AN INTRODUCTION TO THE NBER INTERNATIONAL TRANSMISSION MODEL: MARK I

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AN INTRODUCTION TO THE NBER INTERNATIONAL TRANSMISSION MODEL: MARK I

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I. Introduction

This paper reports on work in progress at the NBER aimed at modeling the international transmission of inflation through the world monetary system.[1] The Mark I model is a "first draft" of 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 1977.

A model is a tool designed for a particular job. So it is necessary to motivate the modeling approach taken by stating the goals of the research program for which the model is designed. (1) First we wish to explain variations over time in the world inflation rate and of individual countries around that rate. (2) We wish to determine the major channels by which inflation is transmitted internationally and assess their relative importance. (3) We wish to evaluate the implications of alternative international monetary arrangements for the level and stability of inflation rates. (4) We wish to provide a consistent data base which can be used by other empirical researchers in international macroeconomics.

We choose a quarterly model so that we can use the short-run adjustment pattern to distinguish among alternative channels of international transmission. The eight countries in the sample dominate free-world output and other countries

[1] Anna J. Schwartz, Benjamin Klein, and James Lothian are also participating in various aspects of the project. The research has been supported by grants from the National Science Foundation, Scaife Family Trusts, Alex C. Walker Educational and Charitable Foundation, and Relm Foundation. The author acknowledges numerous helpful conversations with his colleagues and assistants on the project.

can be later linked to our model should they be of particular interest. Since only major macroeconomic aggregates such as the price level are desired, the model has a limited number of semi-reduced form equations to describe each national economy. These are supplemented by reaction functions which account for the response of national policymakers to foreign influences. We wish to examine whether variation in the world inflation rate can be traced to structural changes in these reaction functions -- particularly that for the U.S. money supply. Since different reaction functions are consistent with different monetary systems, alternative monetary systems can then be evaluated by simulation experiments.

The present version of the model can be described easily since it consists of eight nearly identical submodels for each country. Aside from necessary differentiation in the U.S. reaction functions due to its reserve-currency status, each country model is the same. It is planned in future revisions of the model to tailor the national submodels somewhat to domestic institutions.

Section II presents the general theoretical approach underlying the modeling. The determination of the major macroeconomic aggregates is explained in Section III. The distinctively international variables (the balance of payments and the short-term interest rate) are discussed in Section IV. Section V presents the still-rudimentary reaction functions. Plans for future development and estimation are the subject of Section VI.

II. Theoretical Approach

The basic theoretical approach or paradigm can be viewed as combining elements of the monetarist, rational expectations, and monetary approach to the balance of payments literatures. Perhaps a more accurate description would say that the model emphasizes these elements within the context of the general macroeconomic/monetary literature.[2]

The movements of the major macroeconomic aggregates are viewed as reflecting two types of forces: (1) Macroeconomic shocks or innovations which either change the moving equilibrium of the economy or move the economy away from an unchanged equilibrium. (2) Equilibrating forces which move the economy toward[3] equilibrium when the economy is away from equilibrium. The monetarist/Keynesian debate has largely been due to differences of opinion as to the variances and impacts of different types of shocks and to the rapidity of the adjustment toward equilibrium. I have attempted to formulate the model so as to allow the data (rather than assumptions) to answer these empirical questions.

Macroeconomic shocks can be broadly described as unexpected changes in the conditions underlying the macroeconomic equilibrium of the economy. Thus when Hume, Thornton, or Fisher discussed the transitory effects on real income of an increase in the nominal money stock, they were implicitly assuming a normal expectation of a constant money stock. Friedman and others emphasized that with a normally growing money stock, it is the accelerations which are unexpected changes in conditions.[4] Lucas (1973), Sargent and Wallace (1975), Sargent (1976),

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[2]Many of the ideas on dynamic adjustments to macroeconomic shocks are contained in Part III of the author's <u>Macroeconomics: The Theory of Income, Employment, and the Price Level</u> (1976a).

[3]But not necessarily smoothly or rapidly toward.

[4]See Milton Friedman's interesting description (1975, pp. 177-178) of emphasis on accelerations as an expositional way station en route to the rational expectations formulation.

and Barro (1977) in a series of well-known papers have refined the expression of the shock as an unanticipated "innovation" in the stochastic development of a variable.

