THE NBER INTERNATIONAL
TRANSMISSION MODEL: MARK II

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This paper is a second interim report on work in progress at the NBER

aimed at modeling the international transmission of inflation through the

world monetary system.[1] The current version, designated the Mark II model,

is a quarterly macroeconometric model of Canada, France, Germany, Italy,

Japan, the Netherlands, the United Kingdom, and the United States to be

applied to data from 1955 through 1976.

The primary purpose of the model is to provide a means for measuring

the relative importance of various channels by which inflation can be

transmitted from country to country. We hope to identify how the relative

importance of these channels has changed with changes in exchange rate

regimes. This will provide information on the implications for inflation

of alternative international monetary systems.

The Mark II model clearly distinguishes between the reserve-currency country

(the United States) and all others. In Darby (1978) it is shown that in the long-

run equilibrium, the world price level and inflation rate under fixed exchange

rates are determined entirely within the reserve-currency country by its domestic

demand for and supply of money. This is contrary to the heuristic arguments

of Swoboda (1976) and others who attribute price level effects to domestic

credit in proportion to country size. This long-run result does not preclude

interesting short-run adjustments as variations in the U.S. inflation rate

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[1]The initial report is contained in Darby (1977).

are transmitted through the international monetary system. It is also possible that reverse causation will occur as U.S. money supply and demand respond to short-run adjustments abroad. Under floating exchange rates, all countries are in effect reserve countries (except as they attempt to "stabilize" exchange rates) and a world inflation rate is no longer an appropriate concept.

The model is presented as follows: In Section I, the U.S. submodel is presented with foreign variables treated as exogenous. Section II displays the standard nonreserve country submodel. Section III then explains how the submodels are integrated and highlights the parameters which indicate the importance of alternative channels by which inflation is transmitted. Plans for further development and estimation are the subject of Section IV.

I. The U.S. Submodel

The U.S. submodel has two alternative forms, one corresponding to a fiat-reserve-currency country and the other to a commodity-reserve-currency country. One hypothesis which we wish to test is whether the U.S. shifted from a commodity to fiat standard in the early 1960s and whether this resulted in a worldwide inflation. For expositional purposes, we will start with the simpler fiat case and then add the complications of the commodity case.

Notation

Capital letters are used to denote nominal (currency value) variables and lower case letters are used for real (deflated) variables. The variables will be defined as they are introduced and are collected for reference in Table 1. The subscript 1 is used to denote the United States and the subscripts 2 through 8 denote the other countries in our sample. All logarithms are taken with respect to the natural base e. Asterisks are used to indicate expected values formed in the previous period.

Table 1

Symbols Used in Mark II Model

B_j Balance of payments measured in billions of domestic currency units (DCUs) per annum. (For nonreserve countries this is the official reserve settlement basis. For the U.S., we will try changes in the gold stock and the official reserve settlement basis.)

E_j Exchange rate in DCUs per U.S. dollar ($E_1 \equiv 1$).

g_j Fiscal policy variable. (We plan to try both NIA real government spending and deficit.)

H_j High-powered (or base) money in billions of DCUs.

M_j Money stock in billions of DCUs. (We will try both M_1 and M_2 definitions to see which best fits the country's institutional framework.)

P_j Price deflator for GNP (or GDP) in DCUs per base-year DCU. (1970 = 1.000)

P_j^R Index of foreign prices converted by exchange rates into U.S. dollars per base-year U.S. dollar.

Q_j Purchasing power ratio ($E_j P_j^R / P_j$) in base-year DCUs per base-year U.S. dollar.

R_j Short-term nominal interest rate in decimal per annum form. (Three-months treasury bill yield where available.)

s_j Strike variable. (Man days lost per annum divided by civilian labor force where available.)

t Time index (1955 I = 1, 1955 II = 2, etc.)

u_j Unemployment rate in decimal form.

y_j Real GNP (or GDP if GNP unavailable) in billions of base-year DCUs.

y_j^P Permanent income in billions of base-year DCUs.

y_j^R Index of foreign real income. (1970 = 1.000)

μ_j Money multiplier ($\mu_j \equiv M_j/H_j$).

Overview

The U.S. (fiat) submodel consists of five equations and two identities which explain the endogenous variables real income y_1, price level P_1, nominal interest rate R_1, unemployment rate u_1, and nominal money supply, M_1.

The first four variables are explained in a relatively standard semi-reduced form model in which: (1) The long-run equilibrium values of real variables are unaffected by nominal variables. (2) Unanticipated variations in the nominal money supply, real government spending, strike activity, foreign real income, and foreign prices have transitory effects on domestic real variables.

An unusual feature of the model is the endogeneity of the nominal money supply. This variable is determined via a monetary policy reaction function by unemployment, the price level, and interest rates.

Notably missing from both the list of endogenous variables and the monetary policy reaction function are the exchange rate and the balance of payments. The exchange rate for the reserve-currency country is identically equal to one.[2] The balance of payments is irrelevant and ill-defined for a fiat-reserve-currency country. It might be defined formally as net foreign government purchases of U.S. securities, but this will not affect U.S. monetary policy as a gold flow would under a gold standard.[3]

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[2] That is the number of dollars per dollar $E_1 \equiv 1$.

[3] We plan to test whether the U.S. monetary policy reaction function nonetheless showed a response to a balance-of-payments measure in the post-gold-standard era. Preliminary work by John Price (1978) suggests it did not.

We will now present the U.S. fiat submodel equation-by-equation and then summarize the discussion in tabular form.

The Price Level Equation

We use the same price level equation for both the reserve and nonreserve countries. In the case of nonreserve countries it is designed to test for the relative importance of direct price linkages;[4] for the U.S. it captures both the influence of foreign price shocks and the possibility of reverse causation. The idea is that the price level is a weighted average of (1) the price level that would equate the domestic nominal supply of and demand for money and (2) the price level implied by complete international commodity arbitrage.

The price level implied by domestic monetary equilibrium is

$$\log P_1 = \log M_1 - \log m_1^d$$

(1)
$$\log P_1 = \log M_1 - [\xi_{11} + \xi_{10}\xi_{12}t + \xi_{10}\xi_{13}\log y_1 + \xi_{10}\xi_{14}R_1 +$$
$$(1-\xi_{10})\log (M_{1t-1}/P_{1t-1}) + \sum_{i=1}^{4} w_{1i}\hat{M}_{1,t-i+1}]$$

where t is the time index and $\hat{M}_1$ is the innovation or unexpected portion of the nominal money supply measured as $\log M_1 - (\log M_1)^*$. The short-run demand for money in square brackets is taken from Carr and Darby (1977). It combines a standard short-run demand for money with a transitory effect of monetary shocks on money demand similar to Darby (1972). We intend to experiment further with this specification, although it has performed well in preliminary estimations of equation (1).[5]

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[4] That is, to what extend does the "law of one price level" determine the prive level?

[5] Details are in M. R. Darby, "Estimates of Standard Short-Run Money Demand Functions," Memo MD10, Sept. 23, 1977, available upon request.

