THE USE OF HIGH FREQUENCY DATA IN MODEL-BASED FORECASTING AT THE FEDERAL RESERVE BOARD

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OVERVIEW OF MODEL LINKAGE APPROACH TO SHORT-TERM FORECASTING

Goal of FRB Model Linkage Project:

- To produce reliable and **replicable** projections of macroeconomic variables in formats that can be readily **interpreted** by operational forecasters and/or policy-makers.

Focus of presentation:

- How and what high frequency information is used in the FRB Model Linkage system, including selected tests of the system's efficiency.

Topics to be covered include:

- An overview of the model linkage approach to forecasting.
- Review of components of model linkage system.
- Presentation of a facsimile projection.

Notation

x(m)	denotes a monthly variable for month m, m = 1, 3*T, where T = number of quarters.
X(Q)	denotes a quarterly variable for quarter Q, appropriately aggregated from x(m), with Q = 1, T.
x(m)	denotes a vector of monthly variables.
X(Q)	denotes a vector of quarterly variables.
A(L)	denotes a polynomial in the lag operator, i.e., $A(L)x(m) = a(0)x(m) + a(1)x(m-1) + \ldots$

Definitions

r(m)	a release variable, typically, a piece of underlying monthly GNP source data.
y(m)	a GNP component or macro-aggregate, monthly.
Y(Q)	a GNP component or macro-aggregate, quarterly.
z(m)	any other monthly indicator variable.

BACKROUND: KALMAN FILTER FORMULATION

A Model in State-Space Format

Consider a general linear discrete-time quarterly structural model represented as follows:

$$A(L)\ \mathbf{Y}_1(Q) + B(L)\ \mathbf{Y}_2(Q) = \mu_1(Q)$$

where $\mathbf{Y}_1(Q)$ is a vector of "endogenous" or forecast variables;
$\mathbf{Y}_2(Q)$ is a vector of "exogenous" or input variables; and
$\mu_1(Q)$ is a vector of equation disturbances.

Because the distinction between endogenous and exogenous variables is illusory in forecasting, the vector $\mathbf{Y}_2$ will be represented as a stochastic process

$$C(L)\mathbf{Y}_2(Q) = \mu_2(Q).$$

Thus, we have

$$D(L)\mathbf{Y}(Q) = \mu(Q) \qquad (2.1)$$

$$\mathrm{Cov}(\mu) = \Sigma_{\mu\mu}$$

where, $\mathbf{Y} = [\mathbf{Y}_1\ \mathbf{Y}_2]'$, $\mu = [\mu_1\ \mu_2]'$, and $D(L)$ is stacked accordingly. The compact structural model is then written as

$$F\ \mathbf{Y}(Q) = G(L)\mathbf{Y}(Q-1) + \mu(Q),$$

where, $F = D_0$ and $G(L) = -D_1L - D_2L^2 - \ldots$etc.

Therefore, in state-space format the model is

$$\mathbf{Y}(Q) = H(L)\mathbf{Y}(Q-1) + \nu(Q), \qquad (2.2)$$

$$\mathrm{Cov}(\nu) = \Sigma_{\nu\nu}.$$

where $H(L) = D_0^{-1}[-D_1L - D_2L^2 - \ldots]$, and $\nu(Q) = D_0^{-1}\mu(Q)$.

A Model Projection

$$\hat{\mathbf{Y}}(Q) = H(L)\mathbf{Y}(Q-1). \tag{2.3}$$

An Observation System

$$\mathbf{R}(Q) = K\,\mathbf{Y}(Q) + \varepsilon(Q) \tag{2.4}$$

$$\mathrm{Cov}(\varepsilon) = \Sigma_{\varepsilon\varepsilon},$$

where K is a matrix linking forecast variables with release variables.