The rational expectations approach divides changes in variables into those which could be rationally predicted by extracting the information in the past values of the variable and related series and the residual or innovation. Much emphasis has been placed on the proposition that expected changes in money will be reflected in price changes alone while innovations in money affect real income and employment. Similar distinctions between the effects of expected changes and innovations in such other variables as government spending, exchange rates, and the foreign price level can be fruitfully made as indicated below. However especially for a quarterly model, care must be taken to allow for the existence of "long-term" contracts stretching beyond the period of analysis. In the presence of such contracts past innovations can easily have present effects since the past shocks occurred after the contracts were formed.

The national macroeconomic sectors emphasize two major equilibrium tendencies. The first is the adjustment of nominal income towards levels where the nominal money demand and supply are equated. The second is a tendency for resources to be employed at their normal rate -- a generalized version of the natural-rate-of-unemployment hypothesis. A short-hand version of the latter tendency is that actual real income tends toward "full"-employment real income.

Existing macroeconomic models attempt to explain the price level P and either nominal income Y or real income y with the other income concept implied by the identity

(1) $$Y \equiv Py \ .$$

The explanations of the price level are generally based on some more-or-less *ad hoc* version of an expectations-adjusted Phillips curve. These equations are poorly suited to explaining the complex price-level behavior implied by the adjustment of nominal and real income. Typically, for example, the new moving equilibrium implied by the price adjustment equation implies that velocity falls despite higher rates of inflation and nominal interest rates. These problems could be corrected in the price equation, but a more natural approach followed here is to explain nominal and real income with the price level implied by identity (1).[5] This permits much more complex and realistic variations in the rate of inflation and separation of the tendencies toward equilibrium of nominal and real income.

The balance of payments and interest rate equations are initially modeled in terms of a generalized monetary approach to the balance of payments. For the balance of payments, the central idea is that the balance of payments varies with the excess demand for money. It should be noted that the exchange rate is treated as the policy variable[6] with the balance of payments adjusting. These roles could be reversed in a simultaneous model, but this approach seemed closer to the facts and more easily modified to take account of changing monetary arrangements.

The short-term interest rate equation starts from the covered interest arbitrage equation so much emphasized in the MABP literature. That equation relates the domestic interest rate to the reserve-currency interest rate and the expected growth rate of the exchange rate over the term to maturity. In view of potential controls and other risks associated with particular countries, it is also assumed that domestic conditions may influence the interest rate

[5] The implicit price equation derived from the equations in section III below appears to be consistent with a short-run demand for money equation with shock-absorber response to money supply shocks (see Carr and Darby (1977)).

[6] That is, the variable determined by a reaction function. So the government (potentially) determines the exchange rate given its goals and other factors influencing the rate.

directly.[7] This standard approach (similarly for the balance of payments) must be modified for the U.S. because of its reserve-currency status.

The reaction functions are modeled in terms of changes in the policy variables rather than their levels. This is done because goals may slowly change so that it is difficult to explain the level of, say, the nominal money supply in any given quarter. The quarter-to-quarter changes in the growth rate of the money supply, on the other hand, would apparently be dominated by changes in economic conditions unexpected by policymakers when the previous policy was adopted. Thus our approach views policymaking as a dynamic process responsive to unexpected changes in conditions rather than a process begun anew each quarter.

Finally, there was a selfconscious attempt in the modeling to let the data rather than the modeler's prejudices decide which influences are important and which are trivial as far as possible. To be sure, this process is at best imperfect and some empirical issues may have been settled by the way the model is written. I will appreciate having my blind spots pointed out so that appropriate changes can be made in the revised model. In particular, the following channels for the international transmission of inflation are included in the model: (1) the MABP-emphasized price level and interest rate arbitrage, (2) the traditional Humian price-level/balance-of-payments/money-supply process, (3) Keynesian export demand shocks, and (4) commodity supply shocks.[8]

However congenial (or perhaps uncongenial) the theoretical approach, the value of the model is determined by how it is implemented. The next three sections present the work to date on that task.

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[7] That is, other than through the expected growth rate of the exchange rate.

[8] Unfortunately, these supply shocks are still rudimentary in the Mark I model as discussed below.