The price level implied by complete international commodity arbitrage is measured in our model by the income-weighted index P_1^R of prices in the other countries converted by the exchange rates into dollars per unit of output. The details of this calculation are given in Section III. Writers in the monetary approach to the balance of payments literature point out that P_1^R may be multiplied by a constant factor of proportionality, but this goes into the constant term upon taking logarithms.

Upon combining equation (1) with $\log P^R$ and simplifying the notation, the equation to be estimated is

$$(2) \quad \log P_1 = \beta_{11} + T_1 \log P_1^R + (1-T_1) \log M_1 + \beta_{12} t + \beta_{13} \log y_1$$

$$+ \beta_{14} R_1 + \beta_{15} \log (M_{1t-1}/P_{1t-1}) + \sum_{i=0}^{3} \beta_{1,6+i} \hat{M}_{1t-1} + \varepsilon_{11}$$

where ε_{11} is the stochastic disturbance. The weight T_1 measures the importance of direct price linkages relative to domestic conditions in determining the price level, which we term the degree of _price linkedness_.

The Real Income Equation

The real income equation combines a partial adjustment toward the natural-employment level with the effects of unanticipated innovations in certain stated macroeconomic variables plus those of others represented by a disturbance term.

$$(3) \quad \log y_1 - \log y_{1t-1} = \psi_{11} + \psi_{12} (\log y_{1t-1}^n - \log y_{1t-1})$$
$$+ \text{ innovation effects}$$

The natural-employment real income will not grow steadily because booms and recessions will have lasting effects on the capital stock and hence the level of real income associated with the natural unemployment rate.[6]

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[6] Some preliminary calculations and estimates suggest that any adjustment of the capital-labor ratio as predicted by neoclassical growth models proceeds at too slow a pace to be detectible as a movement of natural-employment income toward steady-state income.

The most obvious approach -- and the one to be tried first -- is to represent natural-employment income by permanent income y_1^P. Logarithmic permanent income is customarily calculated as

$$(4) \quad \log y_1^P \equiv (1-\theta_1)\psi_{11} + \theta_1 \log y_1 + (1-\theta_1) \log y_{1t-1}^P$$

It is not feasible to estimate the form which results from applying a Koyck-type transformation to equations (3) and (4) because of numerous nonlinear constraints. So the permanent income approach would require estimating conditional upon a value of θ derived from previous research on permanent income and checking that the results are not unacceptably dependent on the particular value of θ used.

We wish to include innovation effects for the major macroeconomic shocks which are believed to affect real income: monetary policy, fiscal policy, foreign real income shocks, and unusual strike activity. The first three shocks operate through unexpected growth in aggregate demand for final goods and inventory adjustments. We assume that their maximum effect is achieved within one year and that thereafter any residual effects are eliminated as indicated by the partial adjustment scheme (3). This implies that the nominal money supply does not affect real income in the long run and that there is complete long-run "crowding-out" of real income effects of fiscal policy and foreign real income shocks. We are thus treating as negligible any effects operating via the interest elasticity of money demand on the investment-income ratio and the aggregate production function. The strike variable will be measured as a ratio of man days lost to the civilian labor force. These aggregate supply shocks appear to have a quick effect and recovery which would be completely captured by a one-year distributed lag on their level. We plan to check that the aggregate demand shocks enter as innovations only and not also as anticipated levels.

The combined real income equation to be estimated is

$$(5) \quad \log y_1 = \alpha_{11} + \alpha_{12} \log y^P_{1t-1} + (1-\alpha_{12}) \log y_{1t-1}$$

$$+ \sum_{i=0}^{3} \alpha_{1,3+i} \hat{M}_{1t-i} + \sum_{i=0}^{3} \alpha_{1,7+i} \hat{g}_{1t-i} + \sum_{i=0}^{3} \alpha_{1,11+i} \hat{y}^R_{1t-i}$$

$$+ \sum_{i=0}^{3} \alpha_{1,15+i} s_{1t-i} + \epsilon_{12}$$

where the fiscal policy innovation is measured as $\hat{g}_1 = \log g_1 - (\log g_1)*$, the foreign real income shock is $\hat{y}^R_1 = \log y^R_1 - (\log y^R_1)*$, and the strike variable is s_1.

An alternative approach is to use Okun's law to replace $(\log y^n_{1t-1} - \log y_{1t-1})$ in equation (3) with $(u_{1t-1} - u^n_{1t-1})$. This at first does not appear attractive because the natural rate of unemployment u^n is an unknown variable. If, however, we take first differences of this unemployment version of equation (3), we obtain

$$(6) \quad \log y_1 = 2 \log y_{1t-1} - \log y_{1t-2} + \alpha_{10} + \alpha_{12} \Delta u_{1t-1}$$

$$+ \Delta (\text{innovation effects})$$

where movements in u^n other than trend are lumped into the disturbance. This explains accelerations in the growth of real income by the lagged change in the unemployment rate and distributed lags of the changes in the innovations. A third alternative is to directly model the natural unemployment rate. The unemployment rate approaches are alternatives for future use because of the questionable unemployment data in many countries in our sample.

The Unemployment Equation

Ideally we would like to determine the unemployment rate as either the natural rate plus an Okun's Law type adjustment on $\log (y/y^P)$ or else as the

natural rate plus innovation effects corresponding to the real income

innovation effects a la Barro (1977). Either approach requires modeling the

natural unemployment rate for each country.

For the present we will assume that the natural unemployment rate

has followed a trend if it has changed at all. This means that we can stick

with the simple Okun's Law equation.

$$(7) \quad u_1 = \gamma_{11} + \gamma_{12} + \gamma_{13} \log (y_1/y_1^p) + \epsilon_{13}$$

An alternative approach similar to that used to derive equation (6)

is also of interest. Suppose that the unemployment rate displays a partial

adjustment to the lagged difference between the natural and actual unemploy-

ment rates and a response to the innovations present in the real income

equation.[7]

$$(8) \quad \Delta u = \lambda_{11}(u_{1t-1}^n - u_{1t-1}) + \text{innovation effects}$$

If we take first differences in (8) and again relegate changes in the natural

rate (aside from trend) to the disturbance term, then

$$(9) \quad \Delta u_1 = \lambda_{10} + (1-\lambda_{11})\Delta u_{1t-1} + \Delta(\text{innovation effects}) + \epsilon_{13}'$$

So while we plan to try the permanent-income real income and unemployment

equations, we have good alternatives as well.

