows how to estimate α, β, and the monthly value of y, given quarterly averages of y and the monthly values of x.

If the Litterman procedure results in a negative estimate for α, we then use the Chow-Lin (1971) procedure, which assumes the error process, u_t, follows a first-order Markov process

$$u_t = \alpha u_t + e_t$$

where e_t is white noise. It is possible, however, that the result of the Chow-Lin interpolation is also unsatisfactory. For example, if the errors are large, we replace (when possible) the related monthly series with some other related monthly series, or we add some other related monthly series to the related series. We then start from the Litterman procedure again.

If the result is still unsatisfactory, we apply the Fernandez (1981) procedure, which assumes the error process, u_t, follows a random walk process

$$u_t = u_{t-1} + e_t$$

where e_t is white noise.

We do not redetermine the kind of interpolation procedure each time we run the model. Once chosen, the method of interpolation stays fixed. Table 5 lists the quarterly series, the method of interpolation, and the related monthly series for each of the quarterly series. Figure 3 provides an example comparing an interpolated with a quarterly series.

Table 5

Interpolated Quarterly Series

Quarterly Series	Interpolation Method*	Related Monthly Series**
Change in business inventories, farm	CL	•Change in CCC investments, deflated by GNP deflator (from 70:1) •Constant, Trend, CON70, and TRND70
Change in business inventories, manufacturing, durable goods	CL	•Change in real value of manufacturing inventories, durable goods •Constant and Trend
Change in business inventories, manufacturing, nondurable goods	CL	•Change in real value of manufacturers' inventories, nondurable goods •Constant and Trend
Change in business inventories, merchant wholesalers, durable goods	CL	•Change in real inventories of merchant wholesalers, durable goods •Constant and Trend
Change in business inventories, merchant wholesalers, nondurable goods	CL	•Change in real inventories of merchant wholesalers, nondurable goods •Constant and Trend
Change in business inventories, nonmerchant wholesalers and other nonfarm durable goods	CL	•Real change in inventories on hand and on order •Constant and Trend
Change in business inventories, nonmerchant wholesalers and other nonfarm nondurable goods	CL	•Real change in inventories on hand and on order •Constant and Trend
Change in business inventories, retail trade, durable goods	CL	•Change in real retail trade inventories, durable goods •Constant and Trend

*L = Litterman (1983); CL = Chow-Lin (1971); F = Fernandez (1981).

**CONxx is a dummy series which is 1 before xx and 0 from xx on; TRNDxx is a dummy series which is t before xx and 0 from xx on.

(cont.)

Table 5, continued

Quarterly Series	Interpolation Method*	Related Monthly Series**
Change in business inventories, retail trade, nondurable goods	CL	•Change in real retail trade inventories, nondurable goods •Constant and Trend
Compensation of employees (divided by real GNP after interpolation)	L	•Log of average hourly earnings, manufacturing •Log of hours, wage and salary, nonagricultural establishments •Log of hourly earnings index, total •Constant and Trend
Corporate profit (divided by real GNP after interpolation)	L	•Standard and Poor's 500-stock index •Hourly earnings index, total •Personal income •Industrial production •Total retail sales •Constant and Trend
Employment cost index	L	•Average hourly earnings, manufacturing •Hourly earnings index, total •Constant and Trend
Exports	L	•Exports, deflated by exports deflator •Constant and Trend
Exports, implicit price deflator	L	•Weighted-average exchange value of U.S. dollar •Constant and Trend
GNP deflator	L	•Consumer price index •Producer price index •Constant and Trend
Government purchases, change in CCC inventories	CL	•Change in CCC investments, deflated by GNP deflator (from 70:1) •Constant, Trend, CON70, and TRND70

*L = Litterman (1983); CL = Chow-Lin (1971); F = Fernandez (1981).

**CONxx is a dummy series which is 1 before xx and 0 from xx on; TRNDxx is a dummy series which is t before xx and 0 from xx on.

(cont.)

Table 5, continued

Quarterly Series	Interpolation Method*	Related Monthly Series**
Government purchases, federal national defense	L	•Second-degree polynomial distributed lag of 0-11 lags of net outlays for national defense, deflated by GNP deflator •Constant, Trend, CON69, and TRND69
Government purchases, eral nondefense and change in CCC inventories	CL	•Constant and Trend
Government purchases, state and local	CL	•Total employees, state and local governments •Constant and Trend
Imports	F	•Imports, deflated by imports deflator (from 69:1) •Constant, Trend, CON69, and TRND69
Imports, implicit price deflator	L	•Imported petroleum and petroleum product (from 65:1) •Weighted-average exchange value of U.S. dollar •Constant, Trend, CON65, and TRND65
Nonresidential fixed investment, equipment	L	•Industrial production •Total retail sales of new domestic cars (from 68:1) •Commercial and industrial loans outstanding, deflated by GNP deflator •Value of manufacturers' shipments, nondefense capital goods deflated by three lags of PPI, capital equipment (from 58:1) •Real value of manufacturers' new orders, capital goods industries •Constant, Trend, CON58, TRND58, CON68, and TRND68

*L = Litterman (1983); CL = Chow-Lin (1971); F = Fernandez (1981).

**CONxx is a dummy series which is 1 before xx and 0 from xx on; TRNDxx is a dummy series which is t before xx and 0 from xx on.

(cont.)

Table 5, continued

Quarterly Series	Interpolation Method*	Related Monthly Series**
Nonresidential fixed investment, structures	L	•Industrial production •Real value of new construction put in place, total private nonresidential (from 64:1) •Commercial and industrial loans outstanding, deflated by GNP deflator •Constant, Trend, CON64, and TRND64
Residential fixed investment	L	•Real value of new construction put in place, total private residential (from 64:1) •Constant, Trend, CON64, and TRND64
Total nonfinancial debt (from 52:1; extended back to 48:1)	CL	•Consumer credit outstanding •Commercial and industrial loans outstanding •Monthly proxy for stock of domestic nonfinancial debt minus the above two variables (from 55:1) •Constant, Trend, CON55, and TRND55

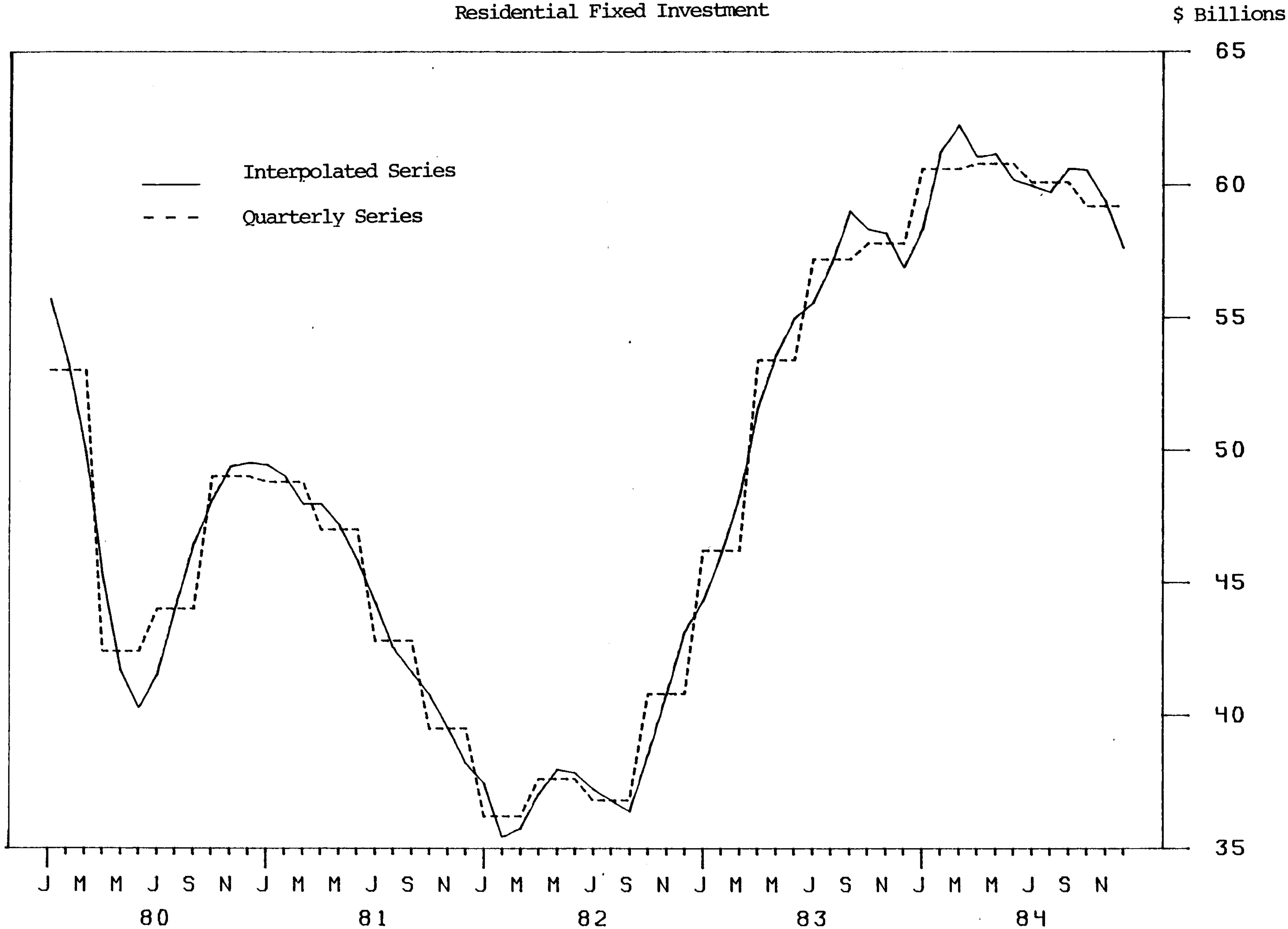
*L = Litterman (1983); CL = Chow-Lin (1971); F = Fernandez (1981).

