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# Rules for Regulating Intervention under a Managed Float

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# 1 INTRODUCTION

Since March 1973, the major industrialized nations have allowed the values of their currencies to fluctuate with market forces, subject to intervention at their discretion. Prior to that time, economists had expressed concern that a managed float would give rise to two kinds of problems. First, they anticipated some of the problems associated with freely fluctuating exchange rates. Second, they argued that optional intervention on the part of national authorities would introduce the potential for the manipulation of exchange rates in ways contrary to the interests of the international community. Since the advent of the managed float, some authors have praised its functioning while others have cited incidents "indicative of the nature of weaknesses in present foreign exchange arrangements" (Ethier and Bloomfield, 1978, p. 222).

Because of these concerns, there is a growing literature that proposes the imposition of regulations by an international group such as the International Monetary Fund permitting intervention by national authorities in the foreign-exchange market except under certain circumstances. The goal behind such proposals is to gain the benefits of allowing national authorities some control over their exchange rates while precluding unacceptable manipulation.

This Study examines and compares the potential performance of such rules when confronted by various intervention strategies. It uses a computer simulation model to describe the determination of a country's exchange rate under a managed float. The model includes a foreign-exchange market in which traders, speculators, and arbitrageurs participate, along with the country's monetary authorities. The country's domestic economy is described in the model insofar as is necessary to capture interactions between the foreign-exchange market and the internal economy. The various parameters and lag structures are based on empirical estimates drawn from the literature. Actual values of the variables in January 1970 are im-

Professors Richard Froyen, Ed Howle, and Dennis Appleyard of the University of North Carolina at Chapel Hill provided valuable assistance with my Ph.D. thesis, on which this Study is based. A paper by Kenen (1975) and subsequent correspondence with him suggested the approach developed here. Kenen used a simulation model to compare alternative rules for intervention. This Study employs the same method (but a very different model) to compare alternative rules that limit intervention under certain circumstances.

posed initially. A preliminary simulation traces the path of the model as it converges to an equilibrium. In subsequent simulations, a disturbance is introduced and the paths of key variables are studied with alternative national strategies governing intervention and alternative international regulations limiting it.

The motives attributed to the country's monetary authorities are: indifference to exchange-rate change, desire to maintain the existing exchange rate, desire to avoid currency appreciation or depreciation, desire to cause gradual currency appreciation or depreciation, and desire to "lean against the wind."

The international regulations examined in the model never *require* intervention but instead limit it under certain circumstances. They are: a ceiling on the volume of intervention permitted per period, a limit on the duration of intervention in the same direction, a requirement that a country's reserve changes sum to no more than a specified limit over some time interval, and the "reference rate proposal."

# 2 THE MODEL

I begin by presenting in general form the equations of the model, neglecting lag structures and particular parameter values.[1] The model contains two countries—the home country, called "US," and the rest of the world, called "ROW." I call the home country "US" because convenience requires that it have some name and because parameters are drawn from empirical estimates for the United States and initial variable values are taken from data for the United States. In the presentation that follows, the absence of any subscript indicates use of the current value of that variable; the subscript $-1$ indicates that the variable is lagged only one period; the subscript $-j$ indicates that two or more lagged values of the variable appear in the equation. The variables are defined when introduced and again in the Appendix, in alphabetical order.

*The US Goods Sector*

In the US economy, real income is determined by real aggregate demand:

$$RY = RC + RI + \frac{GS}{P} + NEX\,, \tag{1}$$

where $RY$ is real income, $RC$ is real consumption, $RI$ is real investment, $GS$ is nominal government spending, $P$ is the price index, and $NEX$ is the level of real net exports.