III. National Macroeconomic Sectors

The current version of the national macroeconomic sectors consists of four equations for each country: A nominal income equation, a real income equation, a price level identity, and an unemployment equation. The three equations are conceived of as semi-reduced forms of a more complete (linearized) structural sector. The price level identity is simply[9]

(2)* $\log P \equiv \log Y - \log y$.

As discussed in Section I, this approach involves an implicit price adjustment which is rather more complex than the standard Phillips curves with adjustments for expectations and foreign shocks.

Except where noted explicitly otherwise, all the variables used in sections III through V have an implicit subscript i (to denote the country) which has been omitted for simplicity. All variables refer to time t unless a lag is indicated.

The Nominal Income Equation

The (logarithm of) nominal income is explained by the equation:

(3) $$\log Y - \log Y_{t-1} = (\Delta \log Y^{eq})^* + \rho(\log Y^{eq}_{t-1} - \log Y_{t-1}) + (\text{innovation effects}) + \varepsilon_1$$

That is, the logarithmic change in nominal income equals the expected logarithmic change in equilibrium nominal income plus a partial adjustment due to the lagged difference between equilibrium and actual nominal income plus the effects of (unexpected) innovations in macroeconomic variables and a random disturbance term. Note that the equation as specified implies that if expectations are fulfilled nominal income tends toward its equilibrium value if away from it and grows with the equilibrium value if they are equal. Macroeconomic innovations or shocks may cause nominal income to grow at a different rate however.

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[9]An asterisk following an equation number indicates that the equation is included in the standard model.

The equilibrium nominal income towards which the economy tends is defined as that which equates nominal money demand and supply. Inverting the Cambridge equation gives this equilibrium nominal income as

$$(4) \qquad Y^{eq} = \frac{y}{m^d} M \, .$$

That is, equilibrium nominal income equals the ratio of real income to real money demand times the nominal money supply.

Long-run real money demand is taken as

$$(5) \qquad \log m^d = \beta_1 + \beta_2 t + \beta_3 \log y + \beta_4 r \, ,$$

where t is the time index and r is the short-term interest rate. This is a fairly standard formulation with the time trend admitted to capture possible trends in payments practices and as a proxy for permanent income which may have differential (wealth) effects from current measured real income.[10]

Thus equilibrium nominal income is given by

$$(6) \qquad \log Y^{eq} = \log M - \beta_1 - \beta_2 t + (1-\beta_3)\log y - \beta_4 r \, .$$

The partial adjustment toward this equilibrium value -- $\rho(\log Y^{eq} - \log Y)$ -- can be viewed as reflecting individual money receipt and expenditure plans aimed at achieving and maintaining desired money holdings based on current and expected future values of the arguments of the individual money demand equations.[11]

Before estimating equation (3), the expected logarithmic change in equilibrium nominal income and the innovation effects must be given explicit form. The expected logarithmic change in equilibrium nominal income is taken (see equation (6))

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[10] More complicated money demand functions with explicit differentiation between estimated permanent and transitory income were tried with no apparent return for the increased estimation costs and multicollinearity.

[11] In this sense, the partial adjustment term can be viewed in the algebraically equivalent form $\rho(\log M - \log M^d)$ and related to models of the short-run demand for money following Chow (1966).

to be the expected logarithmic change in the nominal money supply less the normal growth rate β of desired fluidity (the inverse of income velocity)[12]

$$(7) \qquad (\Delta \log Y^{eq})^* = (\log M)^* - \log M_{t-1} - \beta .$$

The inclusion of shocks or innovations is less straightforward. First, there is the question of which shocks to include. For the current model, we are working with innovations in the nominal money supply, real government spending, foreign real income, and foreign prices converted at current exchange rates. This means that we have not yet allowed for strikes or foreign supply shocks a la OPEC.[13] The money, government spending, and foreign real income innovations represent shocks to aggregate demand while the foreign price innovations cause both demand and supply shifts. Equation (3) contains a general partial adjustment mechanism which implies a geometrically decaying effect of past shocks on current nominal income. Besides this general distributed lag, it is appropriate to allow for differing impact in the first few quarters as demand shocks work through inventories to affect nominal output. Therefore, the innovations are included with short distributed lags.