The Interest Rate Equation

We explain the U.S. nominal interest rate by a variable real interest

rate version of a Darby (1975) tax-effect modified Fisher equation. That is,

the nominal interest rate is the sum of an inflationary premium plus a

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[7]Barro (1977) allows for no partial adjustment and instead uses long
distributed lags on the innovations. A more structured approach is required here.

real before-tax interest rate:

$$(10) \quad R_1 = \delta_{11} 4 \cdot [(\log P_{1t+1})^* - \log P_1] + r_1$$

The coefficient δ_{11} of the expected (per annum) inflation rate will exceed unity if the effective marginal tax rate on interest income exceeds the effective capital-gains tax rate on inflationary increases in capital value. We assume that the real interest rate fluctuates around an invariant long-run δ_{10} in response to the aggregate demand innovations described in the real income equation (5).[8] So the equation to be estimated is

$$(11) \quad R_1^{\cdot} = \delta_{10} + \delta_{11} \; 4[(\log P_{1t+1})^* - \log P_1]$$
$$+ \sum_{i=0}^{3} \delta_{1,2+i} \hat{M}_{1t-i} + \sum_{i=0}^{3} \delta_{1,6+i} \hat{g}_{1t-i} + \sum_{i=0}^{3} \delta_{1,10+i} y_{1t-i}^{R} + \varepsilon_{14}$$

The standard presumption is that positive money supply innovations temporarily decrease the real interest rate while positive fiscal or foreign-real-income innovations have the opposite effect.

The Money Supply Reaction Function

A recurrent problem with reaction function studies is that the goals of policymakers change over time. We assume that these changes are gradual so that they are small in any quarter relative to the perceived changes to which the policymakers respond. This allows us to explain changes in (but not levels of) monetary policy reasonably well on the basis of changes in the policymakers' information set.[9] Considerable preliminary empirical investigation of money supply reaction functions has been carried out using this approach as reported by Price (1978).

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[8]Alternative versions of such a tax-effect modified Fisher equation with variable real interest rate are discussed and tested in Carr, Pesando, and Smith (1976)

[9]A formal theoretical development of this approach is contained in M. R. Darby, "Notes on Expectations and Reaction Functions," Memo MD1, July 11, 1977, which is available upon request.

Our U.S. fiat money supply reaction function relates accelerations in money supply growth to accelerations in interest rates, inflation, and the unemployment rate.

$$(12) \quad \log M_1 = 2 \log M_{1t-1} - \log M_{1t-2} + \eta_{11} + \eta_{12} \, (R_1 - 2R_{1t-1} + R_{1t-2})$$

$$+ \, \eta_{13} \, (\log P_{1t-2} - 2 \log P_{1t-3} + \log P_{1t-4})$$

$$+ \, \eta_{14} \, (u_{1t-2} - 2u_{1t-3} + u_{1t-4}) + \varepsilon_{15}$$

The two quarter lags for the inflation and unemployment accelerations are empirical reflections of recognition and inside lags. The Fed's standard operating procedure involves contemporaneous interest rate stabilization, so that term is not lagged. In this regard, our reaction function may be regarded as a semi-reduced form explaining the money supply as determined by the interaction of the banking system and credit policy. We anticipate the need for further empirical experimentation with the lag structure in the context of simultaneous estimation.

Expected Values

We have so far used four asterisked variables denoting expected values formed in the previous quarter of the indicated variable. For the most part, these expected values refer to the current or earlier periods and are therefore based on past information. These values are predetermined and can be treated as exogenous in estimating the model. The model estimates will be conditional on the particular expectations formation schemes used, however.

Initially we are basing our expected values on univariate time series analysis of each variable following Box and Jenkins (1970). This is not a full

rational expectations approach unless the cost of obtaining or using information in other series is prohibitively costly.[10] As the model is refined we intend to formulate transfer function estimates of expected values which are based on the own series and on other (lagged) variables which are important in determining the current value. These more elaborately formulated expectations can be used to check the robustness of our conditional estimates of the model.

We are postponing the explicit modeling of $(\log P_{1t+1})^*$ and other future expectations required for the other country submodels until the transfer functions have been fitted empirically. We are particularly interested in seeing whether U.S. prices and money supply affect foreign anticipated price levels.

It should be observed that the expected values will generally differ substantially from the predicted value of the corresponding equation in the model. This is because of a difference in timing of information. Consider for example $(\log M_1)^*$ and the money reaction function. The Federal Reserve System bases its behavior -- at least in part -- on information which comes available within the current period. That information is unavailable at the time expectations are formed. Expectations are formed based on expected values of the variables determining the Fed's monetary policy, but innovations in those variables will contribute to the monetary innovations $\hat{M}_1 = \log M_1 - (\log M_1)^*$.[11]

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[10] See Darby (1976).

[11] The stochastic disturbance in the money reaction will also contribute to monetary innovations.

Summary of the U.S. Fiat Submodel

The fiat standard version of the U.S. submodel thus consists of the five equations (2), (5), (7), (11), and (12), identity (4), and a second yet unspecified identity defining $(\log P_{1,t+1})^*$ as a function of current and lagged $\log P_1$ and other variables. These equations and the variables in the model are displayed in Table 2.

A fiat-reserve-currency country is the implicit standard case for most macroeconomics, so the submodel follows generally familiar lines. Innovations in the nominal money supply, real government spending, and foreign real income have standard short-run effects on real income and the nominal interest rate. The price level adjusts to equate nominal money demand to the anticipated nominal supply, with allowance for possible effects of foreign price shocks. The endogenous nominal money supply -- surprising to some in a "monetarist" model -- evolves over time in response to the effects on interest rates of innovations in fiscal policy and foreign real income as well as the evolution of inflation and unemployment and other shocks.

Gold Standard Amendments to the U.S. Submodel

This version of the U.S. submodel is proposed to test empirically whether the U.S. was in fact on the gold standard during the early part of our sample period. It is an empirical question since it depends on whether or not the Fed adjusted the money supply in response to changes in the gold stock. If not, the fixed exchange rate of gold for dollars amounted to no more than a price support program without substantial economic implications.

There are two alternative explanations for the acceleration of U.S. money supply growth in the 1960's and the consequent worldwide inflation: (1) The removal of gold reserve requirements on Federal Reserve notes and deposits may have freed the Fed from a powerful restraining force. Afterward

Table 2

Fiat Standard Version of U.S. Submodel

Equations

(2) $\log P_1 = \beta_{11} + T_1 \log P_1^R + (1-T_1) \log M_1 + \beta_{12}t + \beta_{13} \log y_1$

$\qquad + \beta_{14}R_1 + \beta_{15} \log (M_{1t-1}/P_{1t-1}) + \sum_{i=0}^{3} \beta_{1,6+i}\hat{M}_{1t-1} + \varepsilon_{11}$

(5) $\log y_1 = \alpha_{11} + \alpha_{12} \log y_{1t-1}^P + (1-\alpha_{12}) \log y_{1t-1}$

$\qquad + \sum_{i=0}^{3} \alpha_{1,3+i}\hat{M}_{1t-i} + \sum_{i=0}^{3} \alpha_{1,7+i} \hat{g}_{1t-i} + \sum_{i=0}^{3} \alpha_{1,11+i} \hat{y}_{1t-i}^R$

$\qquad + \sum_{i=0}^{3} \alpha_{1,15+i}s_{1t-i} + \varepsilon_{12}$

(7) $u_1 = \gamma_{11} + \gamma_{12}t + \gamma_{13} \log (y_1/y_1^P) + \varepsilon_{13}$