Real consumption is a function of real permanent disposable income, $DYP$, and the stock of real liquid assets, represented here by the real money stock:

$$RC = f\left(DYP,\ \frac{MS}{P}\right), \tag{2}$$

where $MS$ is the nominal money stock (M1). Permanent disposable income is a weighted average of current and past levels of real disposable income:

[1] Because many equations include several variables with long lags, space constraints prohibit inclusion of the precise equation employed. The lag structures are important, however, in two respects: first, lags affect adjustment processes in the economy; the changes induced by any shock to the system do not occur instantaneously. Second, the inclusion of lags makes it possible to deal with many interactions between economic variables without having to solve a large simultaneous-equations system, because the model can be solved recursively.

$$DYP = f\left(\left(\frac{Y - DEP - TAX}{P}\right), \left(\frac{Y - DEP - TAX}{P}\right)_{-j}\right), \tag{3}$$

where $Y$ is nominal income, $DEP$ is capital-stock depreciation, $TAX$ is taxes. (Nominal tax revenues grow at such a rate that real tax revenues increase 1.8 per cent annually.)

Real investment spending depends on the level of real income, the interest rate, $R$, and the level of real investment in preceding periods, as well as on the depreciation rate, $SQ$, and current and previous capital stocks, $RK$. Thus,

$$RI = f(RY_{-j}, R_{-j}, RI_{-j}, SQ, RK, RK_{-j}) . \tag{4}$$

$SQ$ is held constant (at 0.00417 per month) throughout. The capital stock is defined by

$$RK = RK_{-1} - (SQ \cdot RK_{-1}) + RI_{-1} . \tag{5}$$

The third component of real income, real government spending, is controlled by the government in accord with political and economic goals. As explained below, I assume in reported results that government spending is adjusted monthly to keep real income growing at 1.8 per cent per year.

Net exports in real terms equal output of real exports, $XPR$, minus real import payments in the period. Thus

$$NEX = XPR - \frac{MP \cdot RM}{P} , \tag{6}$$

where $MP$ is the value of import payments in foreign currency and $RM$ is the exchange rate. (See equations 15, 19, and 32 below for export orders, import payments, and the exchange rate.)

### *The US Financial Sector*

Although the home country is called "US," its currency is called "dollars," and parameters for the United States economy are used in the model, the financial sector is not a faithful representation of that country's financial sector. The real money stock is the policy target of the central bank, whose only tool is open-market operations. The assumed goal is a constant annual growth rate in the real money stock of 1.1 per cent: [2]

[2] The model assumes significant economies of scale in holding money. Though real income grows 1.8 per cent per year, the real money stock needs to grow only about 1.1 per cent per year. The money-demand equation in the model reflects estimates by Goldfeld (1973).

$$MS = 1.000912 \cdot \frac{MS_{-1} \cdot P}{P_{-1}} . \tag{7}$$

The model solves for the number of consols that must be sold to achieve the targeted money stock in the face of exchange-market intervention and imbalances in the government budget. The first step recognizes that the money stock is determined by the reserves available to the banking system:

$$MS = MS_{-1} + (MM \cdot \Delta \text{ bank reserves}) , \tag{8}$$

where $MM$ is the money multiplier.[3] Equation (8) reflects several simplifying assumptions. First, nominal financial assets other than those in M1 are ignored. Second, intervention in the foreign-exchange market is conducted only by US authorities and affects bank reserves; it is not sterilized automatically by institutional arrangements. Third, budget deficits are completely monetized by central-bank bond purchases from the treasury. Thus, deficit spending increases bank reserves. Open-market operations, exchange-market intervention, and deficit spending are the only actions that affect bank reserves.

To achieve the desired nominal money stock implied by the real money-stock target, the central bank buys or sells consols priced at $1/R$ each. Therefore, the number of consols, $GB$, that must be sold is

$$GB = R \cdot MM\,(MS_{-1} - MS) + R\,(RSC_{-1} + GS - TAX) , \tag{9}$$

where $RSC$ denotes the dollar value of US purchases (or sales if negative) of international reserve assets.