The version of (3) to be included in the model is

$$(8)^* \qquad \log Y = (\log M)^* - \beta_0 + (1-\rho)\log(Y_{t-1}/M_{t-1}) - \rho\beta_2 t + \rho(1-\beta_3)\log y_{t-1} - \rho\beta_4 r_{t-1} + \sum_{j=0}^{n} v_{1j}\hat{M}_{t-j} + \sum_{j=0}^{n} v_{2j}\hat{g}_{t-j} + \sum_{j=0}^{n} v_{3j}\hat{y}^R_{t-j} + \sum_{j=0}^{n} v_{4j}\hat{P}^R_{t-j} + \varepsilon_1$$

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[12] Desired fluidity is defined as m^d/y. On a full rational expectations approach, we would have $\beta = \beta_2 - (1-\beta_3)(\Delta \log y)^* + \beta_4(\Delta r)^*$. The final term is negligible in any case, but it may be better in future versions to explicitly model the expected growth rate of real income rather than take it as a constant trend rate as is implicitly done in equation (7).

[13] These will also have to be integrated into the real income equations in the next version of the model. The correct treatment turns on some technical issues in the definitions of the income edflators and so their systematic inclusion is suspended temporarily.

where the logarithmic innovation in any series X is defined as $\hat{X} \equiv \log X - (\log X)^*$; g is real government spending, y^R is foreign real income, and $\hat{P}^R$ is foreign prices converted at the current exchange rates; and $\beta_0 = \beta + \rho(\beta_1 - \beta_2)$. Equation (8) can also be viewed as an income velocity equation where current velocity is measured as the ratio of nominal income to the expected nominal money supply.

Definitions of Foreign Variables

Operationally, foreign real income and prices are defined as income-weighted indices of the other seven countries in the model. We have opted for using fixed-weight indices based on 1969 income and exchange rates -- a year of apparent equilibrium. Define the exchange rate E_j for any country j as the units of domestic currency per U.S. dollar.[14] Then, denoting 1969 averages by overbars, the overall income weight of any country j is

$$(9) \qquad z_j \equiv \frac{\bar{Y}_j/\bar{E}_j}{\sum_{k=1}^{8} (\bar{Y}_k/\bar{E}_k)} .$$

For each country j, the weight of our typical country i in the income of countries foreign to j is

$$(10) \qquad \begin{aligned} z_{ij} &\equiv z_i/(1-z_j) && \text{for } i \neq j \\ &\equiv 0 && \text{for } i = j \end{aligned}$$

So, the nominal-income-weighted index of foreign real income for our country i is

$$(11)^* \quad \log y^R \equiv \log y_i^R \equiv \log y_{it-1}^R + \sum_{j=1}^{8} z_{ji}(\log y_j - \log y_{jt-1})$$

where $\log y_{i0}^R \equiv 0$. The corresponding index of foreign price levels at current exchange rates is

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[14] The U.S.A. is denoted as country 1 with $E_1 \equiv 1$.

$$(12)^{*} \log P^R \equiv \log P_i^R \equiv \log P_{it-1}^R + \sum_{j=1}^{8} z_{ji}(\log P_j - \log E_j - \log P_{jt-1} + \log E_{jt-1})$$

I had originally considered using variable-nominal-income weights but deferred to suggestions that this added unduly to the complexity of the model and placed undue weight on short-term exchange rate fluctuations.

The Real Income Equation

The real income equation combines normal growth at a rate α_1 with a tendency of real income toward its "full-employment" (or better, natural-employment) level and with effects of nominal income innovations and foreign price innovations.[15]

$$(13) \qquad \log y - \log y_{t-1} = \alpha_1 + \alpha_2(\log y_{t-1}^n - \log y_{t-1})$$
$$+ \text{(innovation effects)} + \varepsilon_2$$

The main problem is representing natural-employment real income y^n. A simple exponential growth trend does not work well for two reasons: (1) In the earlier years most countries were still recovering from war and depression of the 1930's and 1940's so that growth in the capital stocks and real income was faster than in later years. (2) Booms and recessions have lasting effects on the capital stock and hence the level of real income associated with the natural unemployment rate.[16]

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

[15] As mentioned in connection with the nominal income equation, it is planned to include strikes and OPEC-type supply shocks in a later version.