**CONxx is a dummy series which is 1 before xx and 0 from xx on; TRNDxx is a dummy series which is t before xx and 0 from xx on.

Figure 3

Interpolated Versus Quarterly Series:

Residential Fixed Investment



Extension of the Interpolated Series

In some cases, we need to extend our interpolated series through ENDDATA. Suppose, for instance, that the date is mid-January 1985 and we want to construct our data base to run the model. At this time the quarterly series corresponding to the components of real GNP are available through the third quarter of 1984. Moreover ENDDATA is November 1984; that is, we have updated the consumption series through that month. But after interpolating the quarterly series, the interpolated series exist only through September. Take, for example, the interpolation of the quarterly series for residential fixed investment. For this variable we use only one related monthly series--the real value of new construction put in place, residential--for which data exist through November. Because the two extra months (October and November) might contain a significant piece of information, we would somehow like to use these observations to update the interpolated residential fixed investment series. To solve this problem we use the equation estimated from the interpolation procedure, where the errors for October and November can be extended. By using the estimated equation and the monthly values for October and November for the related monthly series, the interpolation of residential fixed investment can be extended through ENDDATA (November). (We can also extend the interpolated series backwards over a period for which the quarterly series is not available by using the same procedure--as is the case, for example, with total nonfinancial debt.)

Sometimes the related monthly series do not extend through ENDDATA. In this case we often use a 6-lag UVAR model to project them through ENDDATA. For some series--such as the real change in inventories on hand and on order--we use some other time series in the VAR as well. (Refer to Table 2 for a list of related monthly series that are projected through ENDDATA.)

Transformation of Data

In a few cases we transform some of the data before completing the construction of our data base. For instance, we may transform a variable to introduce a series in which we are more interested, as is the case when we divide corporate profits by real GNP. We may also transform a variable in order to remove a volatile component of a series from its smoother part, as is the case when we sum the change in Commodity Credit Corporation (CCC) inventories and government purchases, federal nondefense. Other transformations are mentioned in the sector-by-sector listing of series in Annex A.

ANNEX A

CONSTRUCTION OF THE MODEL'S DATA BASE BY SECTOR

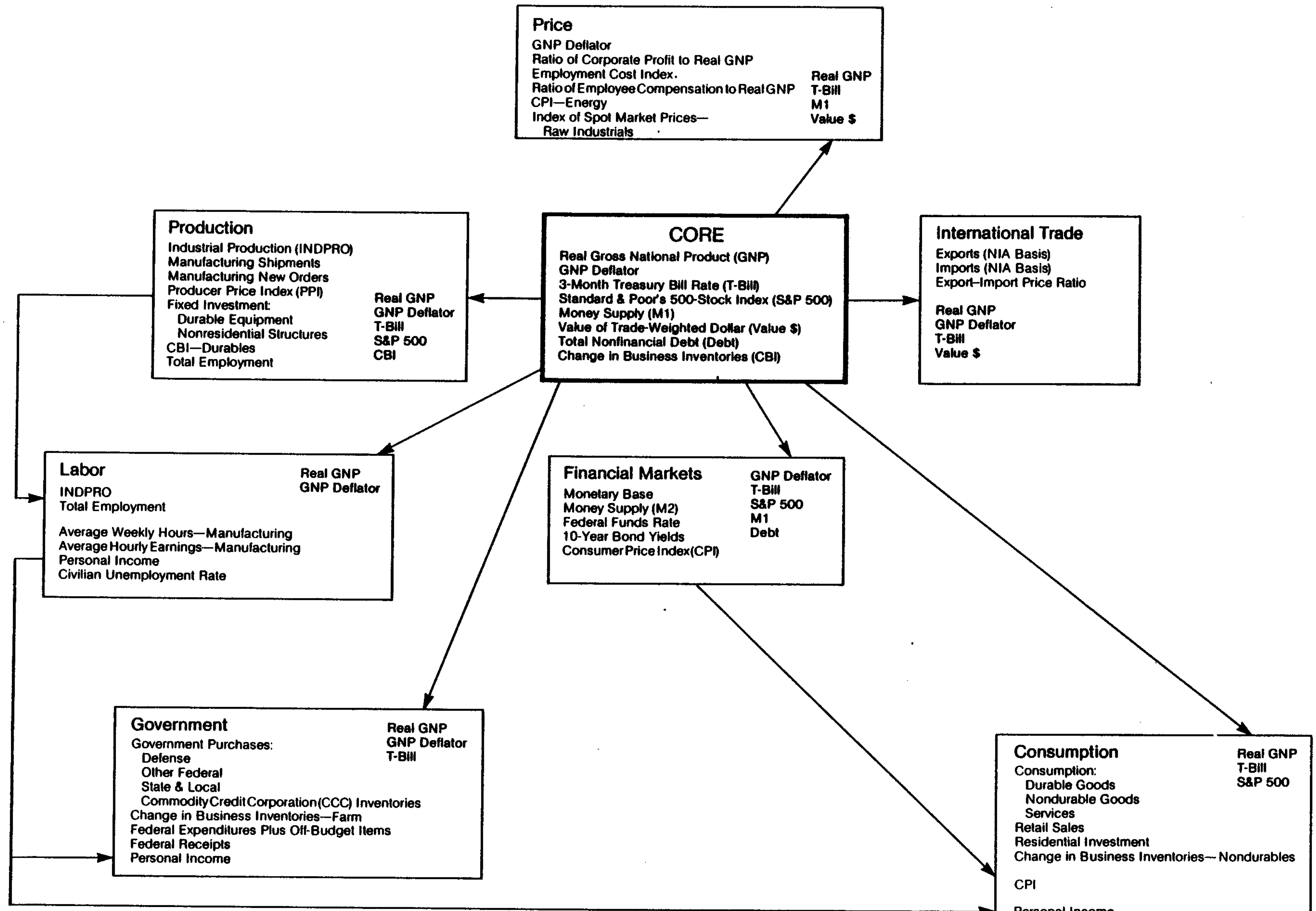
This annex provides a sector-by-sector commentary on how each of the model's 47 forecasting series is constructed. The eight sectors are discussed in the following order:

1. Core
2. Production
3. Labor
4. Financial Markets
5. Consumption
6. Government
7. International Trade
8. Price.

An overview of the sectors and their interactions is provided in Figure A1.

Figure A1

The Main Interactions of Our Model's Variables



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1. CORE SECTOR

Real Gross National Product

The monthly real GNP series is generated by summing the published monthly total consumption expenditures with the following series:

- Nonresidential fixed investment, durable equipment (Production)
- Nonresidential fixed investment, structures (Production)
- Residential fixed investment (Consumption)
- Change in business inventories, durables (Production)
- Change in business inventories, nonfarm nondurables (Consumption)
- Change in business inventories, farm (Government)
- Government purchases, defense (Government)
- Government purchases, other federal (Government)
- Government purchases, state and local (Government)
- Government purchases, Commodity Credit Corporation (CCC) inventories (Government)
- Exports, NIA basis (International Trade)
- Imports, NIA basis (International Trade)

Each of these series is separately constructed by one or more interpolations, and each appears in one of the model's other sectors (given in parentheses). CCC inventories and exports are both negative in the summation.

GNP Deflator

The monthly GNP deflator is based on a Litterman interpolation using monthly data on the consumer price index, the producer price index, and a constant and trend.

Three-Month Treasury Bill Rate

This series is the monthly average of yields on 3-month Treasury securities.

Standard & Poor's 500-Stock Index

This series is the monthly average of Standard and Poor's index of 500 securities' prices.

Money Supply (M1)

This series is the seasonally adjusted monthly value for the money supply (M1) as published by the Federal Reserve Board. This data is available from 1959:1. Values for M1 from 1948:1 through 1958:12 were generated by scaling the old M1 series by the ratio of the new to the old value for 1959:1.

Value of Trade-Weighted Dollar

This series is the Commerce Department's index of the weighted-average exchange value of the U.S. dollar, available from 1967:1. For 1948:1 through 1966:12, a trade-weighted dollar series was constructed following the usual formula and weights. Rather than being based on the ten countries in the current index, however, the constructed series is based only on the exchange rates between the United States and Germany, France, and Great Britain. The constructed series is scaled so that the value for 1967:1 coincides with the current index.