The demand for real money balances, denoted by $RMD$, is a function of real income and the interest rate:

$$ln\ RMD = f\,(ln\ RY_{-j},\ ln\ R,\ ln\ R_{-j}) . \tag{10}$$

The interest rate equates money supply and money demand:

$$MS = MD . \tag{11}$$

*The US Price Level*

The US price index, $P$, is given by

$$P = P_{-1}\,(1 + NF) , \tag{12}$$

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[3] $MM = (C + 1)/(LR + C + X)$, where $C$ is the desired ratio of currency to demand deposits, $LR$ is the legally required ratio of reserves to demand deposits, and $X$ is the desired ratio of excess reserves to demand deposits.

where $NF$ denotes the inflation rate. The inflation rate is a function of the unemployment rate, $U$, the rate of growth of labor productivity, $G$, previous inflation rates, and the average rate of change of imported-goods prices in the preceding year, $PM$:

$$NF = f(1/U_{-j}, G_{-j}, NF_{-j}, PM) . \tag{13}$$

Unemployment follows "Okun's Law," which asserts (Okun 1970) that

$$U = 4.0 + \frac{1}{0.032} \cdot \frac{RYP - RY}{RY} , \tag{14}$$

where $RYP$ is potential real output and is assumed to grow at 1.8 per cent per year from its initial level, which is estimated using equation (14) and the initial levels of $U$ and $RY$.

*US Trade*

The exchange rate between the dollar and ROW currencies clears the foreign-exchange market. The transactions in that market are discussed below. Many of the equations are based on those employed by Kenen (1975).

Orders by ROW for US goods, $XO$, depend on the terms of trade, $TT$, and ROW real income, $RYF$. Thus,

$$XO = f(TT_{-j}, RYF_{-j}) , \tag{15}$$

where

$$TT = \frac{P}{PF \cdot RM} , \tag{16}$$

and $PF$ is the price index in ROW. When an export order is placed, a dollar price is stated. Thus, the number of dollars demanded in a given period to pay for exports of home goods, $XP$, will depend on the price and quantities of previous orders:

$$XP = f(XO_{-j}, P_{-j}) . \tag{17}$$

Orders by US for ROW goods, $MO$, will vary with the terms of trade and US real income. Thus,

$$MO = f(TT_{-j}, RY_{-j}) . \tag{18}$$

When an import order is placed, a foreign-currency price is stated. Thus, import payments in foreign currency in any period will depend on previous orders and prices:

$$MP = f(MO_{-j}, PF_{-j}) . \tag{19}$$

To determine the number of dollars, $DMP$, that must be sold to obtain $MP$ units of foreign currency, multiply $MP$ by the exchange rate:

$$DMP = MP \cdot RM . \tag{20}$$

*Interest-Sensitive Capital Flows*

Real capital flows occur in response to changes over time in the interest-rate differential between US and ROW. Adopting conservative estimates (Branson, 1970; Willett and Forte, 1969; Branson and Willett, 1972; Miller and Whitman, 1972), an increase in the differential by 1 percentage point raises the capital inflow by $780 million, regardless of the level of the differential. This is the parameter $F$ in equation (21). The size of the flow increases, however, with increases in the rate of change of real wealth in US and ROW. (Wealth in ROW is assumed to grow at approximately the same rate as in US). Thus,

$$CA = F \left(1 + \frac{DW}{W_{-1}} + NF\right) \Delta (R - RF)_{-j} , \tag{21}$$

and

$$RCA = \frac{CA}{P} , \tag{22}$$

where $CA$ is the volume of interest-sensitive capital flows into US, $DW$ is the change in real wealth, $W$ is real wealth, and $RCA$ is the real value of interest-sensitive capital inflows. The change in real wealth equals the change in the real money stock minus real capital inflows plus the real value of new bond sales plus real net investment:

$$DW = \Delta \left(\frac{MS}{P}\right) - RCA_{-1} + \frac{GB_{-1}}{P_{-1} \cdot R_{-1}} + RI_{-1} - SQ \cdot RK_{-1} . \tag{23}$$