[16] 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.

is customarily calculated as

(14) $\log y^P = (1-\theta)\alpha_1 + \theta \log y + (1-\theta) \log y^P_{t-1}$

It is not feasible to estimate the form which results from applying a Koyck-type transformation to equations (13) and (14) 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. On this basis, the equation to be estimated is[17]

(15)* $$\log y = \alpha_1 + \alpha_2 \log y^P_{t-1} + (1-\alpha_2) \log y_{t-1} + \sum_{j=0}^{n} w_{1j}\hat{Y}_{t-j} + \sum_{j=0}^{n} w_{2j}\hat{P}^R_{t-j} + \varepsilon_2$$

An alternative approach is to use Okun's law to replace $(\log y^n_{t-1} - \log y_{t-1})$ with $(u_{t-1} - u^n_{t-1})$. 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 the unemployment version of equation (13), we derive

(16) $$\log y = 2 \log y_{t-1} - \log y_{t-2} + \alpha_2 \Delta u_{t-1} + \sum_{j=1}^{n} w_{1j}\Delta\hat{Y}_{t-j} + \sum_{j=1}^{n} w_{2j}\Delta\hat{P}^R_{t-j} + (\varepsilon_2 - \alpha_2 \Delta u^n_{t-1})$$

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.

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[17] Combining equations (2), (8), and (15) does provide a theoretically acceptable albeit cumbersome price level equation. (See project memo MD8, August 10, 1977.)

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.

$$(17)^* \qquad u_t = \gamma_1 + \gamma_2 t + \gamma_3 \log (y/y^P) + \varepsilon_3$$

An alternative approach similar to that used to derive equation (16) is also of interest. Suppose that the unemployment rate displays a partial adjustment to the lagged difference between the natural and actual unemployment rates and a response to the innovations present in the real income equation.[18]

$$(18) \qquad \Delta u = \xi(u^n_{t-1} - u_{t-1}) + \sum_{j=1}^{n} w_{3j}\hat{Y}_{t-j} + \sum_{j=1}^{n} w_{4j}\hat{P}^R_{t-j} + \varepsilon_4$$

An alternative to modeling the natural unemployment rate in equation (18) is to take first differences.

$$(19) \qquad u = \xi\Delta u^n_{t-1} + (1-\xi)\Delta u_{t-1} + \sum_{j=1}^{n} w_{3j}\Delta\hat{Y}_{t-j} + \sum_{j=1}^{n} w_{4j}\Delta\hat{P}^R_{t-j} + \varepsilon_4 - \varepsilon_{4t-1}$$

Now the quarter-to-quarter changes in the natural rate would appear to be small relative to the cyclical changes in the unemployment induced by innovations in aggregate spending. So let us model them as a constant γ_4 plus a random disturbance ε_5. Then

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

$$(20) \qquad \Delta u = \gamma_4 + (1-\xi)\Delta u_{t-1} + \sum_{j=1}^{n} w_{3j}\Delta\hat{Y}_{t-j} + \sum_{j=1}^{n} w_{4j}\Delta\hat{P}^R_{t-j} + (\epsilon_5 + \epsilon_4 - \epsilon_{4t-1})$$

The disturbance term may present problems of autocorrelation, but this need not deter us from experimentation with equation (20) as an alternative to equation (17).

Expected Values

An expected value, (log M)*, appears explicitly in equation (8). This variable and four others[19] are implicit in the innovation terms of equations so far listed. A sixth (log P)* will appear later. In each case, the concept of expectation used is based on information available in the previous period. This has the interesting implication for estimation of the model that these values are predetermined so that the model can be estimated taking all expected values as exogenous. Of course this means that the estimates model will be conditioned upon the particular expectations formation schemes used.

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.[20] 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.

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[19] The other four are (log g)*, (log Y)*, (log y^R)*, and (log P^R)*.

[20] See Darby (1976b).

IV. International Variables

On the monetary approach to the balance of payments, the balance of payments is an essentially monetary phenomenon and interest rates are internationally arbitraged. The present draft of the model includes generalizations of empirical equations which have been used to implement these views. This section of the model is one where much further work appears needed, but our starting place at least can be indicated.

The Balance of Payments Equation

Writers in the MABP such as Kemp (1975) have attempted to refine the definition of the (official-settlements-basis) balance of payments to a concept of what automatically alters high-powered money. This concept of the balance of payments is then explained by the portion of the flow demand for high-powered money which is not satisfied by domestic credit creation.