The Information Vector

The information in **R** is defined as that which could not be previously projected by the model,

$$\mathbf{I}(Q) = \mathbf{R}(Q) - K\,\hat{\mathbf{Y}}(Q).$$

Updating Solutions

The filtering solution for the optimal 1-step ahead forecast for **Y**, given $\hat{\mathbf{Y}}(Q)$, $\mathbf{R}(Q)$, Σ_{vv}, and $\Sigma_{\varepsilon\varepsilon}$ is

$$\mathbf{Y}(Q)^* = \hat{\mathbf{Y}}(Q) + \Gamma\mathbf{I}(Q) \tag{2.5}$$

where

$$\Gamma = E\{v(Q)\mathbf{I}(Q)'\}\,E\{\mathbf{I}(Q)\mathbf{I}(Q)'\}^{-1},$$

$$= [\Sigma_{vv}K' - \Sigma_{v\varepsilon}][K\Sigma_{vv}K' + \Sigma_{\varepsilon\varepsilon} - K\Sigma_{v\varepsilon} - \Sigma_{\varepsilon v}K']^{-1}.$$

As may be seen, information may be effectively empty if it is either predictable ($\mathbf{I} \to 0$) or excessively noisy ($\Gamma \to 0$).
The error variance of the optimal forecast $\mathbf{Y}(Q)^*$ is given by

$$\mathrm{Cov}(\mathbf{Y} - \mathbf{Y}^*) = [I - \Gamma K]\Sigma_{vv}$$

Note that the covariance matrix of the original projection, Σ_{vv}, exceeds that of the optimal forecast: (proof omitted)

OVERVIEW, CONTINUED

1. **Questions:**

   - What kinds of models should be considered for short-term forecasting?
   - Can the role of outside information in macro-econometric forecasting be codified?
   - Does the **systematic** use of high-frequency information improve the reliability of near-term model-based forecasts?

2. **Answers:**

   - All. Our practical problem has been to develop techniques that may be used in conjunction with a **structural** macro-econometric model to improve its tracking ability. In fact, we have chosen to develop an explicit short-run forecasting tool, which is a **monthly** macro-model whose "standard" solutions are augmented with individually specified updating relations that achieve efficient utilization of relevant release information.
   - Yes. "Outside" information is a relative concept. In forecasting with macro-econometric models, it typically refers to information contained in timely (usually high frequency) measurements outside the model's own data-base that are incorporated into projections of selected variables. It can also refer to the practice of scrutinizing the forecasts of alternative competing models and adjusting solutions accordingly.
   - Yes. The project has been generally quite successful to date, having accumulated a track record that compares favorably with commercial forecasters:

Mean Absolute Error of Current-Quarter Real GNP Forecasts, 1983 Q3 - 1987 Q3

	Average of DRI, WEFA and Merrill-Lynch	Model Linkage
Total:	1.8	1.6
Early Quarter:	2.0	1.9
Late Quarter:	1.6	1.3

EXAMPLE OF USE OF SECOND MOMENT ESTIMATES

QUESTION: What is the Indicator value of Major Release Variables?

TWO-QUARTER MODEL LINKAGE SYSTEM ERRORS FOR REAL GNP ARE REGRESSED ON TWO-QUARTER MODEL LINKAGE ERRORS FOR THE FOLLOWING:

	Percent Reduction in Forecast Error Variance
Production worker hours	52.3
Industrial production index	29.5
Auto sales	34.7
Retail sales	29.1
Housing starts	6.3
Nondefense capital goods orders	13.2
Nonres. bldg. contracts and permits	13.0
Manuf.& Trade CC/BV Inventories	3.1
Merchandise Trade: exports	3.3
imports	4.6
Consumer price index	1.3
Producer price index, fin.gds.	1.0
Unemployment rate	17.8
M1 money stock	0.0
M2 money stock	0.1
90-day bill rate	1.8
AAA corporate bond rate	1.8
S&P 500 stock price index	0.4
Exchange rate index	1.8

Notes:
1. Period of evaluation - 1977 Q1 to 1986 Q4.
2. Model Linkage errors are generated using information available "as of" the day of the BLS Employment Situation release for the first month of the quarter.

ANSWER: As may be seen, in terms of short-term, two-quarter forecasts of real GNP prepared at the beginning of the quarter, measures of production have the highest indicator value (hours, IP), followed by measures of consumer activity (auto sales, retail sales) and commitments for fixed investment (orders, building contracts and permits, and housing starts). Actual data on prices and financial activity have little indicator value for short-term **real** GNP projections.

FRB

MODEL LINKAGE PROJECT

The Linkage System has three components:

- Estimates of **Monthly GNP** have been developed as a "model" of how BEA translates underlying monthly source data on economic activity to published quarterly GNP figures.

- A short-run **Monthly Forecasting Model** has been designed and built with special simulation features that enable it to utilize information contained in the most recent data releases.