(11) $R_1 = \delta_{10} + \delta_{11} 4[(\log P_{1t+1})^* - \log P_1]$

$\qquad + \sum_{i=0}^{3} \delta_{1,2+i} \hat{M}_{t-i} + \sum_{i=0}^{3} \delta_{1,6+i} \hat{g}_{t-i} + \sum_{i=0}^{3} \delta_{1,10+i} \hat{y}_{t-i}^R + \varepsilon_{14}$

(12) $\log M_1 = 2 \log M_{1t-1} - \log M_{1t-2} + \eta_{11} + \eta_{12} (R_1 - 2R_{1t-1} + R_{1t-2})$

$\qquad + \eta_{13} (\log P_{1t-2} - 2 \log P_{1t-3} + \log P_{1t-4})$

$\qquad + \eta_{14} (u_{1t-2} - 2u_{1t-3} + u_{1t-4}) + \varepsilon_{15}$

Identities

(4) $\log y_1^P \equiv (1-\theta_1)\psi_{11} + \theta_1 \log y_1 + (1-\theta_1) \log y_{1t-1}^P$

$$(-) \quad (\log P_{1,t+1})^* \equiv f(\log P_1, \ \log P_{1,t-1}, \ \cdots)$$

ENDOGENOUS VARIABLES

$\log P_1, \quad \log y_1, \quad u_1, \quad R_1, \quad \log M_1, \quad \log y_1^P, \quad (\log P_{1,t+1})^*$

PREDETERMINED VARIABLES

Exogenous Variables

$t, \ \log g_1, \ \log g_{1,t-1}, \ \log g_{1,t-2}, \ \log g_{1,t-3}, \ s_1, \ s_{1,t-1}, \ s_{1,t-2}, \ s_{1,t-3}$

Lagged Endogenous Variables

$\log M_{1,t-1}, \ \log M_{1,t-2}, \ \log M_{1,t-3}, \ \log P_{1,t-1}, \ \log P_{1,t-2}, \ \log P_{1,t-3},$

$\log P_{1,t-4}, \ \log y_{1,t-1}, \ \log y_{1,t-1}^P, \ u_{1,t-1}, \ u_{1,t-2}, \ u_{1,t-3}, \ R_{1,t-1}, \ R_{1,t-2}$

Expected Values Based on Prior Information

$(\log M_1)^*, \ (\log M_{1,t-1})^*, \ (\log M_{1,t-2})^*, \ (\log M_{1,t-3})^*, \ (\log g_1)^*, \ (\log g_{1,t-1})^*,$

$(\log g_{1,t-2})^*, \ (\log g_{1,t-3})^*, \ (\log y_1^R)^*, \ (\log y_{1,t-1}^R)^*, \ (\log y_{1,t-2}^R)^*, \ (\log y_{t-3}^R)^*$

Foreign Variables (endogenous in full model)

$\log P_1^R, \ \log y_1^R, \ \log y_{1,t-1}^R, \ \log y_{1,t-2}^R, \ \log y_{1,t-3}^R$

it was free to pursue more rapid monetary growth than it would otherwise have chosen. (2) The Fed paid no attention to the gold stock anyway. The accelerated growth of the nominal money supply was in response to the pressure on the interest rate of accelerating deficits to finance the Vietnamese War. It is not, therefore, indicative of future accelerating inflation absent such extraordinary fiscal shocks.

If the U.S. were de facto on a gold standard in the early part of our period, the gold stock would enter the money reaction function. Some experimentalism with lags and form will be necessary, but let us suppose for the current exposition that we add to our money reaction function the change in the change in the gold stock B_1. Our alternative money reaction function would be

$$(12') \quad \log M_1 = 2 \log M_{1t-1} - \log M_{1t-2} + \eta_{11} + \eta_{12}(R_1 - 2R_{1t-1} + R_{1t-2})$$

$$+ \eta_{13}(\log P_{1t-2} - 2 \log P_{1t-3} + \log P_{1t-4})$$

$$+ \eta_{14}(u_{1t-2} - 2u_{1t-3} + u_{1t-4})$$

$$+ \eta_{15}(B_{1t-2} - B_{1t-3}) + \varepsilon_{15}$$

While the U.S. stood ready to exchange gold at \$35 per ounce, it was the residual supplier or demander of gold. The change in the U.S.gold stock equalled the excess supply of gold taking account of all _other_ international supplies and demands. The excess supply of gold is an increasing function of the price of gold relative to the equilibrium price of gold. The price of gold in terms of goods is the inverse of the price level, so the price ratio referred to is P_1^{eq}/P_1. A linear version of the required excess demand function is

$$(13) \quad B_1 = \xi_{11} + \xi_{12} \log \frac{P_1^{eq}}{P_1}$$

Suppose that the equilibrium price level P_1^{eq} follows a martingale with drift in the logarithms

$$(14) \quad \log P_1^{eq} = \log P_{1t-1}^{eq} + \xi_{13} + \gamma_t$$

Taking first differences in equations (13), (14), substituting, and simplifying the notation

$$(15) \quad B_1 = B_{1t-1} + \rho_{11} + \rho_{12} \, (\log P_1 - \log P_{1t-1}) + \epsilon_{16}$$

If the gold standard version (12') of the money reaction function proves empirically interesting, we will proceed further with specification of the gold stock change equation.

II. Nonreserve Country Submodels

All of the country submodels other than the United States have the same form. We anticipate future modifications -- particularly in the money supply reaction functions -- to tailor these models to national institutional arrangements, but that has not been done yet. We present in this section the prototypical model for country j (j = 2, 3, ..., 8), taking foreign variables as exogenous. As with the U.S., the endogeneity of the foreign variables will be introduced in Section III.

Overview

The real income, price level, and unemployment rate equations are the same as in the U.S. submodel. These equations are of quite general form and can accommodate national differences -- such as in price linkedness T_j -- by different parameter values. The nominal interest rate equation is generalized to allow for interest arbitrage linkages. The money supply reaction function -- as in the gold standard version of the U.S. submodel-- allows for possible influences of the balance of payments.[12] The balance of payments is determined by a generalization of the standard monetary approach equation under pegged exchange rates. This generalization allows for substitution effects due to changes in the purchasing power ratio as well as the familiar liquidity effects due to excess money demand. Under floating exchange rates the dual equation allows for possible transitory effects on the purchasing power ratio from excess money demand and government intervention in the foreign exchange market. Such government intervention is determined by a stabilization function.

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[12]This influence is necessary but not sufficient both for the specie-flow mechanism and for monetary adjustment under complete price linkedness $(T_j = 1)$.