We do not follow this line however. In the presence of (partial) sterilization by the monetary authority, the interesting question is not what would affect the money supply if the monetary authority did nothing. Rather the question is what concept of the balance of payments does influence the money supply via the reaction function of the central bank. Our current hypothesis is that this can be adequately represented by the official settlements balance and that this balance can be explained by the MABP. We may of course later find it necessary to add a balance of trade equation to the model.

There are three main sources of difference between our balance of payments equation (derived below) and the equation estimated by most authors in the MABP literature:[21] (1) One is that most MABP authors assume continuous equilibrium in the money market,[22] while I posit a partial adjustment and let the data

[21] See Magee (1976), eqn. (1), p. 164.

[22] A notable exception is Genberg (1976, pp. 310-24) who does allow for partial adjustment of money supply to money demand.

determine the speed of adjustment. (2) Second, monetary policy (as specified in the reaction function) determines the money supply rather than domestic credit. Therefore the balance of payments is conditioned on the money supply with domestic credit adjusting implicitly. (3) Finally, normal growth is allowed for as required for a partial adjustment model.

The balance of payments for a non-reserve country may be viewed as the sum of (1) normal growth in desired reserves and (2) a partial adjustment of the disequilibrium in the demand for 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

$$(21)^* \qquad \log H \equiv \log M - \log \mu \, .$$

Suppose that the normal growth in reserves (for a nonreserve country) is a fraction[23] ζ_1 of the expected growth in nominal high-powered money due to trend growth ζ_2 in real demand and expected inflation.

$$(22) \qquad B^* = \zeta_1(\zeta_2 + \log \frac{P^*}{P_{t-1}})H_{t-1}$$

Multiplying the right side by H/H and simplifying,

$$(23) \qquad B^* = \zeta_1\zeta_2(1 - \log \frac{H}{H_{t-1}})H + \zeta_1(\log \frac{P}{P_{t-1}}) \; (1 - \log \frac{H}{H_{t-1}})H$$

This reflects the fact that the recorded balance of payments would have to rise with increased inflation to maintain real reserve holdings. Of course if the interest rate paid on reserves rises by the increase in expected inflation, the current account is thereby increased just sufficiently to cover the increased accumulation of reserves.

Combining the normal growth with a partial adjustment model gives the

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[23] This fraction ζ_1 may be called the marginal desired reserve ratio of the monetary authority.

balance of payments as

$$(24) \qquad B = \zeta_1\zeta_2(1 - \log \frac{H}{H_{t-1}})H + \zeta_1(\log \frac{P^*}{P_{t-1}})\ (1 - \log \frac{H}{H_{t-1}})H$$

$$+\phi[\log m^d - \log(M/P)]H + \varepsilon_6$$

Divide both sides of (23) by H and substitute for the real demand for money from equation

$$(25) \qquad \frac{B}{H} = \zeta_1\zeta_2(1 - \log \frac{H}{H_{t-1}}) + \zeta_1(\log \frac{P^*}{P_{t-1}})\ (1 - \log \frac{H}{H_{t-1}})$$

$$+ \phi[\beta_1 + \beta_2 t + \beta_3 \log y + \beta_4 r - \log(M/P)] + \varepsilon_6$$

Therefore, the equation to be estimated is

$$(26)^* \qquad \frac{B}{H} = \zeta_1\zeta_2(1 - \log \frac{H}{H_{t-1}}) + \zeta_1(\log \frac{P^*}{P_{t-1}})\ (1 - \log \frac{H}{H_{t-1}})$$

$$+ \phi\beta_1 + \phi\beta_2 t + \phi\beta_3 \log y + \phi\beta_4 r - \phi \log(M/P) + \varepsilon_6$$

The dependent variable -- the balance of payments as a fraction of high-powered money -- is what has been explained in empirical tests of the MABP with fair success. It is also conveniently scaled for use in the reaction functions discussed in Section V below.

In future versions, it is planned to modify equation (26) to allow for balance of payments effects of monetary disequilibria to be absorbed in part by changes in exchange rates.[24]

<u>The Interest Rate Equation</u>[25]

The MABP literature has emphasized the covered interest arbitrage condition. This condition states that the, say, 3-months government bill rate in a non-reserve

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[24]See Magee (1976), p. 168.