Total Domestic Nonfinancial Debt

This is a monthly data series generated by interpolating the flow of total nonfinancial debt published in the Federal Reserve Board's "Flow of Funds" data set. The quarterly series is constructed by subtracting seasonally adjusted credit market funds raised by foreigners from seasonally adjusted total nonfinancial sector credit market debt. The method of interpolation is Chow-Lin. The related monthly series are: seasonally adjusted commercial and industrial loans outstanding; consumer credit outstanding; "other debt," defined as a monthly proxy for the stock of domestic nonfinancial debt minus the sum of the previous two variables; and a constant, trend, and dummies for constant and trend from 1952:1 through 1954:12, when the monthly proxy is unavailable. Because the flow of funds data are released with essentially a one-quarter lag, the equation relating monthly variables to the quarterly variable, together with the projected residuals, is used to extend the interpolated series through ENDDATA. And since the flow of funds series begins in 1952:1, we use the equation in a similar manner to extend the series back to 1948:1. The monthly proxy is unpublished data; it can be obtained from the Federal Reserve Board, Series FL384104005M.

Change in Business Inventories

This series is generated from the sum of change in business inventories for durables, nondurables, and farm.

2. PRODUCTION SECTOR

Industrial Production

This series is the seasonally adjusted index of industrial production published by the Federal Reserve Board.

Manufacturing Shipments

This series is the seasonally adjusted value of manufacturers' shipments for all manufacturing industries, in current dollars, published in the Census Bureau's release, "Manufacturers' Shipments, Inventories, and Orders."

Manufacturing New Orders

This series is the seasonally adjusted value of manufacturers' new orders for all manufacturing industries, in current dollars, published in the Census Bureau's release, "Manufacturers' Shipments, Inventories, and Orders."

Producer Price Index (PPI)

This series is the Bureau of Labor Statistics' producer price index in level form, seasonally adjusted using our own procedure.

Nonresidential Fixed Investment: Durable Equipment

This is a monthly series based on a Litterman interpolation of nonresidential fixed investment, durable equipment. The interpolation uses the following related monthly series: industrial production; commercial and industrial loans deflated by the GNP deflator; value of manufacturers' shipments, nondefense capital goods, deflated by three lags of the capital equipment component of PPI; real value of manufacturers' new orders, capital goods industries; total retail sales of new domestic cars; and a constant, trend, and dummies for constant and trend from 1948:1 through 1957:12 and from 1948:1 through 1967:12. The data for manufacturers' shipments and retail sales of new domestic cars begins from 1958:1 and 1968:1, respectively. Retail sales of new domestic cars is published by the Bureau of Economic Analysis. We use our own procedure to seasonally adjust the following monthly data series: value of manufacturers' shipments, nondefense capital goods; and PPI, capital equipment.

Nonresidential Fixed Investment: Structures

This is a monthly series based on a Litterman interpolation of nonresidential fixed investment, structures. The interpolation uses the following related monthly series: industrial production; commercial and industrial loans deflated by the GNP deflator; value of new construction put in place, total private nonresidential, in dollars of 1977, published in the Census Bureau's release, "Construction Expenditures"; and a constant, trend, and dummies for constant and trend from 1948:1 through 1963:12. The data for value of new construction is available from 1964:1.

Change in Business Inventories: Durables

The monthly durable change in business inventories is generated by summing monthly durable manufacturing, durable merchant wholesalers, durable retail trade, and the "durable other" change in business inventories--each of which is separately interpolated. The quarterly series are published by the Bureau of Economic Analysis (BEA, NIPA, Table 5.9). The "durable other" component is defined as the sum of other durable nonfarm and durable non-merchant wholesalers. The Chow-Lin method is used for each of the interpolations. The related monthly series used in each interpolation are constant and trend in addition to the monthly version of the quarterly series (except for the "durable other," for which the net change in inventories on hand and on order is used). The source of the related monthly series is also the BEA.

Since the quarterly data for other nonfarm, merchant wholesalers, and nonmerchant wholesalers are not available for 1948:1 through 1958:12, the construction of durable change in business inventories for this period is slightly different from the above. Here the "durable other" also includes merchant wholesalers, and this quarterly variable is simply obtained by subtracting durable manufacturers' inventories and durable retail trade inventories from the total durable change in business inventories. The monthly interpolated version of this series is based on a Chow-Lin interpolation, and the related monthly series are the net change in inventories on hand and on order plus a constant and trend.

Total Employment

This series is the seasonally adjusted total employees on payrolls, nonagricultural industries, published in the Bureau of Labor Statistics' "Employment and Earnings" release.

3. LABOR SECTOR

Average Weekly Hours: Manufacturing

This series is the seasonally adjusted average weekly hours for manufacturing, published in the Bureau of Labor Statistics' "Employment and Earnings" release.

Average Hourly Earnings: Manufacturing

This series is the seasonally adjusted average hourly earnings for manufacturing, published in the Bureau of Labor Statistics' "Employment and Earnings" release.

Personal Income

This series is seasonally adjusted personal income, in current dollars, published in the Bureau of Economic Analysis' "Personal Income and Outlays" release.

Civilian Unemployment Rate

This series is the seasonally adjusted civilian unemployment rate, published in the Bureau of Labor Statistics' "Employment and Earnings" release.

4. FINANCIAL MARKETS SECTOR

Monetary Base

This series is the Federal Reserve Bank of St. Louis' monetary base, adjusted for changes in reserve requirements.

Money Supply (M2)

This series is the seasonally adjusted monthly value for the money supply (M2), published by the Federal Reserve Board. The data are available from 1959:1.

Federal Funds Rate

This series is the monthly federal funds rate, published in the Federal Reserve Board's "Selected Interest Rates" release.

Ten-Year Bond Yields

This series is the monthly average of ten-year bond yields on U.S. government securities, published by the Federal Reserve Board.

Consumer Price Index

This series is the Bureau of Labor Statistics' producer price index in level form. It is seasonally adjusted using our own procedure.

5. CONSUMPTION SECTOR

Consumption Expenditures: Durable Goods

This series is the seasonally adjusted monthly consumption expenditures, durable goods, in dollars of 1972, published by the Bureau of Economic Analysis.

Consumption Expenditures: Nondurable Goods

This series is the seasonally adjusted monthly consumption expenditures, nondurable goods, in dollars of 1972, published by the Bureau of Economic Analysis.

Consumption Expenditures: Services

This series is the seasonally adjusted monthly consumption expenditures, services, in dollars of 1972, published by the Bureau of Economic Analysis.

Retail Sales

This series is the seasonally adjusted total retail sales in current dollars, published in the Census Bureau's "Advance Monthly Retail Sales" release.

Residential Fixed Investment

This is a monthly series based on a Litterman interpolation of residential fixed investment. The interpolation uses the following related monthly series: value of new construction put in place, total private nonresidential, in dollars of 1977; constant, trend, and dummies for constant and trend from 1948:1 through 1963:12. The data for the value of new construction are available from 1964:1 and are published in the Census Bureau's "Construction Expenditures" release.

Change in Business Inventories: Nondurables

The monthly nondurable change in business inventories is generated by summing monthly nondurable manufacturing, nondurable merchant wholesalers, nondurable retail trade, and the "nondurable other" change in business inventories--each of which is separately interpolated. The quarterly series are published by the Bureau of Economic Analysis (BEA, NIPA, Table 5.9). The "nondurable other" component is defined as the sum of other nondurable nonfarm and nondurable nonmerchant wholesalers. The Chow-Lin method is used for each of the interpolations. The related monthly series used in each interpolation are constant and trend in addition to the monthly version of the quarterly series, except for the "nondurable other." For this series we use the net change in inventories on hand and on order. The source of the related monthly series is also the BEA.

Since the quarterly data for other nonfarm, merchant wholesalers, and nonmerchant wholesalers are not available for 1948:1 through 1958:12, the construction of nondurable change in business inventories for this period differs slightly from the above. Here the "nondurable other" also includes merchant wholesalers, and this quarterly variable is simply obtained by subtracting nondurable manufacturers' inventories and nondurable retail trade inventories from the total nondurable change in business inventories. The monthly interpolated version of this series is based on a Chow-Lin interpolation, and the related monthly series are the net change in inventories on hand and on order plus a constant and trend.

6. GOVERNMENT SECTOR

Government Purchases: Federal National Defense

This is a monthly series based on a Litterman interpolation of government purchases, federal national defense. The related monthly series are a second-degree polynomial distributed lag from zero to eleven lags of net outlays, national defense, deflated by the GNP deflator; and constant, trend, and dummies on constant and trend for 1948:1 through 1969:12. The monthly series net outlays, national defense is published in the Treasury Department's "Monthly Treasury Statement" release.

Government Purchases: Other Federal

This is a monthly data series generated by interpolating the sum of government purchases, federal nondefense and the change in Commodity Credit Corporation (CCC) inventories. By summing these two series, we remove the series's volatile CCC inventory component, which is a negative component of federal nondefense purchases. The method of interpolation is Chow-Lin, and the related monthly series are only constant and trend.