The Price Level Equation

The price level equation is of the same form as the U.S. equation (2):

$$(16) \quad \log P_j = \beta_{j1} + T_j (\log P_j^R + \log E_j) + (1-T_j) \log M_j + \beta_{j2}t$$

$$+ \beta_{j3} \log y_j + \beta_{j4}R_4 + \beta_{j5} \log (M_{jt-1}/P_{jt-1}) + \sum_{i=0}^{3} \beta_{j,6+i} \hat{M}_{j,t-i} + \epsilon_{j1}$$

Here the coefficient of price linkedness T_j provides a ready measure of

the importance of direct price linkages, so much emphasized by the "global

monetarists."[13] If this coefficient is small, then the effect of the balance

of payments on the money supply would be the main channel by which long-run

purchasing power parity at a fixed exchange rate could be achieved.

The Real Income Equation

The real income equation applicable to the U.S. holds generally, so

$$(17) \quad \log y_j = \alpha_{j1} + \alpha_{j2} \log y_{j,t-1}^P + (1-\alpha_{j2}) \log y_{j,t-1} + \sum_{i=0}^{3} \alpha_{j,3+i} \hat{M}_{j,t-i}$$

$$+ \sum_{i=0}^{3} \alpha_{j,7+i} \hat{g}_{j,t-i} + \sum_{i=0}^{3} \alpha_{j,11+i} \hat{y}_{j,t-i}^R + \sum_{i=0}^{3} \alpha_{j,15+i} s_{j,t-i} + \epsilon_{j2}$$

This approach also requires the definitional identity for permanent income

$$(18) \quad \log y_j^P \equiv (1-\theta_j)\psi_{j1} + \theta_j \log y_j + (1-\theta_j) \log y_{j,t-1}^P$$

As with the U.S., we plan to consider an alternative unemployment-rate

approach to real income determination. It is generally supposed that foreign

real income shocks will be relatively more important for the smaller countries

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[13]See Whitman (1975) and Darby (1978). Note that P_j^R is an index of foreign prices converted into dollars per unit of output. Therefore the product $P_j^R E_j$ is in terms of j currency per unit of output. Details of the calculation are in Section III.

in our sample. We can check this hypothesis by examining the coefficients $\alpha_{j,11}, \ldots, \alpha_{j,14}$.

The Unemployment Equation

As with the U.S. submodel, we posit a simple Okun's Law relation

$$(19) \quad u_j = \gamma_{j1} + \gamma_{j2}t + \gamma_{j3} \log (y_j/y_j^P) + \varepsilon_{j3}$$

There is an alternative approach to be tried relating the change in the unemployment rate to the lagged change and changes in the innovations.

Balance of Payments: Pegged Exchange Rates Case

The discussion that follows is simplified by defining the logarithm of the purchasing power ratio as

$$(20) \quad Q_j \equiv \log P_j^R + \log E_j - \log P_j$$

Since $\log P_j^R$ and $\log P_j$ are determined elsewhere in the model, determination of Q_j is equivalent to determining the logarithm of the exchange rate, $\log E_j$.

In the monetary approach to the balance of payments and exchange rates, it is generally assumed that Q_j is always at its parity value because of commodity arbitrage (the law of one price level). The balance of payments is related to the difference between the nominal demand for (high-powered) money and the nominal supply of (high-powered) money from sources other than central bank foreign exchange operations. The logic of a depreciation of the exchange rate is that it increases the domestic price level, which increases nominal demand for high-powered money, which causes reserves to flow in until the gap is filled. There is no role here for the specie-flow mechanism in which changes in Q_j cause reserve flows by making tradable-goods consumption less attractive and their production more attractive.

So to consider the possibility that inflation is transmitted through the specie-flow mechanism, we must generalize the monetary approach.

Let us first consider the case of pegged exchange rates. In that case we take exchange rates as exogenous. The balance of payments, as is customary in the monetary approach, is scaled by taking it as a ratio to high-powered money, or B_j/H_j. The scaled balance of payments is supposed normally to be some fraction of the logarithmic change in high-powered money.[14] This amount will be increased if monetary policy is used to create an excess demand for money for the standard monetary approach reasons. It will also be increased if the purchasing power ratio Q_j exceeds its parity value.[15]

A combined balance of payments equation would be

$$(21) \quad \frac{B_j}{H_j} = w_{j0} + w_{j1}(\log H_j - \log H_{j,t-1}) + w_{j2}Q_j + w_{j3}(\log M_j - \log P_j)$$
$$+ w_{j4}t + w_{j5}\log y_j + w_{j6}R_j + \sum_{i=0}^{3} w_{j,7+i}\hat{M}_{j,t-i} + \varepsilon_{j6}$$

This equation is derived on the assumption that the parity value of Q_j follows a trend which can be incorporated in w_{j0} and w_{j4}. The influence of the real supply of money relative to its real demand is measured by w_{j0} and w_{j3}, w_{j4}, ... w_{j10}. A significantly positive coefficient w_{j2} indicates relative price level changes do have a role in explaining the balance of payments as required for the specie-flow adjustment process. Since the parity value of Q_j may well follow a martingale with drift,[16]

_____

[14]Note that $B_j = w_{j1}(H_j - H_{jt-1})$ implies $B_j/H_j = w_{j1}(\log H_j - \log H_{j,t-1})$.

[15]This model is similar to that discussed in a no-growth context by Connolly and Taylor (1976). However the variations in relative prices there were between tradable and nontradable goods.

[16]That is, if $\bar{Q}_j$ is the parity value, it may be that $\bar{Q}_j = a + \bar{Q}_{j,t-1} + v$, where the v's are uncorrelated random variables. This would be consistent with changes in $\bar{Q}_j$ over time because of relative price changes for individual exports and imports.

the first difference form of equation (21) will be tried also.

Since the balance of payments is related, following the monetary approach, to the change in the reserve component of high-powered money, we must use the money multiplier μ; to move from the money supply (determined by the money supply reaction function) to high-powered money. We take the money multiplier μ as exogenously determined so that (the logarithm of) high-powered money is defined by the identity

$$(22) \quad \log H_j \equiv \log M_j - \log \mu_j$$

Exchange Rates and Balance of Payments: Floating Exchange Rate Case

Under floating exchange rates, the monetary approach would suggest that the exchange rate will adjust to equate Q_j with its parity value given $\log P_j^R$ and $\log P_j$. If we are to allow Q_j to differ from parity in the pegged rate case, we must admit a corresponding possibility in the floating case, particularly with regard to government "exchange-rate stabilization" operations.

Writers in the monetary approach literature would argue that it would make no difference to the guilder/dollar exchange rate, say, whether the Dutch central bank achieved a given nominal money supply by purchasing U.S. treasury bills or Netherlands treasury bills. We suppose that these assets might not perfect substitutes so that there would be different net capital flows -- and relative yields -- in the two cases.[17] These different net capital flows would imply different net exports and values of Q_j if the law of one price level does not hold.

----

[17]Milton Friedman suggested that a useful analogy would be to consider whether it would affect the price of real estate if the Fed bought real estate instead of U.S. treasury bills to achieve a given increase in the money supply. Whether the effects are sufficiently small and transient to be negligible is an empirical, not theoretical, question.