Real wealth is thus:

$$W = W_{-1} + DW . \tag{24}$$

*Speculative Capital Flows*

In any given period, exchange-rate speculators make a point estimate of the exchange rate for the next period, denoted by $AR$. In simulations used to compare alternative regulations in this paper, I assume that

$$AR = \frac{P}{PF} . \tag{25}$$

Speculators rely on the concept of purchasing power parity in predicting the next period's exchange rate.[4]

The discrepancy between the current period's exchange rate, *RM*, and the rate anticipated for the next period, *AR*, indicates the size of speculators' prospective profits. For this reason, their desired short position in foreign currency, *SFD*, is

$$SFD = S\left(\frac{RM - AR}{AR}\right), \tag{26}$$

where $S$ is a scalar whose size is related to export volume. This links the volume of speculation to the volume of trade. In all runs reported,

$$S = 60\, XO_{-1} \cdot P_{-1}\,. \tag{27}$$

Space limitations prevent comparisons of model performance with alternative specifications of $S$, though such comparisons would demonstrate the importance of speculative flows to the model. The desired short position in foreign currency has as its counterpart this desired long position in dollars, *SHD*:

$$SHD = SFD \cdot RM\,. \tag{28}$$

Speculators attain their desired foreign-exchange positions gradually; they purchase (or sell) dollars in an amount, *CSH*, equal to a fraction of the discrepancy between desired and actual holdings:

$$CSH = Q\,(SHD - SH_{-1})\,, \tag{29}$$

where $SH_{-1}$ represents their actual long position in dollars at the end of the preceding period, and $Q$ is the stock-adjustment coefficient. Initially, $SH = 0$, but thereafter,

$$SH = SH_{-1} + CSH\,. \tag{30}$$

Except for equations (25) and (27), the speculative behavior incorporated here is that described by Kenen (1975).

[4] It would be worthwhile to compare performance of the model under several assumptions regarding the formation of exchange-rate expectations to see how speculative behavior affects the success of intervention strategies and regulations. I do not investigate this issue at length, but I did employ one alternative assumption in the free-float runs:

$$AR = \frac{1}{12}\sum_{j=1}^{12} RM_{-j}\,.$$

In runs with *AR* determined in this manner, there was greater volatility in exchange rates, export orders, and import payments than with the purchasing-power-parity assumption. The increased volatility is not surprising, since speculative responses will not modify trends in currency values as much when expectations are themselves sensitive to recent rate changes. Expectations based on purchasing-power parity are sensitive to exchange-rate trends only insofar as the trends affect relative price levels.

*Official Intervention and Exchange-Rate Determination*

The nominal dollar value of international reserves held by US's monetary authorities, denoted by *RES*, is

$$RES = RES_{-1}\left(1 + \frac{RM - RM_{-1}}{RM_{-1}}\right) + RSC \quad (31)$$

The initial value of *RES* is set at a level high enough to prevent reserves from being exhausted during any of the runs reported. The volume of reserve purchases and sales will vary with the motivation of the government, the state of the economy, and international regulations, discussed below. Reserve assets in the model consist entirely of foreign currency, so that their dollar value changes when the exchange rate changes, as shown in equation (31).

The exchange rate in a given period clears the foreign-exchange market, given the trade and financial transactions above. The following equation is solved to arrive at the exchange rate:

$$XP - MP \cdot RM + CSH + CA - RSC + CON = 0 , \quad (32)$$

where *CON* is the constant that balances the equation for January 1970.[5]

*The ROW Economy*

Real income in ROW is assumed to grow at a constant 2.4 per cent per year (or 0.2 per cent per month). Thus,

$$RYF = (1.002)\, RYF_{-1} . \quad (33)$$

The growth rate of *RYF* is entirely arbitrary and could easily be altered, but it is essential to the particular equilibrium solution discussed in the next section.