Government Purchases: State and Local

This is a monthly series based on a Chow-Lin interpolation of government purchases, state and local. The interpolation uses the following related monthly series: seasonally adjusted total employees of state and local governments, constant, and trend. The monthly series of total employees, state and local governments is published in the Bureau of Labor Statistics' "Employment and Earnings" release.

Government Purchases: Commodity Credit Corporation (CCC) Inventories

This is a monthly data series generated by a Chow-Lin interpolation of the Bureau of Economic Analysis' change in CCC inventories. The interpolation uses the following related monthly series: CCC investments, constant, trend, and dummies on constant and trend for 1948:1 through 1969:12. CCC investments, published by the U.S. Department of Agriculture CCC, is available from 1970:1. This series is seasonally adjusted by our own procedure.

Change in Business Inventories: Farm

This is a monthly data series based on a Chow-Lin interpolation of the change in business inventories, farm. The interpolation uses the following monthly series: CCC investments, constant, trend, and dummies on constant and trend for 1948:1 through 1969:12. CCC investment, published by the U.S. Department of Agriculture CCC, is available from 1970:1.

Federal Expenditures Plus Off-Budget Items

This series, the monthly sum of federal expenditures plus off-budget items, is available in the Treasury Department's "Monthly Treasury Statement" release. The data series begins from 1968:2. The data from 1948:1 through 1968:1 have been obtained by a linear interpolation of the annual data using the monthly outlays series on a cash basis. The data are then seasonally adjusted by our own procedure.

Federal Receipts

This series, monthly federal government receipts, is available in the Treasury Department's "Monthly Treasury Statement" release. The data series is available from 1968:2. The data from 1948:1 through 1968:1 have been obtained by a linear interpolation of the annual data using the monthly receipts series on a cash basis. The data are then seasonally adjusted by our own procedure.

7. INTERNATIONAL TRADE SECTOR

Real Exports

The monthly real exports series is based on a Litterman interpolation using monthly data on the seasonally adjusted exports, excluding military, reported on a f.a.s. value basis, constant, and trend. The monthly exports data are deflated by the interpolated exports deflator. This series is published by the Census Bureau.

Real Imports

The monthly real imports series is based on a Fernandez interpolation using monthly data on the seasonally adjusted general imports (reported on a f.a.s. value basis), constant, trend, and dummies for constant and trend for 1948:1 through 1968:12. The monthly general imports data are deflated by the interpolated imports deflator. This series is published by the Census Bureau and is available from 1969:1.

Export-Import Price Ratio

This is a monthly series based on the ratio of two interpolated series: the exports price deflator over the imports price deflator. The interpolation of the exports deflator is generated by the Litterman method using the following related monthly series: the weighted-average exchange value of the U.S. dollar, constant, and trend. The imports deflator is also obtained through the Litterman interpolation method; its related monthly series are the weighted-average exchange value of the U.S. dollar, imported petroleum and petroleum products price, constant, trend, and dummies for constant and trend for 1948:1 through 1964:12. The monthly series, imported petroleum and petroleum products price, is published by the Census Bureau and begins from 1980:1. For 1965:1 through 1979:12, the petroleum series is extended back using other related data series.

8. PRICE SECTOR

GNP Deflator

This series is the same as the GNP deflator in the core sector.

Ratio of Corporate Profits to Real GNP

This series is the monthly ratio of corporate profits to real GNP. The monthly corporate profits series is generated by a Litterman interpolation using the following related monthly series: Standard & Poor's 500-stock index, hourly earnings index, personal income, industrial production, total retail sales, constant, and trend. The monthly hourly earnings index is available from 1963:1.

Employment Cost Index

The monthly employment cost index is based on a Litterman interpolation using the following related monthly series: average hourly earnings, manufacturing; hourly earnings index; constant; and trend. The hourly earnings index is available from 1963:1. The period 1948:1 through 1962:12 was generated by scaling the ratio of the hourly earnings index to average hourly earnings, manufacturing for 1963:1.

Ratio of Compensation of Employees to Real GNP

This series is the monthly ratio of the compensation of employees to real GNP. The monthly compensation of employees is generated by a Litterman interpolation using the following related monthly series: log of average hourly earnings, manufacturing; log of hours, wage and salary workers, nonagricultural establishments; log of hourly earnings index; constant; and trend. The hourly earnings index is available from 1963:1. The period 1948:1 through 1962:12 was generated by scaling average hourly earnings, manufacturing by the ratio of the hourly earnings index to average hourly earnings for 1963:1.

Consumer Price Index: Energy

This series is the Bureau of Labor Statistics' consumer price index in level form. It is seasonally adjusted by our own procedure.

Index of Spot Market Prices: Raw Industrials

This series is an index of spot market prices, raw industrials, published by the Commodity Research Bureau of the Bureau of Labor Statistics. This series is seasonally adjusted by our own procedure.

ANNEX B

QUARTERLY AND MONTHLY DATA SERIES

This annex provides lists of the quarterly and monthly data series used in the model. Each list presents the series codes (mnemonics) used in the model's program and by two commercial data bases--Automated Data Processing (ADP) and Interactive Data Corporation (IDC). The lists are alphabetized according to the code name used in the model's program. Information about each series, provided below the codes, describes the series briefly, gives the unit of measurement, indicates if and how the data are seasonally adjusted, and states the source. The quarterly series are listed first. The abbreviations used in the lists are explained at the end of the annex.

QUARTERLY SERIES

National Model	ADP	IDC
CBID Change in business inventories, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 1.4	NIA878	IR72(NIPA)
CBIFRM Change in business inventories, farm Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 5.9	NIA789	IIFRM72(NIPA)
CBIMD Change in business inventories, manufacturing, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA792	IIMFGD72(NIPA)
CBIMN Change in business inventories, manufacturing, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA793	IIMFGN72(NIPA)
CBIMWD Change in business inventories, merchant wholesalers, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA798	IIMWSD72(NIPA)
CBIMWND Change in business inventories, merchant wholesalers, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA795	IIMWSN72(NIPA)
CBIN Change in business inventories, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 1.4	NIA901	IIGDSN72(NIPA)
CBINMWD Change in business inventories, nonmerchant wholesalers, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA802	IINWSD72(NIPA)

National Model	ADP	IDC
CBINMWND Change in business inventories, nonmerchant wholesalers, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA802	IINWSN72(NIPA)
CBIONFD Change in business inventories, other nonfarm, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA807	IIOTHD72(NIPA)
CBIONFND Change in business inventories, other nonfarm, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA808	IIOTHN72(NIPA)
CBIRTD Change in business inventories, retail trade, durable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA804	IIRETD72(NIPA)
CBIRTND Change in business inventories, retail trade, nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 5.9	NIA805	IIRETN72(NIPA)
COMPEMP Compensation of employees Billions of current dollars, s.a.a.r. BEA, NIPA, Table 1.11	NIA964	WB(NIPA)
CORPP Corporate profits with IVA and CCADJ Billions of current dollars, s.a.a.r. BEA, NIPA, Tables 1.7, 1.11, 6.20	NIA977	Z(NIPA)
DEFLTR Gross national product Implicit price deflator, 1972 = 100, s.a. BEA, NIPA, Tables 7.1, 7.3, 7.4, 7.5	NIA1380	PDGNP(NIPA)
ECINDX Employment cost index, wages and salaries, Private industry workers June 1981 = 100, no seasonal patterns BLS, "Employment Cost Index" release	EMP824	JECWAP_U(US)

National Model	ADP	IDC
EXDEF Exports, total Implicit price deflator, 1972 = 100, s.a. BEA, NIPA, Tables 7.1, 7.16	NIA1393	PDIEX(NIPA)
EXP Exports, total Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 4.2	NIA886	EX72(NIPA)
FINRESE Fixed investment, nonresidential, producers' durable equipment Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 1.2	NIA877	IPE72(NIPA)
FINRESS Private nonresidential construction, total Billons of 1972 dollars, s.a.a.r. BEA, unpublished data	NIA876	IPS72(NIPA)
FIRES Fixed investment, residential Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Table 1.2	NIA878	IR72(NIPA)
FORDEBT Foreign debt claims Period-end outstanding level Billions of dollars, s.a. FR Board, "Flow of Funds" release	S264104005(FLOW)	S264104005(FLOW)
GPCCC Government purchases, change in CCC inventories Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 3.8B Mr. George Smith (202) 523-0821	---	---
GPFDEF Government purchases, federal national defense Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 3.8B	NIA890	GPFD72(NIPA)
GPFNDEF Government purchases, federal nondefense Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 3.8B	NIA891	GPFN72(NIPA)

National Model	ADP	IDC
GPSTLOC Government purchases, state and local, total Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 3.8B	NIA892	GPN72(NIPA)
IMDEF Imports, total Implicit price deflator, 1972 = 100, s.a. BEA, NIPA, Tables 7.1, 7.16	NIA1394	PDIIM(NIPA)
IMP Imports, total Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 4.2	NIA887	IM72(NIPA)
RGNP Gross national product Billions of 1972 dollars, s.a.a.r. BEA, NIPA, Tables 1.2, 1.4, 1.6, 1.8	NIA868	GNP72(NIPA)
TOTDEBT Nonfinancial sectors credit market debt Period-end outstanding level Billions of dollars, s.a. FR Board, "Flow of Funds" release	S394104005(FLOW)	S394104005(FLOW)