- **Linkage** of monthly forecasting model projections with those of the Board's quarterly MPS model occurs via a temporally disaggregated minimum variance pooling technique.

MONTHLY GNP SYSTEM

- A central feature of the project has been the development of monthly GNP estimates that serve, in effect, as a "model" of how the Bureau of Economic Analysis translates publicly available high frequency data into their published reports on quarterly GNP.

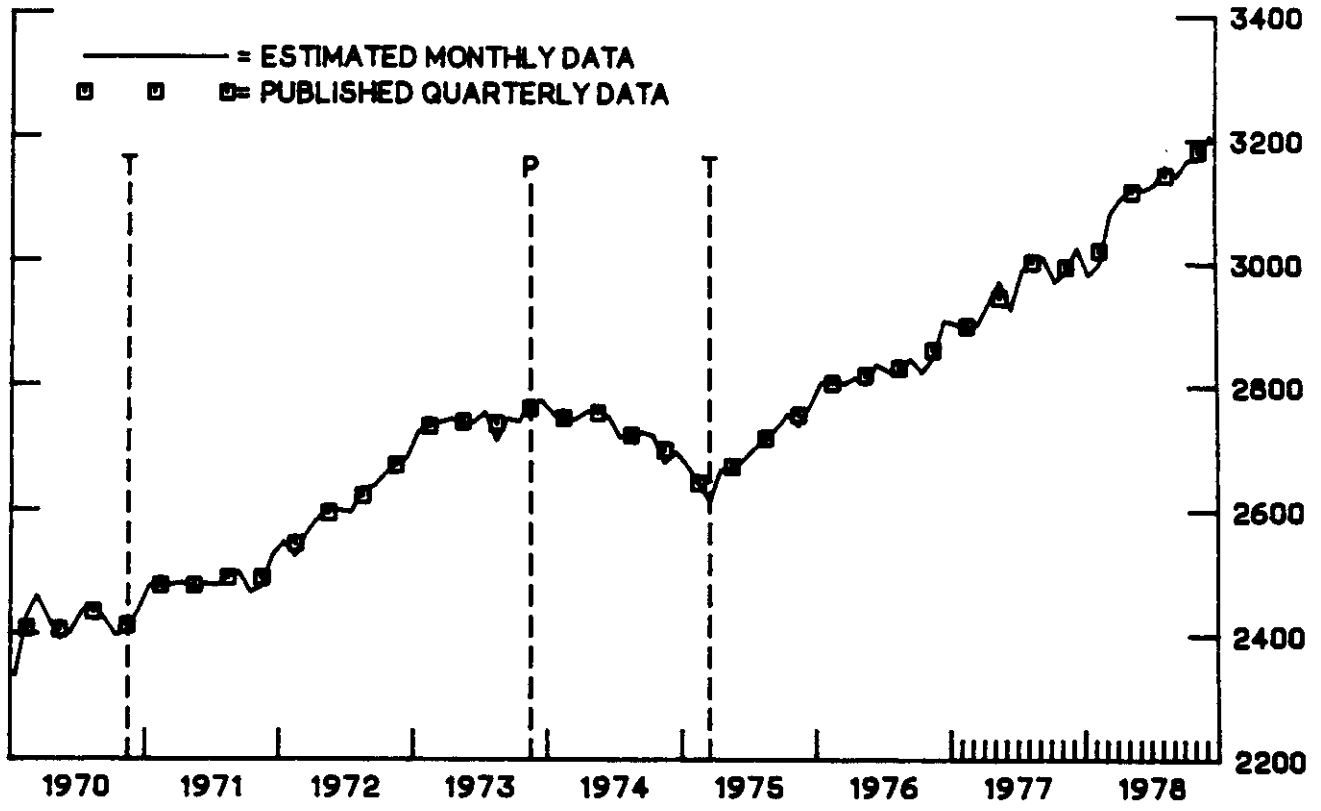
- Estimates of personal consumption expenditures are already published on a monthly basis and are incorporated directly. The remaining portions are interpolated to the monthly frequency on the basis of movements in related series, where methods used by BEA to report quarterly GNP dictate the choice of related series used in the interpolation.