The dual of equation (21) which we propose to estimate under floating exchange rates is

$$(21') \quad Q_j = z_{j0} + z_{j1}(\log H_j - \log H_{j,t-1}) + z_{j2}\frac{B_j}{H_j}$$

$$+ z_{j3}(\log M_j - \log P_j) + z_{j4}t + z_{j5}\log y_j$$

$$+ z_{j6}R; + \sum_{i=0}^{3} z_{j,7+i}\hat{M}_{j,t-i} + \varepsilon_{j6}'$$

If the law of one price level and perfect asset substitution are acceptable empirical approximations, only factors determining the parity value of Q_j — here the constant and time — will enter.[18] Here we allow for the possibility of short-run effects on the parity ratio from exchange-market intervention and monetary policy effects on real interest rates.

If we were dealing with clean floats, B_j/H_j would be exogenously set independently of the exchange rate.[19] In the dirty floats which we have observed, there appears to be an attempt to stabilize the exchange rate. So we assume that B_j/H_j is determined by a policy reaction function as a distributed lag of current and past exchange rate changes:

$$(23) \quad \frac{B_j}{H_j} = c_{j1} + \sum_{i=0}^{3} c_{j,2+i}(\log E_{j,t-i} - \log E_{j,t-i-1}) + \varepsilon_{j7}$$

Money Supply Reaction Function

Movement to equilibrium under pegged exchange rates requires that an increased balance of payments surplus lead to increased monetary growth.

---

[18]Then the equation would reduce to the standard monetary approach equation (after first-differencing): $\Delta\log E_j = a + \Delta\log P_j - \Delta\log P_j^R + \nu$.

[19]This would not necessarily be zero since the Netherlands might wish to invest transitory natural gas revenues in U.S. treasury bills for portfolio reasons.

This is true whether one emphasizes direct price linkages or specie-flows as the adjustment mechanism.[20] Thus the reserve currency reaction function would be supplemented by a term in the change of the scaled balance of payments.

Preliminary experimentation reported in Price (1978) suggests that the scaled balance of payments should be lagged several quarters. This is consistent with the standard central bank practice of automatically sterilizing via open market operations the money supply effects of foreign exchange operations.

Under pegged exchange rates the money supply reaction function would be similar to that of the reserve currency under the gold standard:

$$(24) \quad \log M_j = 2 \log M_{jt-1} - \log M_{jt-2} + \eta_{j1} + \eta_{j2}(R_j - 2R_{jt-1} + R_{jt-2})$$

$$+ \eta_{j3} (\log P_{jt-2} - 2 \log P_{jt-3} + \log P_{jt-4})$$

$$+ \eta_{j4} (u_{jt-2} - 2u_{jt-3} - u_{jt-4})$$

$$+ \eta_{j5}[(\frac{B_j}{H_j})_{t-2} - (\frac{B_j}{H_j})_{t-3}] + \varepsilon_{j5}$$

The floating rate version would drop the η_{j5} term, although we intend to test whether this is in fact the case.

The Interest Rate Equation

As with the price equation, we wish to allow the data to determine the relative importance of domestic forces and international forces (interest

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[20] It may be that pegged exchange rates are periodically adjusted instead of monetary growth. This possibility is discussed in Darby (1978). Unfortunately it is empirically impossible to estimate a reaction function for the infrequent exchange rate changes so we treat them as exogenous shocks.

arbitrage) in determining the nominal interest rate. Strict interest arbitrage would relate the nominal interest rate to the U.S..nominal interest rate and the expected growth rate per annum of the exchange rate. We add a term in the scaled balance of payments to allow for variations in the risk premium. Adding these to the domestic variables in the U.S. equation (11) yields

$$
(25) \quad R_j = \delta_{j0} + \delta_{j1} \, 4[(\log P_{jt+1})^* - \log P_j]
$$

$$
+ \sum_{i=0}^{3} \delta_{j,2+i} \hat{M}_{jt-i} + \sum_{i=0}^{3} \delta_{j,6+i} \hat{g}_{jt-i} + \sum_{i=0}^{3} \delta_{j,10+i} \hat{y}^R_{jt-i}
$$

$$
+ \delta_{j,14} R_1 + \delta_{j,15} \, 4[(\log E_{jt+1})^* - \log E_j]
$$

$$
+ \delta_{j,16} \frac{B_j}{H_j} + \epsilon_{j4}
$$

Summary of the Standard Nonreserve Country Submodel: Pegged Exchange Rate Version

The pegged exchange rate version of the nonreserve country submodel is presented in Table 3, which includes the yet unspecified identities for expected future values. The major difference from the U.S. fiat submodel is the potential importance of the scaled balance of payments in determining the money supply. There is also an interest rate linkage and direct price linkage which would probably be more important than in the U.S. case.

The nonreserve country money stock will evolve over time in response to domestic shocks and the balance of payments. If the degree of price linkedness is high, U.S. inflation would be transmitted directly,with the nominal money supply then rising to make up for the inflation-induced fall in the real money supply. Our model alternatively permits the purchasing power ratio to get out of line (if price linkedness were low) so that the

Table 3

Pegged Exchange Rate Version of Nonreserve Country Submodel

EQUATIONS

$$(16) \quad \log P_j = \beta_{j1} + T_j (\log P_j^R + \log E_j) + (1-T_j) \log M_j + \beta_{j2} t$$

$$+ \beta_{j3} \log y_j + \beta_{j4} R_4 + \beta_{j5} \log (M_{jt-1}/P_{jt-1}) + \sum_{i=0}^{3} \beta_{j,6+i} \hat{M}_{j,t-i} + \epsilon_{j1}$$

$$(17) \quad \log y_j = \alpha_{j1} + \alpha_{j2} \log y_{j,t-1}^P + (1-\alpha_{j2}) \log y_{j,t-1} + \sum_{i=0}^{3} \alpha_{j,3+i} \hat{M}_{j,t-1}$$

$$+ \sum_{i=0}^{3} \alpha_{j,7+i} \hat{g}_{j,t-1} + \sum_{i=0}^{3} \alpha_{j,11+i} \hat{y}_{j,t-1}^R + \sum_{i=0}^{3} \alpha_{j,15+i} s_{j,t-1} + \epsilon_{j2}$$

$$(19) \quad u_j = \gamma_{j1} + \gamma_{j2} t + \gamma_{j3} \log (y_j/y_j^P) + \epsilon_{j3}$$

$$(21) \quad \frac{B_j}{H_j} = w_{j0} + w_{j1} (\log H_j - \log H_{j,t-1}) + w_{j2} Q_j + w_{j3} (\log M_j - \log P_j)$$

$$+ w_{j4} t + w_{j5} \log y_j + w_{j6} R_j + \sum_{i=0}^{3} w_{j,7+i} \hat{M}_{j,t-1} + \epsilon_{j6}$$

$$(24) \quad \log M_j = 2 \log M_{jt-1} - \log M_{jt-2} + \eta_{j1} + \eta_{j2} (R_j - 2R_{jt-1} + R_{jt-2})$$

$$+ \eta_{j3} (\log P_{jt-2} - 2 \log P_{jt-3} + \log P_{jt-4})$$

$$+ \eta_{j4} (u_{jt-2} - 2u_{jt-3} - u_{jt-4})$$

$$+ \eta_{j5} [(\frac{B_j}{H_j})_{t-2} - (\frac{B_j}{H_j})_{t-3}] + \epsilon_{j5}$$