[25]I have drawn heavily on James Lothian's research, experience, and patience in formulating this equation.

country will equal the same rate in the reserve country plus four[26] times the expected percentage change in the exchange rate:

$$(27) \qquad r = r_1 + 4[(\log E_{t+1})^* - \log E_t]$$

This is called a covered arbitrage condition because the expected exchange rate 3-months hence $(\log E_{t+1})^*$ has a market counterpart in the price of forward exchange. Thus domestic policies can affect the domestic interest rate only by acting on the spot or forward exchange rate or both, taking the U.S. interest rate r_1 as given.

But there are alas slips between the cup and the lip. Transactions costs of a round-trip into and out of a foreign currency have been discussed in the literature. A more pervasive influence is that the issuers of the two bills and the forward contract are all different. Not only may taxation differ on each of the items of income or loss in equation (27), there are also frequently impediments in the form of exchange controls. Finally, it is not unknown for governments to de facto default on their bonds by changing currency convertibility and inflating.

For these reasons, equation (27) is not imposed by assumption. Instead we consider a somewhat more general version:

$$(28) \qquad r = \omega_1 + \omega_2 r_1 + \omega_3(\log y - \log y^P) + \omega_4 \frac{B}{H} + \omega_5[(\log E_{t+1})^* - \log E_t] + \varepsilon_7$$

If $\omega_2 = 1$, $\omega_5 = 4$ and all other terms are zero, then we have equation (27). The ω_3 term is included to capture the potential effects of cyclical variations in income on interest rates. The ω_1 and ω_4 terms are meant to capture the effect of capital barriers in retarding the flows of funds into or out of the country. It is assumed that these barriers vary with the size of the "balance of payments problem."

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[26] Multiplication by four is required to convert the three months' change into an annual rate conformable to the bill rate.

The expected depreciation in the exchange rate must be modeled endogenously. It would be a very costly effort to collect data on the forward exchange discount for our entire sample, so we do not plan to include it as a separate endogenous equation within the model. Instead, the model of the forward discount will be substituted directly into equation (28) to obtain the interest rate equation to be estimated. At this stage in the project we can only suggest proxies which we will try. Our best hope is differential inflation rates plus a partial adjustment of the purchasing power parity gap:

$$(29) \qquad (\log E_{t+1})^* - \log E_t = \omega_6[(\log P_{t+1})^* - \log P - (\log P_{1t+1})^* + \log P_1] + \omega_7[\log P - \log E - \log P_1 - \log (\bar{P}/\bar{E}\bar{P}_1)]$$

where base purchasing power parity is $\bar{P}/\bar{E}\bar{P}_1$. We intend to investigate this and other formulations using what data on forward exchange discounts is conveniently available.

Substituting equation (29) into (28), the "first draft" interest rate equation to be estimated is

$$(30)^* \qquad r = \omega_0 + \omega_2 r_1 + \omega_3(\log y - \log y^P) + \omega_4 \frac{B}{H} + \omega_8[(\log P_{t+1})^* - \log P - (\log P_{1t+1})^* + \log P_1] + \omega_9(\log P - \log E - \log P_1) + \varepsilon_7$$

where $\omega_0 = \omega_1 - \omega_5\omega_7 \log(\bar{P}/\bar{E}\bar{P}_1)$, $\omega_8 = \omega_5\omega_6$, and $\omega_9 = \omega_5\omega_7$.

In future research, measures of monetary disequilibrium will be tried as substitutes for the simple cyclical indicator of domestic influences.

V. Reaction Functions

We plan to have three governmental policy variables included as endogenous variables in the final model. Work on the reaction functions is still quite incomplete however. For the present version of the model, real government spending and exchange rates are treated as exogenous. This will be remedied in the near future. The nominal money supply reaction function must serve to indicate our approach to reaction functions.

The Money Supply Reaction Function[27]

We relate changes in the growth rate of the nominal money supply to changes in the information set available to policymakers. If one rebels at the idea of the monetary authority at particular places and times having a money supply policy, our reaction function may as well be thought of as a reduced form explaining the money supply as determined by the banking system and credit policy. The appeal of our approach is that we allow changes in goals to be left to the random disturbance on the assumption that these changes in the aims of policy will be dominated by changes in the information to which the authority reacts.[28]

The changes in the information set to which the authority reacts are assumed to be changes in: the short-term interest rate, the unemployment rate, the inflation rate, and the balance of payments as a fraction of high-powered money. Central banks traditionally attempt to lean against interest rate changes, so other factors tending to increase the interest rate will tend to increase the growth rate of the money supply. One would expect increases in the unemployment

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[27] Modeling of reaction functions has been the primary responsibility of Benjamin Klein. The empirical work discussed in this subsection is his.