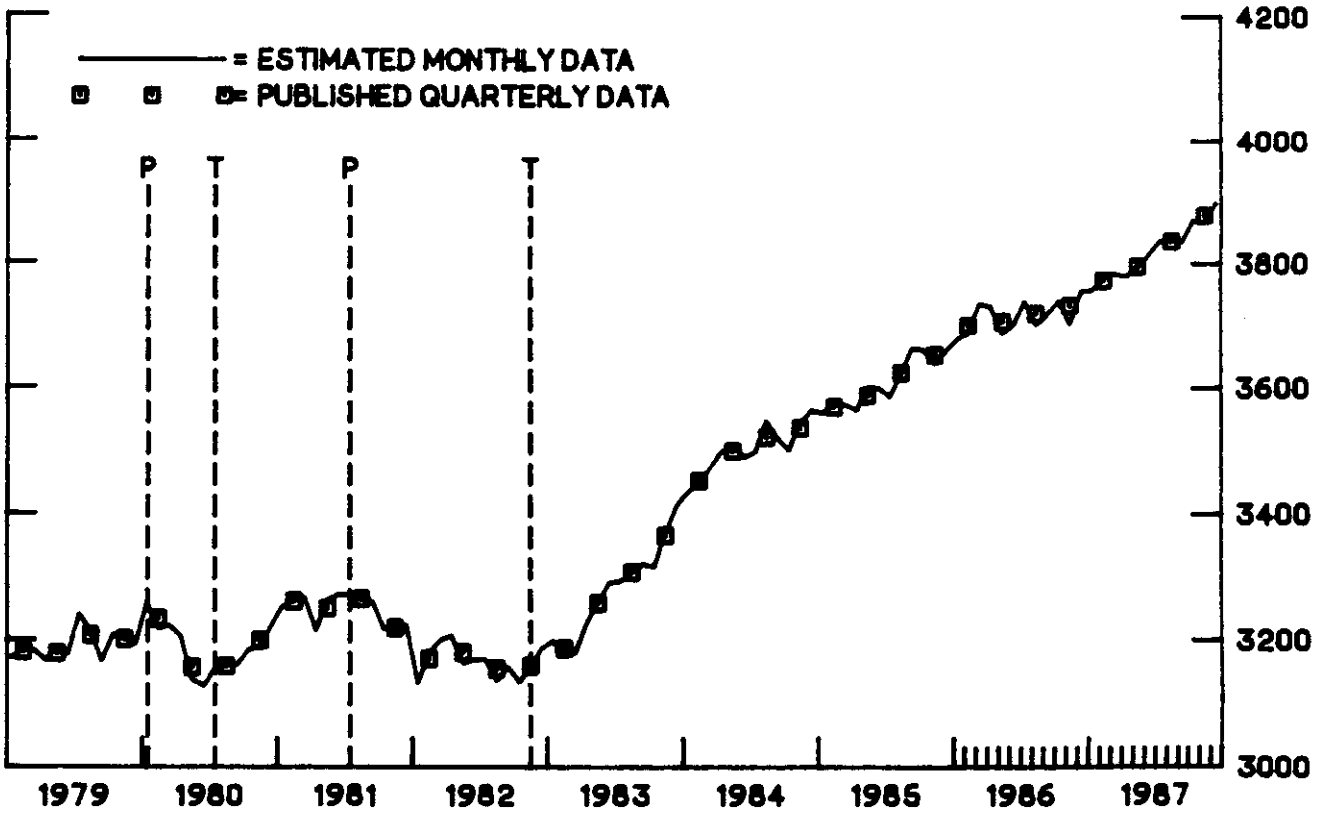
- We specify a linear regression relationship between $y(m)$, the variable to be interpolated (unobserved at the monthly frequency), and $\mathbf{r}(m)$, a vector of related monthly series: $\mathbf{y}(m) = B\,\mathbf{r}(m) + \mathbf{u}(m)$. GLS estimates of B, $\mathbf{y}(m)$, and $\mathbf{u}(m)$ are obtained using the technique of Chow and Lin (1971) and its Fernandes (1981) and Litterman (1983) variants.