(25) $\quad R_j = \delta_{j0} + \delta_{j1}\ 4[(\log P_{jt+1})^* - \log P_j]$

$$+ \sum_{i=0}^{3} \delta_{j,2+i}\hat{M}_{jt-i} + \sum_{i=0}^{3} \delta_{j,6+i}\hat{g}_{jt-i} + \sum_{i=0}^{3} \delta_{j,10+i}\hat{y}_{jt-i}^R$$

$$+ \delta_{j,14}R_1 + \delta_{j,15}\ 4[(\log E_{jt+1})^* - \log E_j]$$

$$+ \delta_{j,16}\frac{B_j}{H_j} + \epsilon_{j4}$$

IDENTITIES

(18) $\quad \log y_j^P \equiv (1-\theta_j)\psi_{j1} + \theta_j \log y_j + (1-\theta_j)\log y_{j,t-1}^P$

(20) $\quad Q_j \equiv \log P_j^R + \log E_j - \log P_j$

(22) $\quad \log H_j \equiv \log M_j - \log \mu_j$

(-) $\quad (\log P_{j,t+1})^* \equiv f(\log P_1,\ \log P_{1,t-1},\ \ldots)$

(-) $\quad (\log E_{j,t+1})^* \equiv f(\log E_j,\ \log E_{j,t-1},\ \ldots)$

ENDOGENOUS VARIABLES

$\log P_j$, $\log y_j$, u_j, R_j, $\log M_j$, B_j/H_j, $\log y_j^P$, $\log H_j$, Q_j, $(\log P_{j,t+1})^*$, $(\log E_{j,t+1})^*$

PREDETERMINED VARIABLES

Exogenous Variables

t, $\log E_j$, $\log E_{j,t-1}$, $\log g_j$, $\log g_{j,t-1}$, $\log g_{j,t-2}$, $\log g_{j,t-3}$, s_j, $s_{j,t-1}$, $s_{j,t-2}$, $s_{j,t-3}$, $\log \mu_j$

Lagged Endogenous Variables

$(B_j/H_j)_{t-2}$, $(B_j/H_j)_{t-3}$, $\log H_{j,t-1}$, $\log M_{j,t-1}$, $\log M_{j,t-2}$, $\log M_{j,t-3}$, $\log P_{j,t-1}$, $\log P_{j,t-2}$, $\log P_{j,t-3}$, $\log P_{j,t-4}$, $\log y_{j,t-1}$, $\log y^P_{j,t-1}$, $u_{j,t-1}$, $u_{j,t-2}$, $u_{j,t-3}$, $R_{j,t-1}$, $R_{j,t-2}$

Expected Values Based on Prior Information

$(\log M_j)^*$, $(\log M_{j,t-1})^*$, $(\log M_{j,t-2})^*$, $(\log M_{j,t-3})^*$, $(\log g_j)^*$, $(\log g_{j,t-1})^*$, $(\log g_{j,t-2})^*$, $(\log g_{j,t-3})^*$, $(\log y^R_j)^*$, $(\log y^R_{j,t-1})^*$, $(\log y^R_{j,t-2})^*$, $(\log y^R_{j,t-3})^*$

Foreign Variables (endogenous in full model)

R_1, $\log P^R_j$, $\log y^R_j$, $\log y^R_{j,t-1}$, $\log y^R_{j,t-2}$, $\log y^R_{j,t-3}$

balance of payments is increased via "expenditure-switching." This causes money and prices to rise over time until the purchasing power ratio falls to its parity value.

Changes for the Floating Exchange Rate Version

The minor changes required for the floating exchange rate version of the nonreserve country submodel are presented in Table 4. If the addition of equation (23) is spurious in the sense that the balance of payments is an exogenous variable (say 0) due to nonintervention, then the model is identical to the U.S. fiat submodel except that we happen to normalize on the U.S. exchange rate and include the exchange rate equations here. We choose to allow for the possibility of these countries having temporary effects on the purchasing power ratio via intervention so that the data can decide the issue.

Table 4

Floating Exchange Rate Version of Nonreserve Country Submodel:
Changes from Pegged Exchange Rate Version.

EQUATIONS

Substitute for equation (21):

$$(21') \quad Q_j = z_{j0} + z_{j1}(\log H_j - \log H_{j,t-1}) + z_{j2} \frac{B_j}{H_j}$$

$$+ z_{j3}(\log M_j - \log P_j) + z_{j4}t + z_{j5}\log y_j$$

$$+ z_{j6}R_j + \sum_{i=0}^{3} z_{j,7+i}\hat{M}_{j,t-i} + \varepsilon_{j6}'$$

Add:

$$(23) \quad \frac{B_j}{H_j} = c_{j1} + \sum_{i=0}^{3} c_{j,2+i}(\log E_{j,t-i} - \log E_{j,t-i-1}) + \varepsilon_{j7}$$

ENDOGENOUS VARIABLES

Add: $\log E_j$

PREDETERMINED VARIABLES

Exogenous Variables

Delete: $\log E_j$, $\log E_{j,t-1}$

Lagged Endogenous Variables

Add: $\log E_{j,t-1}$, $\log E_{j,t-2}$, $\log E_{j,t-3}$, $\log E_{j,t-4}$

III. International Connections: Closing the Model

We close the model by making endogenous the previously predetermined current foreign variables and combining the submodels. Nothing is required for the U.S. interest rate R_1 since it is already defined as endogenous in the U.S. submodel. However all eight submodels have foreign real income and price variables (log y_j^R and log P_j^R) which must be defined. This is done by sixteen identities.

The Foreign Real Income Identities

The operational measure of foreign real income for each country j (j = 1, ..., 8) is a nominal-income-weighted index of the real income of the other seven countries. Our nominal-income weights are based on averages for the entire sample period. First the overall nominal income weight V_j is calculated for each country. This is done by converting nominal income Y_j into dollar equivalents via exchange rates and then calculating mean nominal income $\overline{Y/E}_j$ for the country over the sample period. The share of each country in total mean nominal income is

$$(26) \qquad V_j = \frac{\overline{Y/E}_j}{\sum_{i=1}^{8} \overline{Y/E}_i}$$

The overall weight V_j is the share of country j in total mean nominal income. For computing country j's foreign real income, we want the weight of country i in the total mean nominal income of all countries other than j. This is

$$(27) \qquad d_{ji} = \frac{V_i}{1-V_j} \qquad \text{for } i, j = 1, ..., 8; \ i \neq j$$

These computed nominal income weights are used in our foreign real income
identities

$$(28) \quad \log y_j^R \equiv \sum_{\substack{i=1 \\ i \neq j}}^{8} d_{ji} \log y_i - basey_j, \qquad j = 1, \ldots, 8$$

where $basey_j$ is the number that makes $\log y_j^R$ average 0 over the base year.[21]
This index is algebraically equivalent to one which computes the growth rate
of foreign real income as the weighted (by d_{ji}) sum of the individual foreign
real income growth rates.