MONTHLY SERIES

National Model	ADP	IDC
CCC Commodity Credit Corporation, investment Millions of dollars, s.a.* U.S. Dept. of Agriculture, CCC Mr. Briggs (202) 447-6681	---	---
CILO Commercial and industrial loans outstanding Millions of dollars, s.a. BEA, Business Conditions Digest	---	LNSBCD(US)
CNSCR Consumer credit outstanding, total Billions of dollars, s.a.* FR Board, G.19 "Consumer Installment Credit" release	CRE202	MF1086(FIN)
CONTORD Contracts and orders for plant and equipment Billions of 1972 dollars, s.a. BEA, Business Conditions Digest	BCD27	AOM027(US)
CPI Consumer price index, all urban consumers, all items 1967 = 100, s.a.* BLS, "Consumer Price Index" release	CPI213	PCIU_U(US)
CPIE Consumer price index, all urban consumers, special indexes, energy 1967 = 100, s.a.* BLS, "Consumer Price Index" release	CPI210	PCIUENE_U
DOLLAR Weighted-average exchange value of U.S. dollar March 1973 = 100 Currency units per dollar FR Bulletin, Table 3.28	INT148	MF1747(FIN)
EARNHLY Average hourly earnings, manufacturing Current dollars, s.a. BLS, Employment and Earnings	EMP970	WRHPMFG(US)

National Model	ADP	IDC
EARNIDX Hourly earnings index, total private 1977 = 100, current dollars, s.a. BLS, *Employment and Earnings*	JWRPHA_EP@A	AOM740(BCD)
EMPLOY Total employees on payrolls, nonagricultural industries Millions of persons, s.a. BLS, *Employment and Earnings*	EMP1	AOM041(BCD)
EMPYSTL Total employees, state and local government Millions of persons, s.a. BLS, *Employment and Earnings*	EMP38	EMEGSL(US)
EXPND Federal government budget plus off-budget items Billions of dollars, s.a.* Treasury Dept., "Monthly Treasury Statement"	BUD87+BUD2	---
EXPRTS Exports, excluding military aid shipments, f.a.s. value basis Billions of dollars, s.a. Census Bureau	FOR231	AOM502(BCD)
FEDFUND Short-term interest rates, federal funds Percent per annum FR Board, G.13 "Selected Interest Rates" release	INT69	MF1403(FIN)
HRSWKD Average weekly hours, manufacturing Hours, s.a. BLS, *Employment and Earnings*	EMP279	HRWPMFG(US)
HRSWRKA Hours, wage and salary workers, nonagricultural establishments Billions of hours (annual rate) BLS, *Employment and Earnings*	PRO2	HRSPST(US)
IMPRTS Imports, general, c.i.f. value basis Billions of dollars, s.a. Census Bureau	FOR6	AOM512(BCD)

National Model	ADP	IDC
INDPRO Industrial production, total Index: 1967 = 100, s.a. FR Board, G.12.3 "Industrial Production" release	IPR7	AOM047(BCD)
INVHND Change in inventories on hand and on order Billions of 1972 dollars, s.a.a.r. BEA, Business Conditions Digest	BCD36	AOM036(BCD)
INVMFD Value of manufacturers' inventories, durable goods industries Millions of current dollars, s.a. Census Bureau, "Manufacturers' Shipments, Inventories, and Orders" release	MAN387	KIMDG(US)
INVMFD72 Value of manufacturers' inventories, durables Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_EMFD	KIMDG72B(US)
INVMFN Value of manufacturers' inventories, nondurable goods industries Billions of current dollars, s.a. Census Bureau, "Manufacturers' Shipments, Inventories, and Orders" release	MAN391	KIMNG(US)
INVMFN72 Value of manufacturers' inventories, nondurables Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_EMFN	KIMNG72B(US)
INVMWD Wholesale inventories, durable goods Billions of current dollars, s.a. Census Bureau, "Monthly Wholesale Trade" report	SI0318	KIWDG(US)
INVMWD72 Merchant wholesalers' inventories, durable goods Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_ETDWMD	KIWDG72B(US)
INVMWN Wholesale inventories, nondurable goods Billions of current dollars, s.a. Census Bureau, "Monthly Wholesale Trade" report	SI0347	KIWNG(US)

National Model	ADP	IDC
INVMWN72 Manufacturing plus trade inventories, merchant wholesalers, nondurables Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_ETDWMN	KIWNG72B(US)
INVRTD Retail inventories, durable goods Billions of current dollars, s.a. Census Bureau, "Manufacturing and Trade" release	MAN378	KIRDG(US)
INVRTD72 Retail trade inventories, durable goods Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_ETDRD	KIRDG72B(US)
INVRTN72 Retail trade inventories, nondurable goods Billions of 1972 dollars, s.a. BEA, unpublished data	UKGDI72_ETDRN	KIRNG72B(US)
INVRTVN Retail inventories, nondurable goods Billions of current dollars, s.a. Census Bureau, "Manufacturing and Trade" release	MAN380	KIRNG(US)
MBASE Monetary base, adjusted for changes in reserve requirements Billions of dollars, s.a. Federal Reserve Bank of St. Louis	RES73	MBASE(US)
MCED Consumption expenditures, total durable goods Billions of current dollars, s.a.a.r. BEA, unpublished data	UCED	CED(US)
MCED72 Consumption expenditures, total durable goods Billions of 1972 dollars, s.a.a.r. BEA, unpublished data	NIA144	CED72(US)
MCEN Consumption expenditures, total nondurable goods Billions of current dollars, s.a.a.r. BEA, unpublished data	UCEN	CEN(US)
MCEN72 Consumption expenditures, total nondurable goods Billions of 1972 dollars, s.a.a.r. BEA, unpublished data	NIA177	CEN72(US)

National Model	ADP	IDC
MCES Consumption expenditures, total services Billions of current dollars, s.a.a.r. BEA, unpublished data	UCES	CES(US)
MCES72 Consumption expenditures, total services Billions of 1972 dollars, s.a.a.r. BEA, unpublished data	NIA211	CES72(US)
MONE M1 (sum of currency, travelers checks, demand deposits, and OCD) Billions of dollars, s.a. FR Board, H.6 "Money Stock, Liquid Assets, and Debt Measures" release	MON94	MF1475(FIN)
MPROXY Monthly proxy for stock of domestic nonfinancial debt Millions of dollars, s.a. FR Board, John F. Wilson (202) 452-2362 Series: FL384104005M	---	---
MTWO M2 (M1 plus overnight RPs and Eurodollars, MMMF balances, MMDAs, savings and small time-deposits) Billions of dollars, s.a. FR Board, H.6 "Money Stock, Liquid Assets, and Debt Measures" release	MON95	MF1637(FIN)
NEWORDR Value of manufacturers' new orders, all manufacturing industries Billions of current dollars, s.a. Census Bureau, "Manufacturers' Shipments, Inventories, and Orders" release	ONV_EMF	NOROO(US)
NTOLY Net outlays, national defense Billions of dollars, s.a.* Treasury Dept., "Monthly Treasury Statement"	BUD108	UBOUND(US)
OILPRC Imports, petroleum and petroleum products price Dollars, no seasonal patterns Census Bureau	---	---