Major Release Variables used in the Monthly GNP System

GNP Item (no.of vars.)	Release (Source Agency)
Fixed Investment	
Structures (6)	•Construction value put-in-place(Census)
Equipment (4)	•Manuf. shipments of nondef. capital goods (Census)
Inventory Investment (2)	•Constant dollar Manuf.& Trade Inventories (BEA)
Farm Output and CCC Transactions (2)	•Cash Receipts from farm marketings (USDA)
Government Purchases (5)	•Monthly Treasury Statement •Employment (BLS)
Foreign Transactions (8)	•Export and Import Trade (Census)
Prices (16)	•Producer Prices (BLS) •PCE deflator (BEA)

MONTHLY ESTIMATES OF GROSS NATIONAL PRODUCT
1982 DOLLARS, 1970 - 1987





QUESTION: How efficiently is high frequency information utilized in the Monthly GNP system?

MONTHLY GNP SYSTEM ERRORS FOR REAL GNP ARE REGRESSED ON CHANGES IN

	Coefficient	(std.error)
Production worker hours	2.630	(2.114)
Personal income	0.018	(0.054)
Consumer installment credit	-0.006	(0.032)
90-day bill rate	-0.967	(1.390)
M1 money stock	-0.201	(0.272)
S&P500 stock price index	0.217	(0.239)

Notes:
Period of evaluation - 1977 Q1 to 1986 Q4
F - statistic (6,34) = .684
F - probability = .664

ANSWER: As may be seen, indicators of overall economic activity (**z** variables) have no incremental predicitive power over measures of sectoral activity (**r** variables) in interpolating real GNP, suggesting that the Monthly GNP system could be expolited as a forecasting tool if it were augmented by coherant means for projecting unknown release variables.

THE FRB MONTHLY FORECASTING MODEL: ITS SPECIAL FEATURES AND SIMULATION PROPERTIES

- The Monthly Model integrates high-frequency indicator data and structural modelling within the framework of a system that is designed to efficiently filter the information in major economic data releases.

- The system is used to produce forecasts of real GNP and related variables along with associated standard errors at a monthly frequency.

- The model includes as a subsystem a "model" of monthly GNP that is a simplified version of U.S. Government procedures for estimating quarterly GNP using monthly flow data.

- Forecasts of the monthly flow data are derived from a blend of structural and time-series relationships that attempt to codify frequently used judgemental forecasting methods.

- The behavioral equations are supplemented by a set of filtering relations that selectively process monthly indicator data.

- The model combines "Keynesian" forecasts of aggregate demand with a forecast of "supply" from a time-series model that translates hours and production into an alternative estimate of output.

- The model's simulation properties differ from those of more conventional models. Forecasting accuracy is emphasized; feedback effects from one variable to another are muted both in the design of the behavioral equations as well as by the combination of demand and supply based forecasts.

Table 1. Major Indicator Data Used in the Monthly Model

Indicator Variable	Primary Target Variable
Production Worker Hours	Industrial production
Industrial Production	Alternative estimate of goods GNP
Housing starts	Residential construction
Nondefense capital goods orders	Producers' durable equipment
Nonres. bldg. contracts and permits	Nonresidential construction
Auto production	Auto inventories
Auto sales	Real consumer and business purchases of new autos
Domestic oil production	Oil Inventories
Oil imports, b.p.d.	Oil imports, dollars
Retail Sales	Consumption of goods
Manuf. & Trade Current Cost Inventories	Constant dollar inventories
Merchandise trade exports and imports, Census basis	GNP exports and imports
Consumer price index	Consumption price deflators
Producer price index	Current period price deflators
Unemployment rate	Medium-term price deflators

Table 5. Sectors of The Monthly Model

Behavorial Sectors:

These sectors contain macro forecasting equations.

Name	Model of:
MMAUTO	— Auto Sales, Production, and Inventories
MMPCE	— Personal Consumption Expenditures
MMRES	— Underlying source data for Residential Investment
MMBFI	— Underlying source data for Business Fixed Investment
MMINV	— Manufacturing and Trade Inventory Investment
MMFGN	— Underlying source data for Exports and Imports
MMGOV	— Underlying source data for Government Purchases
MMFARM	— Farm Production, Sales and CCC Transactions
MMGNP	— BEAs translation of underlying source data to GNP
MMLABOR	— Hours, Employment and Labor Force; Wages and Labor Income
MMPRICE	— Prices
MMINC	— Other Incomes; Profits
MMIND	— Industry Output
MMCRED	— Bank Loans and Nonfinancial Credit Flows
MMMAGG	— Monetary Aggregates; Money Market and Deposit Yields
MMRATE	— Bond and Stock Market Yields

Table 5. (continued)

Tailored Filters:

These sectors are used to selectively filter specific data releases. Depending upon data availability, filter equations supercede macro equations of the previous section.