[28] A formal theoretical development of this approach is contained in the author's NBER international transmission project Memo MD1, July 11, 1977, which is available upon request.

rate and the balance of payments surplus and decreases in the rate of inflation would tend to increase the money supply growth rate.

Given lags in data collection, distribution and policymaking, these variables should effect money supply growth only with a lag except for changes in the interest rate. Interest rate changes are partially offset immediately under standard operating procedure of most central banks.[29] Klein has conducted empirical investigations on these lags using Charles Nelson's Box-Jenkins transfer function estimation program. For the most part the variables enter these empirical reaction functions with a lag of two or three quarters.[30]

So the prototypical money supply reaction function would be

$$(31)^{*} \qquad \log M_t = 2\log M_{t-1} - \log M_{t-2} + \eta_1 + \eta_2(r_t - r_{t-1}) + \eta_3(\log P_{t-2} - 2\log P_{t-3} + \log P_{t-4}) + \eta_4(u_{t-2} - u_{t-3}) + \eta_5\left(\frac{B_{t-2}}{H_{t-2}} - \frac{B_{t-3}}{H_{t-3}}\right) + \varepsilon_8$$

It is anticipated that empirical experimentation with the lag structure will be required here to fit the reaction function to the actual conditions.

An interesting refinement on this basic reaction function is to allow the parameters to vary according to which party is in power and (for η_5) whether the exchange rate is fixed or floating. This refinement and experimentation with the lags must be preceded by further theoretical analysis however.

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[29] This positive policy reaction can only be examined in a simultaneous model because of the negative liquidity effect of acceleration in money supply growth on interest rates.

[30] This is true even for the balance of payments contrary to the usual MABP assumption that balance of payments effects on the money supply cannot be sterilized.

VI. Plans for Future Work

The major purpose of this paper is to solicit comments and suggestions. The plans for further work are laid out in that spirit to find out which seem to be favorably received and which unfavorably. Also by discussing what we think needs to be done, our blind spots may be more obvious to others.

The basic structure of the model appears to hold together well. It focuses on the issues which we wish to examine without any notable digressions or overelaborations explaining minor variables. The main potential problem is the treatment of the balance of payments as market determined and the exchange rate as policy determined. That approach is suitable to a pegged exchange rate but somewhat strained for a floating one -- even for a dirty float. This will have to be resolved as exchange rate changes are worked into the balance of payments equation and the modeling of the exchange rate reaction function is attempted.

Once the reaction functions and balance of payments equation is completed,[31] there are two main modeling issues to be resolved: (1) modifying the U.S. model to account for its special role as the reserve-currency country, and (2) considering inclusion of some rest-of-world variables.

The U.S. model must be extensively revised with little more than the national macroeconomic sector left intact. The U.S. balance of payments cannot be closely related to the U.S. excess demand for money since the U.S. money supply is invariant with foreign central bank purchases of U.S. debt instruments. This was not necessarily the case however during the early and mid sixties when there were substantial gold flows. The U.S. interest rate is to be determined by a Fisherine equation allowing for variations in the real interest rate. The money supply reaction function must be remodeled to account for reserve-currency

[31]There is also minor work to be done on many of the equations (e.g., inclusion of a strike variable in the nominal and real income equations) discussed as the equations were presented.

status and special care must be devoted to the existence and timing of structural shifts. The exchange rate reaction function ceases to exist in the U.S. case since $E_1 \equiv 1$. U.S. policy must enter the modified balance-of-payments equation instead.

The rest-of-world issues have been omitted largely because the rest of the world is made up of many small countries. The law of large numbers suggests that they are not a source of significant shocks to our sample, but OPEC points out the difficulties in the required independence assumption. Further consideration of data availability and theoretical issues seems needed to choose between treating OPEC as a special case in an ad hoc manner or developing general R-O-W variables such as the relative price of primary products.

Then we can finally turn to estimation. Some preliminary work using OLS, GLS, and Box-Jenkins single equation methods has been done in constructing the model. 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. 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.

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