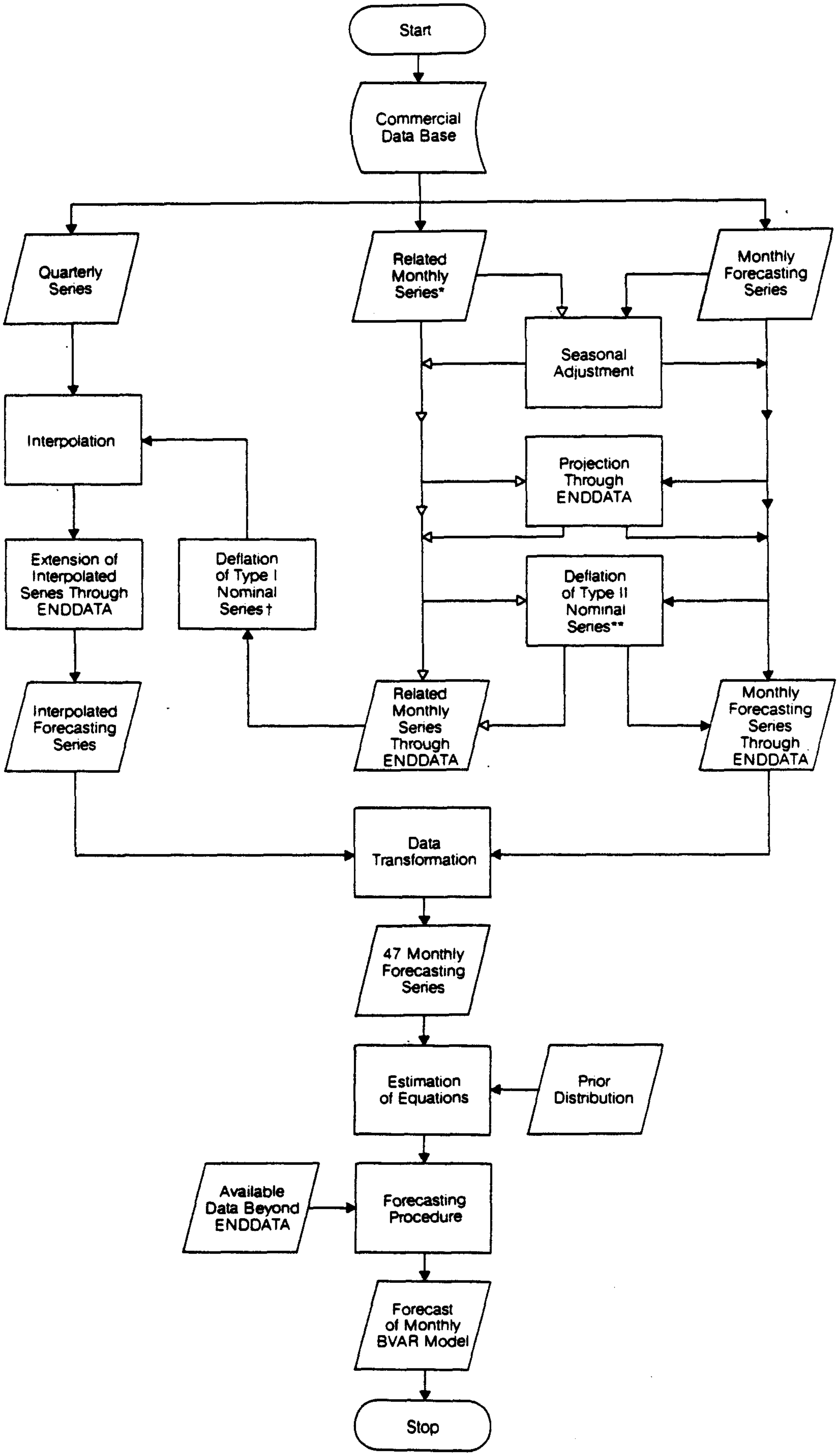
National Model	ADP	IDC
PERINC Personal income Billions of current dollars, s.a.a.r. BEA, "Personal Income and Outlays" release	PER1	MYP(US)
PPI Producer price index, all commodities 1967 = 100, s.a.* BLS, "Producer Price Index" release	PPI112	PPI_U(US)
PPICE Producer price index, capital equipment 1967 = 100, s.a.* BLS, "Producer Price Index" release	PPI27	PPICEQ_U(US)
RCIPT Federal government net receipts Billions of dollars, s.a.* Treasury Dept., "Monthly Treasury Statement"	BUD18	---
RST Retail sales, total Billions of current dollars, s.a. Census Bureau, "Advance Monthly Retail Sales" release	MAN4	SRET(US)
SHIPMNT Value of manufacturers' shipments, all manufacturing industries Billions of current dollars, s.a. Census Bureau, "Manufacturers' Shipments, Inventories, and Orders" release	SHV_EMF	SHP00(US)
SHIPNCG Value of manufacturers' shipments, nondefense capital goods Billions of current dollars, s.a. Census Bureau, "Manufacturers' Shipments, Inventories, and Orders" release	SHV_MSIN	SHPCND(US)
SP500 Standard & Poor's 500 Common Stock Index 1941-43 = 100 Standard & Poor's	IND30	MF743(FIN)
SPTPRC Index of spot market prices, raw industrials 1967 = 100, s.a.* BLS, Commodity Research Bureau	BCD23	UOM023(BCD)

National Model	ADP	IDC
TBILL Short-term interest rates, U.S. government securities Treasury bills (secondary market), 3-month Percent per annum FR Board, G.13 "Selected Interest Rates" release	INT87	MF1405(FIN)
UNEMP Unemployment rate, civilian labor force Percent, s.a. BLS, Employment and Earnings	LAB59	RUCTT(US)
USBND10 Bond yields, U.S. government securities Treasury constant maturities, 10-year Percent per annum FR Board, G.13 "Selected Interest Rates" release	INT95	MF1414(FIN)
USCAR Total retail sales, new domestic cars Millions, s.a.a.r. BEA, unpublished data	TRA3000	USCARDOM(US)
VNCPUTN Value of new construction, private nonresidential, total Billions of 1977 dollars, s.a.a.r. Census Bureau, "Construction Expenditures" release	CON100	IPSNZ(US)
VNCPUTR Value of new construction put in place, private residential, total Billions of 1977 dollars, s.a.a.r. Census Bureau, "Construction Expenditures" release	CON95	IPRZ(US)

Abbreviations Used in Annex B

BEA	Bureau of Economic Analysis, U.S. Department of Commerce
BLS	Bureau of Labor Statistics, U.S. Department of Labor
CCADJ	Capital consumption adjustment
CCC	Commodity Credit Corporation
c.i.f.	Cost, insurance, and freight
f.a.s.	Free alongside ship
FR	Federal Reserve
FR Board	Board of Governors of the Federal Reserve System
IVA	Inventory valuation adjustment
MMDA	Money market deposit account
MMMF	Money market mutual fund
NIPA	National income and product accounts
OCD	Other checkable deposits
RPs	Repurchase agreements
s.a.	Seasonally adjusted by source
s.a.*	Seasonally adjusted by us according to procedure described in this appendix.
s.a.a.r.	Seasonally adjusted, annual rate

ANNEX C: FLOWCHART OF RUNNING THE MODEL



*An outlined arrow is used to distinguish the related monthly series from the monthly forecasting series

**Type II nominal series are those released earlier than their corresponding real series

†Type I nominal series are those related monthly series for which there are no corresponding real versions published

REFERENCES

Chow, Gregory C., and Lin, An-loh. 1971. Best linear unbiased interpolation, distribution, and extrapolation of time series by related series. Review of Economics and Statistics 53 (November): 372-75.

Fernandez, Roque B. 1981. A methodological note on the estimation of time series. Review of Economics and Statistics 63 (August): 471-76.

Geweke, John. 1978. The temporal and sectoral aggregation of seasonally adjusted time series. In Seasonal analysis of economic time series, ed. Arnold Zellner. U.S. Department of Commerce, Bureau of the Census, Economic Research Report, ER-1: 411-27. Proceedings of the conference on the seasonal analysis of economic time series, Washington, D.C., Sept. 9-10, 1976. Washington, D.C.: Government Printing Office.

Litterman, Robert B. 1983. A random walk, Markov model for the interpolation of time series. Research Department Staff Report 84. Federal Reserve Bank of Minneapolis.

Nerlove, Marc. 1964. Spectral analysis of seasonal adjustment procedures. Econometrica 32 (July): 241-86.

Priestly, M. B. 1981. Spectral analysis and time series. New York: Academic Press.

Regression Analysis of Time Series, Version 4.30 (RATS 4.30). 1984. Documentation by Thomas A. Doan and Robert B. Litterman. Minneapolis, Minn.: VAR Econometrics.

TECHNICAL APPENDIX TO THE REGIONAL MODELS

In 1984, a set of new forecasting models for Minnesota, Montana, North Dakota, South Dakota, Wisconsin, and the Upper Peninsula of Michigan were developed by researchers (primarily Richard Todd and Hossain Amirizadeh) at the Federal Reserve Bank of Minneapolis. Partial descriptions of the models and the procedures for constructing and using them have already been published (Amirizadeh 1985; Amirizadeh and Todd 1984; Doan, Litterman, and Sims 1984; Litterman 1980; and Todd 1984). This Appendix does not repeat those partial descriptions but rather attempts to fill the remaining gaps in the description of the new models. Collectively, this appendix and the previously published descriptions are meant to serve as a user's manual for the six regional forecasting models, and users who want even more detailed information can request copies of the models' computer programs from the Research Department of the Federal Reserve Bank of Minneapolis (250 Marquette Avenue, Minneapolis, Minnesota 55480).

Forecasts from each of the regional models are computed by the following 4 steps: construct an up-to-date data base for the model; reestimate the model; calculate the point forecast, the most likely course of the state's variables over the next 8 to 12 quarters; and compute the range of uncertainty around the point forecast. Accordingly, this Appendix is divided into four sections, one for each of the four steps.

Constructing the Models' Database

Both national and regional data are needed to produce a regional forecast. The 6 regional models contain from one to 5 variables each (see Table 1); altogether 23 regional data series are involved. In addition, each regional model is linked to a 15 variable model that forecasts the U.S. economy (see Table 2). We obtain both types of data primarily from commercial data bases (specifically, Automated Data Processing for national data and Interactive Data Corporation for national and regional data). To obtain the most recent regional figures on employment and retail sales, we sometimes also telephone state statistical offices. (See Annex B for the telephone numbers of the offices we sometimes call.)

Our forecasting models use seasonally adjusted data, so we either obtain officially adjusted data or adjust the raw data ourselves. Officially adjusted data on state personal income are available on our commercial data bases, but this is not true of our other state data series. The procedure we use to adjust them is described in Amirizadeh (1985).