Name		Model of:
MMPCUR	—	PCE deflators/CPI or PPI; and Orders and shipments deflators/PPI
MMCCUR	—	Auto sales/10–day auto sales Nominal PCE/Retail sales; and Constant dollar PCE/Nominal PCE and PCE deflator
MMICUR	—	Constant dollar manufacturing and trade inventories/Current–cost inventory data and PPI
MMFCUR	—	Miscellaneous translations and deflation equations
MMAPOOL	—	Domestic auto production and sales/Announced auto assembly schedules
MMQPOOL	—	Goods GNP/Industry output

Table 6. Share-Weighted Mean and Standard Deviation of Real GNP Component Growth Rates, 1980–1985

percent

Item	Share-Weighted Mean	Share-Weighted Standard Deviation	Correlation of Component Change with Remainder
GNP,1982 dollars	2.2	4.71	—
Final Sales	2.1	3.75	–.10
Private	1.4	3.54	.04
Domestic	2.2	4.24	–.17
Consumption	1.7	2.06	.36
Durables	.4	1.29	.49
Nondurables	.4	.58	.50
Services	.9	.66	.23
Fixed Investment	.5	2.38	.44
Residential	.1	1.38	.47
Nonresidential Structures	.1	3.16	.17
Producers' Durable Equipment	.3	1.21	.48
Inventory Investment	.1	3.16	–.07
Nonfarm	.2	2.68	.07
Farm	–.1	1.11	.03
Net Exports			
Exports	–.1	1.27	.27
Less: Imports	.7	2.08	.20
Government Purchases	.7	1.17	–.27
CCC Inventory Change	.1	1.01	–.38
Other	.5	.56	.16

Table 2. Tests of the Efficiency of The Monthly Forecasting Model in Relation to High–Frequency Information

NULL HYPOTHESIS: MONTHLY DATA HAVE NO INCREMENTAL PREDICTIVE POWER FOR MFM PROJECTIONS OF REAL GNP

TWO–QUARTER MFM ERRORS FOR REAL GNP ARE REGRESSED ON THE MOST RECENT TWELVE MONTHS OF DATA FOR:

	Fprob (12,28)
Production Worker Hours	.23
Industrial Production	.47
Housing starts	.55
Nondefense capital goods orders	.65
Nonres. bldg. contracts and permits	.33
Auto production	.41
Auto sales	.55
Domestic oil production	.43
Oil imports, b.p.d.	.93
Retail Sales	.70
Manuf. & Trade Current Cost Inventories	.25
Merchandise trade: exports	.60
imports	.98
Consumer price index	.78
Producer price index	.71
Unemployment rate	.37
M1 money stock	.83
M2 money stock	.96
90–day bill rate	.75
AAA corporate bond rate	.78
S&P 500 stock price index	.68
Exchange rate index	.99

CONCLUSION : ACCEPT THE NULL HYPOTHESIS

Notes: 1. Period of evaluation – 1977 Q1 to 1986 Q4.

2. MFM errors are generated using a psuedo–history of data configured "as of" the day of the BLS Employment Situation release for the first month of the quarter. The regressors used for each release variable included in the test are lagged accordingly.

Table 3. Tests of the Efficiency of The Monthly Forecasting Model in Relation to the Leading Indicators

NULL HYPOTHESIS: MONTHLY DATA HAVE NO INCREMENTAL PREDICTIVE POWER FOR MFM PROJECTIONS OF REAL GNP

TWO–QUARTER MFM ERRORS FOR REAL GNP ARE REGRESSED ON THE MOST RECENT TWELVE MONTHS OF DATA FOR:

	Fprob (12,28)
Index of Leading Indicators	.39
Average workweek, manufacturing production workers	.92
Average weekly initial claims	.84
New orders for consumer goods and materials, deflated	.56
Vendor performance	.78
Net business formation	.49
Contracts and orders for plant and equipment, deflated	.55
New building permits, private housing units	.48
Net change in inventories on hand and on order	.51
Change in sensitive materials prices, smoothed	.87
S&P 500 stock price index	.68
M2 money supply, deflated	.88
Change in business and consumer credit outstanding	.21

CONCLUSION : ACCEPT THE NULL HYPOTHESIS

Notes: 1. Period of evaluation – 1977 Q1 to 1986 Q4.