The simulation model does not attempt to describe money supply and demand conditions in ROW. Rather, it reflects the fact that capital flows between US and ROW will affect ROW interest rates (*RF*):

$$RF = RF_{-1} + 0.64\, \Delta R_{-1} . \quad (34)$$

This equation reflects estimates made by Herring and discussed by Bryant (1975, p. 351).

By definition, the ROW price level is

$$PF = PF_{-1}(1 + NFF) , \quad (35)$$

[5] Equation (32) is quadratic in *RM*, and the method for choosing between its roots is the one employed by Kenen (1975, p. 115).

where *NFF* is the monthly inflation rate in ROW. The annual ROW inflation rate is constant at 10.225 per cent.

*Equilibrium Values*

As explained earlier, the purpose of this project is to analyze the impacts of official intervention in the foreign-exchange market and of regulations limiting such intervention. To isolate those impacts, I run the model until an equilibrium is established, then disturb the equilibrium and examine the path toward a new equilibrium under each alternative intervention strategy and regulation.

I consider equilibrium to exist when the key variables (the unemployment rate, the inflation rate, and the exchange rate) change less than 0.0083 per cent each month for five years. The total change in any key variable will then be less than 0.5 per cent over the five-year period. Obviously, the set of equilibrium values is not unique in that different assumptions about the conduct of fiscal or monetary policy or about ROW economic trends will result in very different paths for the key variables. There is thus nothing particularly significant about the equilibrium described here; it is simply that which results with the policy parameters and foreign trends I have chosen.

When the model starts, it contains built-in disturbances, because its equations include lagged variables whose values are specified from pre-January 1970 data for US and ROW. Long lags in many of the equations lead to slow adjustments, so that the model requires 349 months to reach equilibrium. This equilibrium is attained under the following assumptions: (1) government spending levels in US are adjusted each period to keep real income growing at 1.8 per cent per year and unemployment constant at 3.9 per cent; (2) real tax revenues grow at a constant 1.8 per cent annual rate; (3) the central bank, via open-market operations, keeps the growth rate of the real money stock constant at 1.1 per cent; (4) the ROW inflation rate is constant at 10.2 per cent per year and ROW real income grows at a 2.4 per cent annual rate.

When equilibrium is attained, the unemployment rate is 3.9 per cent, the annual inflation rate is 10.2 per cent, and the exchange rate is 0.918. At this point, I shock the model, study its behavior, and introduce the various intervention goals and regulations.[6]

[6] Though equilibrium is reached in period 349, programming convenience led me to wait until period 361 to begin my analysis. From this point on I therefore ignore the first 360

*Introducing a Disturbance*

The nature of a disturbance to the economic system affects both the ability of the monetary authorities to attain their goals and the performance of alternative regulations limiting intervention. We can envision any number of shocks, differing both in magnitude and in the variables they affect. I introduce just one in the runs reported here. In the first year, the foreign price level increases by 19.36 per cent, not at the equilibrium rate of 10.2 per cent per year. After the first year, ROW inflation is 10.2 per cent per year.

This disturbance creates a disequilibrium. International and domestic variables must adjust to the change in the relative price levels of US and ROW. The final outcome 240 periods after the disturbance begins is a new equilibrium in which the unemployment rate and the annual inflation rate have returned to 3.9 per cent and 10.2 per cent, respectively, but the exchange rate is 0.849. (Fiscal and monetary policies remain those described in assumptions 1 through 3 of the previous section.) The adjustment period is long because of the long lags in many equations of the model. The 8.13 per cent increase in the equilibrium value of the dollar accompanies the 8.05 per cent decrease in the US/ROW price ratio from its initial equilibrium level. This result is consistent with the theory of purchasing-power parity.

The path of adjustment is described in detail below, using several quantitative performance criteria. I focus on the first 120 of the 240 periods required to reestablish equilibrium because virtually all the adjustment takes place within that first interval. After period 120, actual values are very close to the new equilibrium values, and the remaining adjustments occur evenly and slowly.

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periods of the simulation, referring to period 361 as the first month of the ten-year period being studied.