Once we have the seasonally adjusted data series, the next step is to decide which is the most recent quarter for which a sufficiently complete set of data is available. We call this quarter ENDDATA, and it is not always obvious how to choose it. So far we have used judgement (rather than a precise rule) to select ENDDATA.

Part of the problem of choosing ENDDATA is that the 38 data series needed to produce a set of regional forecasts include many monthly variables. When the most recent data on one of those variables is for the first or second month of a calendar quarter, we must decide whether to truncate the series at the third month of its last complete quarter or to extend it to the third month of the partially completed quarter. (The auxiliary forecasting models used for extending monthly series are described in Annex A.)

The choice of ENDDATA is also complicated by the fact that the various quarterly and monthly series end in different quarters. For example, the monthly data on state employment, unemployment, and retail sales are usually released with a short lag and thus end in either the current or the previous quarter. By contrast, the quarterly data on state personal income (earned and unearned) are usually released after a four to eight month lag and thus are rarely available even for the previous quarter. We have tried to mitigate this problem by building our models on the assumption that having one less quarter of personal income data (than of employment, unemployment, or retail sales data) is the rule, not the exception. (This is done by shifting the personal income data series forward one quarter when estimating the model, as described in the section on estimation.) This does not eliminate the problem, however, for sometimes the personal income data lags by two quarters instead of one, or the retail sales data may lag the employment data, or we may be forecasting at a time in the quarter when the monthly state employment data lead the quarterly national data by two months.

So far the closest we have come to a rule of thumb is that the last quarter for which there are at least preliminary (but not just "flash") estimates of the national income and product accounts is ENDDATA. This may mean that we will have almost complete data on several national or state variables for the months of quarter ENDDATA+1. However, we can and often do modify our forecasting procedures to incorporate this post-ENDDATA data (see the forced forecast option described in the forecasting section).

We must also have a beginning point for our data series, of course, and this also raises some problems. In most states, for example, data on employment go back to 1939, but reliable data on unemployment only begin in 1970. This problem does not arise for the Upper Peninsula of Michigan, the only substate region we forecast. There the only reliable data series, employment, begins in 1964, which is thus the beginning point for our Upper Peninsula model. For our other state models, we have chosen our beginning date, called BGNDATA, to be the second quarter of 1958, or 58:2. This is one quarter after the data series on state personal income begin. (We have to start one quarter later because we shift the personal income series forward one quarter in our models, as indicated above.) For the state data series that begin only after 1958:2—namely retail sales (1964:2) and unemployment (1970:1)—we have estimated auxiliary regressions to backcast their seasonally adjusted values to 1958:2 (see Annex A). The seasonally adjusted data on state employment are simply truncated at 1958:2.[1] For the national model that all the regional models are linked to, BGNDATA is the first quarter of 1948.

Unlike the problems of projecting monthly variables through the ends of their most recent quarters and choosing ENDDATA, which recur each quarter, the problems of choosing BGNDATA and backcasting short data series to BGNDATA recur only rarely, if ever. Although we may someday revise BGNDATA or the backcasted data that fills out the short data series, our current practice is to not change these from one forecast to the next.

Once the data series have been assembled, seasonally adjusted, projected to ENDDATA (or possibly ENDDDATA+1), and backcasted to BGNDATA, our data set is almost complete. The last steps before moving on to reestimate the coefficients of the forecasting models are the following three simple data transformations: (1) deflate all nominal variables by the U.S. GNP deflator, (2) take logarithms of most variables (all except those involving interest rates, unemployment rates, or changes in the level of inventories or investment), and (3) shift the state personal income series forward one period, as discussed above.

Reestimating the Forecasting Models

The general method used to estimate the forecasting models, as described in Todd (1984), combines information in the data with prior beliefs that the variables behave approximately as a random walk around a long term trend. To implement the method, those prior beliefs are first expressed in terms of a set of fixed numerical weights and eight unknown scale factors called hyperparameters. The hyperparameters are then selected using the out of sample forecasting criterion

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[1]The complete employment series back to 1939 are used in the seasonal adjustment procedure, however. Dr. Rudi Pinola pointed out that the procedures for estimating state employment were substantially revised and improved in the mid-1950s, and he questioned our use of the earlier data. However, we use the earlier data only to help seasonally adjust the later data, and our tests show that the results are not very sensitive to whether the earlier data is included or not.

outlined in Todd (1984) and discussed further below. Given the chosen hyperparameters, the coefficients of each equation are selected by a mixed estimation procedure that imposes on an ordinary least squares regression the probabilistic restrictions expressed by the weights and hyperparameters.

The motivation for the forms of the eight hyperparameters and sets of weights used in our models is given in general terms by Todd (1984) and in much greater detail by Doan, Litterman, and Sims (1984). A summary of these forms and the specific weights and hyperparameters currently used in our regional models are listed in Tables 3–10.

The hyperparameters shown in Tables 3–10 are those deemed to have maximized the models' performance in a series of out of sample forecasts. That is, many settings of the hyperparameters of each model were tested. With each setting, the model was estimated up to a certain date, say ENDSAMP, and then used to forecast the next eight quarters.[2] As ENDSAMP was varied from about BGNDATA+16 through the current quarter minus one, a series of about 90 (?) one quarter ahead and 80 eight quarter ahead forecasts and forecast errors was accumulated for each variable in each model. The most recent 80 errors of each kind were used to rank the models.

Ranking the models performance requires a metric for these collections of one to eight quarter ahead forecast errors. Initially we inspected the 1, 2, 4, and 8 quarter ahead log determinants of the matrices of forecast error covariances (see Doan, Litterman, and Sims 1984) and the standard errors of forecasts for key variables (such as real gross national product in the national model and employment and earned income in all the state and national models) and then subjectively ranked the various hyperparameter settings. More recently we have tried to define a precise metric

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[2]Throughout these simulated out of sample forecasts we used the shifted (one period forward) form of the personal income series, to reflect the normal one quarter lag in the availability of these series. In other words, for any value of ENDSAMP we assumed that personal income variables were available only through ENDSAMP−1, and we forecasted their next eight values (ENDSAMP through ENDSAMP+7).

that others could use, test, and criticize. Our latest version was to rely solely on the one quarter ahead likelihood statistic described in Doan, Litterman, and Sims (1984), with one exception. The North Dakota model's one quarter ahead likelihood statistic improved steadily but only slowly as the hyperparameter setting moved toward complete relaxation of the prior restrictions. Since neither the similar South Dakota and Montana models nor previous versions of the North Dakota model had forecasted well with such unrestrictive hyperparameter settings, we did not trust this result. If this is true South Dakota and Montana have the same errors. Even if the result was accurate, it also suggested we would lose very little by instead choosing a hyperparameter setting more similar to those of the South Dakota, Montana, or previous North Dakota models, and we did so. We intend to review these results in the near future and to also experiment with metrics that would weight the 1, 2, 4, and 8 quarter ahead forecast errors.

Given BGNDATA, ENDDATA, and the weights and hyperparameters for each model, the coefficients are estimated by applying a Kalman filter to the data, using the prior restrictions to define the initial covariance matrix of the coefficients. The programs we use are available at the address given on page 1.

Forecasting

Once the models have been reestimated, we are ready to forecast. First, we again transform the raw data, as discussed in the section on preparing the database. (Note in particular that the personal income series are shifted forward as part of these trans-formations.) Next we generate either a forced or an unforced national forecast. Using that national forecast, we then forecast regional economic variables.

Unforced national forecasts are generated with only our 15 variable national model. After reestimation, that model has the form

(1) $$x_{t+1} = A_{0t}x_t + A_{1t}x_{t-1} + A_{2t}x_{t-2} + A_{3t}x_{t-3} + e_{t+1}$$

where ENDDATA = t; x_t, x_{t-1}, x_{t-2}, and x_{t-3} are 15 × 1 vectors of transformed data on our 15 variables for the quarters t, t − 1, t − 2, and t − 3; x_{t+1} is a 15 × 1 vector of next quarter's values (currently unknown) of the 15 transformed variables; e_{t+1} is an error term; and A_{0t}, A_{1t}, A_{2t}, and A_{3t} are 15 × 15 matrices of the newly reestimated coefficients. In an unforced national forecast we simply set the error term to zero and repeatedly apply equation (1) to get the forecasts

(2) $$\tilde{x}_{t+1} = A_{0t}x_t + A_{1t}x_{t-1} + A_{2t}x_{t-2} + A_{3t}x_{t-3}$$

(3) $$\tilde{x}_{t+2} = A_{0t}\tilde{x}_{t+1} + A_{1t}x_t + A_{2t}x_{t-1} + A_{3t}x_{t-2}$$

(4) $$\tilde{x}_{t+3} = A_{0t}\tilde{x}_{t+2} + A_{1t}\tilde{x}_{t+1} + A_{2t}x_t + A_{3t}x_{t-1}$$

(5) $$\tilde{x}_{t+4} + A_{0t}\tilde{x}_{t+3} + A_{1t}\tilde{x}_{t+2} + A_{2t}\tilde{x}_{t+1} + A_{3t}x_t$$

(6) $$\tilde{x}_{t+5} = A_{0t}\tilde{x}_{t+4} + A_{1t}\tilde{x}_{t+3} + A_{2t}\tilde{x}_{t+2} + A_{3t}\tilde{x}_{t+1}$$

(7) $$\tilde{x}_{t+k+1} = A_{0t}\tilde{x}_{t+k} + A_{1t}\tilde{x}_{t+k-1} + A_{2t}\tilde{x}_{t+k-2} + A_{3t}\tilde{x}_{t+k-3}.$$

Although k can be as large as we like, we are typically interested in forecasts of the next two or three years and so set k between 8 and 12.