2. MFM errors are generated using a psuedo–history of data configured "as of" the day of the BLS Employment Situation release for the first month of the quarter. The regressors used for each release variable included in the test are lagged accordingly.

MODEL LINKAGE

Pooling of forecasts for common variables

$$\hat{Y}(Q)^{*} = (I - W) \bullet \hat{Y}_{m}(Q) + W \bullet \hat{Y}_{q}(Q)$$

$$W = (\Sigma_{mm} + \Sigma_{qq} + \Sigma_{mq} + \Sigma_{qm})^{-1} (\Sigma_{mm} - \Sigma_{mq})$$

Linkage of Monthly Model forecasts for common variables

Aggregated forecast:

$$Y(Q) - \hat{Y}_{m}(Q) = \beta \bullet [\hat{Y}_{q}(Q) - \hat{Y}_{m}(Q)] + U$$

Disaggregate forecast:

$$Y(M^{i}) - \hat{Y}(M^{i}) = \beta^{i} \bullet [\hat{Y}_{q}(Q) - \hat{Y}_{m}(Q)] + U^{i}$$

$$\beta^{i} = [\Sigma_{mm} + \Sigma_{qq} - \Sigma_{mq} - \Sigma_{qm}]^{-1} [\Sigma_{m}i_{m} - \Sigma_{m}i_{q}]$$

Linkage of Monthly Model forecasts for release variables

$$r(M^{i}) - \hat{r}(M^{i}) = \gamma^{i} \bullet [\hat{Y}_{q}(Q) - \hat{Y}_{m}(Q)]$$

$$\gamma^{i} = [\Sigma_{mm} + \Sigma_{qq} - \Sigma_{mq} - \Sigma_{qm}]^{-1} [\Sigma_{r}i_{m} - \Sigma_{r}i_{q}]$$

Macro Variables in the Information Vector

Domestic Final Sales
Net Exports
Inventory Investment
M2 Money Supply
90-day Treasury bill rate
Compensation per Hour

Table 5. Estimated Standard Errors of Forecast

Horizon	One Quarter Ahead			Two Quarters Ahead		
	Monthly Model	Quarterly Model	Pooled Forecast	Monthly Model	Quarterly Model	Pooled Forecast
Beginning of month 1	2.94	4.13	2.50	4.91	6.16	3.82
Beginning of month 2	2.27	4.09	1.94	4.07	5.84	3.44
Beginning of month 3	1.98	4.09	1.70	3.48	5.84	3.00
End of month 3	1.50	4.09	1.31	3.04	5.84	2.72

Table 6. Minimum Variance Pooling Weights for Forecasts of Real GNP from FRB Staff Monthly and Quarterly Models

Horizon	One Quarter Ahead		Two Quarters Ahead	
	Monthly Model	Quarterly Model	Monthly Model	Quarterly Model
Beginning of month 1	.78	.22	.69	.31
Beginning of month 2	.88	.12	.73	.27
Beginning of month 3	.88	.12	.80	.20
End of month 3	.95	.05	.85	.15

Table 7. Minimum Variance Pooling Weights Applied to Monthly Forecasting Model Components of Real GNP

Component	CNS	CD	PDE	NRS	RES	X	M	GOV	INV
				One Quarter Ahead					
Beginning of month 1	.62	.87	.64	.99	.72	.44	.20	.31	.87
Beginning of month 2	.80	.82	.69	1.00	.87	.50	.37	.73	.85
Beginning of month 3	.95	.89	.92	1.00	.90	.80	.71	.78	.91
End of month 3	.93	.98	1.00	1.00	.97	.83	.81	.75	1.00
				Two Quarters Ahead					
Beginning of month 1	.64	.74	.59	.95	.68	.29	.32	.42	.60
Beginning of month 2	.68	.72	.60	1.00	.71	.39	.34	.54	.73
Beginning of month 2	.74	.79	.70	1.00	.78	.52	.45	.59	.83
End of month 3	.77	.89	.78	1.00	.83	.62	.66	.66	.91