The Foreign Price Identity

The foreign price variable is an index of foreign prices converted
by the exchange rates into dollars per unit of real output. In terms of
levels, we divide country i's price index P_i (in i currency per unit of
output) by its exchange rate E_i (in i currency per dollar) to obtain the
price in dollars of a unit of output in i. Taking the weighted average
over all foreign countries of the log (P_i/E_i) gives our foreign price
identities.

$$(29) \quad \log P_j^R \equiv \sum_{\substack{i=1 \\ i \neq j}}^{8} d_{ji} (\log P_i - \log E_i) - baseP_j, \qquad j = 1, \ldots, 8$$

where $baseP_j$ normalizes $\log P_j^R$ to zero in 1970.

Note that $\log P_j^R + \log E_j$ is the logarithm of a similar index computed
using the implicit exchange rate E_i/E_j of i currency per unit of j currency.

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[21]This corresponds to an index $y_j^R \equiv e^{\log y_j^R}$ which equals 1.000 in
1970.

This index $P_j^R E_j$ is the weighted average cost in j currency of a unit of output abroad.

The sixteen identities (28) and (29) complete the model by making foreign real income and prices endogenous.

International Transmission in the Mark II Model

There have been proposed in the literature a large number of channels by which inflation can be transmitted internationally. The Mark II model represents substantial progress toward empirical measurement of the importance of these various channels.

Let us first consider the channels which existed under the pegged exchange rate system. The extent to which prices are determined via commodity arbitrage (the law of one price level) is measured by T_j, the coefficient of price linkedness. If T_j is near 1, as assumed in much of the monetary approach literature, then country j's price level will adapt quickly to the world price level with the nominal money supply passively adjusting to changes in nominal money demand caused by world price level changes. The speed with which the money supply adjusts would depend on the effect of excess money demand on the scaled balance of payments and the effect of the scaled balance of payments on the nominal money supply.

If price linkedness is low, the world price level will not follow U.S. price developments so closely. In particular an acceleration in U.S. inflation would have little initial effect on the foreign country j's price level but would instead increase the purchasing power ratio. This would induce expenditure-switching increases in the scaled balance of payments which would in turn lead to increases in the money supply. As the money supply increases begin to affect country j's price level, the purchasing

power ratio will finally begin to fall. This process involves a catch-up
period of very rapid money and price growth and finally a permanent increase
in these growth rates by the amount of the permanent increase in U.S.
inflation.[22]

Interest rate and real income linkages are also included. We anticipate
that the most important effects of these linkages will operate through induced
changes in the nominal money supply. We have not yet provided for external
shocks such as OPEC and the famous Peruvian anchovies. The reason is that
the model has the potential to explain the worldwide price explosion of
the early 1970s without such dei ex machinae and we would like to see empirically
how much remains to be attributed to such shocks. Given their unique
nature any direct inclusion in the model at this point might well beg the
question.

Under flexible exchange rates, each country's inflation rate is sub-
stantially determined by its own domestic considerations. It may be that
its domestic monetary policy is influenced by the effects of foreign shocks.
An interesting question is whether government intervention in foreign exchange
markets has had a substantial effect on exchange rates. Such an effect
would be the dual of the ability of a government to exercise short-run
control of its nominal money supply under exchange rates via sterilization.

We hope to discover whether the accelerated U.S. nominal money supply
growth in the decade centered around 1970 can be attributed to abandonment
of the gold standard or to printing money to finance the Vietnamese War.
The answer to this question will be useful in assessing prospects for U.S.
inflation under present and alternative monetary arrangements.

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[22] The dynamic analysis of such a system is quite complicated. It
will be discussed in a forthcoming paper by Dean Taylor and the author.

IV. Plans for Future Work

Most of the known weak spots in the model have been indicated in the presentation. We would particularly appreciate readers bringing unknown weak spots to our attention! Because of considerable difficulties with the international data, we have only just reached the point where we can begin to try the model out and see where additional work must be done.

Preliminary estimates using OLS, GLS, and Box-Jenkins single equation methods will be carried out in these early stages.

The first approach to simultaneous estimation of the model will doubtless be the two stage least squares routine based on principal components which is available in the NBER's TROLL system. Unfortunately the correction for autocorrelated residuals in the presence of lagged dependent variables has unknown statistical properties and uncertain convergence. Therefore we will have to examine alternative estimators. We are currently attracted to the capabilities of C. W. Wymer's estimation package. Nominations of operative candidates are particularly solicited.

Once we have settled on an estimation procedure, we can proceed to the iterative task of estimation and revision until we have a model which we can use in our simulation experiments.

REFERENCES

Barro, R.J. "Unanticipated Money Growth and Unemployment in the United States,"
American Economic Review 67 (March 1977): 101-15.

Box, G.E.P., and Jenkins, G.M. Time Series Analysis: Forecasting and Control.
San Francisco: Holden-Day, Inc., 1970.

Carr, J., and Darby, M.R. "The Role of Money Supply Shocks in the Short-Run
Demand for Money," Discussion Paper 98, UCLA Department of Economics,
August 1977.

_____, Pesando, J.E., and Smith, L.B. "Tax Effects, Price Expectations
and the Nominal Rate of Interest," Economic Inquiry 14 (June 1976):
259-69.

Connolly, M., and Taylor, D. "Adjustment to Devaluation With Money and
Nontraded Goods," Journal of International Economics 6 (August 1976):
289-98.

Darby, M. "The Allocation of Transitory Income Among Consumers' Assets,"
American Economic Review 62 (December 1972): 928-41.

_____. "The Financial and Tax Effects of Monetary Policy on Interest Rates,"
Economic Inquiry 13 (June 1975): 266-76.

_____. "Rational Expectations Under Conditions of Costly Information,"
Journal of Finance 31 (June 1976): 889-95.

_____. "An Introduction to the NBER International Transmission Model:
Mark I," Discussion Paper 99, UCLA Department of Economics, August 1977.

_____. "The Monetary Approach to the Balance of Payments: A Review
Article," Journal of Money, Credit, and Banking, forthcoming 1978.

Price, J. "Time Series Analysis of Money Supply Reaction Functions:
International Evidence," Ph.D. Dissertation, UCLA Economics Department,
1978.

Swoboda, A.K. "Monetary Policy Under Fixed Exchange Rates: Effectiveness,

the Speed of Adjustment, and Proper Use," in J.A. Frenkel and H.G.

Johnson, eds., The Monetary Approach to the Balance of Payments,

Toronto: University of Toronto Press, 1976.

Whitman, M. v.N. "Global Monetarism and the Monetary Approach to the Balance

of Payments," Brookings Papers on Economic Activity, 1975, no. 3,

491-536.