Frequently we alter the national model's unforced forecast by prespecifying part or all of the future paths of some but not all of its variables. We do this to make our forecasts consistent with other forecasts, to answer questions about which future paths of the unprespecified variables would be most likely to accompany the given paths of the prespecified variables (assuming no sharp change in the mechanism by which the economy evolves over time), and to incorporate data for ENDSAMP+1 that may be available for some variables.

To understand more concretely what a forced forecast is and how it is implemented, consider how we regularly incorporate the forecasts of what we regard as a superior national model—the 47 variable monthly BVAR maintained at this bank by Robert Litterman and Hossain Amirizadeh and described in Amirizadeh (1985). That model includes all of the variables in our 15 variable quarterly U.S. model except the three personal income variables, so we use its forecasts of the other 12 variables. We also impose those 12 forecasts on our 15 variable model to generate forecasts of the 3 personal income variables that will be consistent with the 12 forecasts from the larger model. The combined result—the 12 forecasts from the larger national model and the 3 personal income forecasts consistent with those 12 but generated by a forced version of our 15 variable model—is an example of a forced national forecast.

Forcing an alternative U.S. forecast on our 15 variable national model involves mainly three steps. First, the differences between the alternative forecast paths and the paths forecasted by our unforced national model are computed, for each variable and each future quarter that will be prespecified. These differences are then treated as the future error terms in the equations of the prespecified variables, and each of them is multiplied by the appropriate subset of the coefficients that define the unforced model's response to error terms (the model's impulse response coefficients). Finally, these products, which show the effects on all 15 variables of switching from the unforced to the prespecified forecasts, are added to the unforced forecasts of all 15 variables. Readers who are interested in the details of this procedure should consult our computer programs (available upon request) or Doan and Litterman 1984 (p. 17-15).

Given a national forecast (forced or not), the regional forecasts are fairly easily computed. The method resembles the method for computing unforced national forecasts except that there are additional terms to reflect the influence of the past and forecasted future values of the exogenous national variables. In particular, each regional equation has the form

$$(8)\qquad r_{t+1} = B_{1t}r_t + B_{2t}r_{t-1} + B_{3t}r_{t-2} + B_{4t}r_{t-3} + C_{1t}x_t + C_{2t}x_{t-1} + C_{3t}x_{t-2} + C_{4t}x_{t-3} + e_{t+1},$$

where r_t and x_t are vectors or regional and national data, respectively. (The variables in r_t and x_t for each regional equation are listed in Annex A.) Our regional forecasts then take the form

$$(9)\qquad \tilde{r}_{t+1} = B_{1t}r_t + B_{2t}r_{t-1} + B_{3t}r_{t-2} + B_{4t}r_{t-3} + C_{1t}x_t + C_{2t}x_{t-1} + C_{3t}x_{t-2} + C_{4t}x_{t-3}$$

$$(10)\qquad \tilde{r}_{t+2} = B_{1t}\tilde{r}_{t+1} + B_{2t}r_t + B_{3t}r_{t-1} + B_{4t}r_{t-2} + C_{1t}\tilde{x}_{t+1} + C_{2t}x_t + C_{3t}x_{t-1} + C_{4t}x_{t-2}$$

$$(11)\qquad \tilde{r}_{t+3} = B_{1t}\tilde{r}_{t+2} + B_{2t}\tilde{r}_{t+1} + B_{3t}r_t + B_{4t}r_{t-1} + C_{1t}\tilde{x}_{t+2} + C_{2t}\tilde{x}_{t+1} + C_{3t}x_t + C_{4t}x_{t-1}$$

$$(12)\qquad \tilde{r}_{t+4} = B_{1t}\tilde{r}_{t+3} + B_{2t}\tilde{r}_{t+2} + B_{3t}\tilde{r}_{t+1} + B_{4t}r_t + C_{1t}\tilde{x}_{t+3} + C_{2t}\tilde{x}_{t+2} + C_{3t}\tilde{x}_{t+1} + C_{4t}x_t$$

$$(13)\qquad \tilde{r}_{t+5} = B_{1t}\tilde{r}_{t+4} + B_{2t}\tilde{r}_{t+3} + B_{3t}\tilde{r}_{t+2} + B_{4t}\tilde{r}_{t+1} + C_{1t}\tilde{x}_{t+4} + C_{2t}\tilde{x}_{t+3} + C_{3t}\tilde{x}_{t+2} + C_{4t}\tilde{x}_{t+1}$$

$$(14)\qquad \tilde{r}_{t+k+1} = B_{1t}\tilde{r}_{t+k} + B_{2t}\tilde{r}_{t+k-1} + B_{3t}\tilde{r}_{t+k-2} + B_{4t}\tilde{r}_{t+k-3} + C_{1t}\tilde{x}_{t+k} + C_{2t}\tilde{x}_{t+k-1} + C_{3t}\tilde{x}_{t+k-2} + C_{4t}\tilde{x}_{t+k-3}$$

for $k = 5, 6, 7, \ldots$, where a tilde (f) denotes a forecasted variable. To complete the forecast, the forecasted personal income data are shifted back to match their calendar dating, all logged variables are exponentiated, and deflated variables can be undeflated if nominal values are desired.

Estimating the Uncertainties

Although the point forecast is our best guess of the future paths of our regional variables, we are very aware that even our best guess is often well off the mark. This is normal in economic forecasting, for there seems to be a significant random element in aggregate economic performance. We can't eliminate this randomness and achieve perfect forecasts, but we can at least attempt to quantify its magnitude. That is the purpose of our simulation procedure, which estimates the probabilities of various future events.

The simulation procedure takes the point forecast as its jumping off point. The point forecast shows what the future would look like if all unpredictable randomness were eliminated. To get a more realistic picture of the range of possible futures, our simulations add a representative sample of random effects to our point forecast. To do this we first estimate a probability distribution of our models' one quarter ahead forecasting errors. Using that distribution, we randomly choose 8 or 12 vectors (each with one random term for each variable in the model) and arrange them in a sequence e_{t+1}, e_{t+2}, ... These vectors are then added to the point forecast to produce an alternative future. The procedure is then repeated, usually 1,000 times, to produce a large sample of alternative futures. To assess the probability of a future event we then just count the proportion of these alternative futures in which that event occurs. We can also define events that have prespecified probabilities, as when we estimate a 70 percent confidence band for the value of a variable in a given quarter. To do that, we eliminate the highest 15 percent and the lowest 15 percent of the forecasted values of the variable and then use the maximum and minimum of the remaining values to define the band in which there is a 70 percent chance that the variable will fall.

We estimate the probability distribution of our models' one quarter ahead forecasting errors by means of the same kinds of out of sample forecasts as were used in selecting the models' hyperparameters. That is, we estimate the model through a given past date ENDSAMP, forecast one quarter ahead, compare that forecast with the actual value for the next quarter to compute the error, and then do all this again for ENDSAMP+1, ENDSAMP+2, ..., ENDDATA−1. To estimate the probability distribution of the one step ahead errors, we have two options. We can use the collection of one quarter ahead errors to estimate the variance of a mean zero, multivariate normal distribution. Then we would draw from the estimated normal distribution to create our alternative futures. A more direct alternative would be, figuratively, to collect all the computed one step ahead errors into an electronic urn and have the computer draw form this urn (with replacement) in constructing the alternative futures. Currently we use the normal distribution procedure.

References

Amirizadeh, Hossain. 1985. Technical appendix for the Bayesian vector autoregression model of the U.S. economy. Federal Reserve Bank of Minneapolis.

Amirizadeh, Hossain, and Todd, Richard M. 1984. More growth ahead for Ninth District states. *Federal Reserve Bank of Minneapolis Quarterly Review* 8 (Fall): 8–17.

Doan, Thomas A., and Litterman, Robert B. 1984. User's manual: Regression analysis of time series, version 4.30 (RATS 4.30). Minneapolis: *VAR Econometrics.*

Doan, Thomas; Litterman, Robert; and Sims, Christopher. 1984. Forecasting and conditional projection using realistic prior distributions. *Econometric Reviews* 3 (1): 1–100.

Litterman, Robert B. 1980. A Bayesian procedure for forecasting with vector autoregressions. Massachusetts Institute of Technology. Research Department Working Paper, Federal Reserve Bank of Minneapolis.

Todd, Richard M. 1984. Improving economic forecasting with Bayesian vector autoregression. *Federal Reserve Bank of Minneapolis Quarterly Review* 8 (Fall): 18–29.