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Stochastic Monetary Interdependence Currency-Regime Choice and the Operation of Monetary Policy

by

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Abstract

A theory is developed to explain a number of stylized facts well known to international economists: first, countries' real and nominal exchange rates tend to move together under flexible exchange rate systems with the ratios of domestic to rest-of-world price levels showing much less variability; and second, business cycles and medium-term price level movements tend to be international in scope; third, forward exchange rates track the corresponding spot rates very well but show much less variability than spot rates, with forward discounts performing poorly as predictors of subsequent changes in spot rates. It ascribes these phenomena to the maximizing behavior of central banks, each pursuing similar objectives, in a world where information about the future course of economic activity and the timing of the influence of central bank policy upon it is extremely poor. It shows how central banks, given the limited information available to them, are induced to set a path of monetary growth that will neutralize the effects of international portfolio shocks on the exchange rate, while allowing movements in exchange rates that result from changes in technology, oil shocks, the terms of trade and other real forces to go through unopposed. The result is a similarity of credit conditions across countries leading to world-wide variations of outputs and inflation rates. In addition to explaining the conditions under which countries will chose flexible exchange rates rather than fixed rates, the analysis yields important insights for evaluating and extending recent work on the transmission of monetary shocks to economic activity.

I would like to thank Jack Carr, Allan Hynes, Miguel Faig and Kit Pasula for helpful discussions.

1 Introduction

This paper develops a theory that explains important stylized facts now well known to international economists and examines the implications of that theory for countries' decisions as to whether to adopt fixed or flexible exchange rates and, in the latter case, how to conduct and measure the effects of monetary policy. The stylized facts are: first, countries' real and nominal exchange rates tend to move together under flexible exchange rate systems with the ratios of domestic to rest-of-world price levels showing much less variability;[1] second, business cycles and medium-term price level movements tend to be international in scope;[2] third, forward exchange rates track the corresponding spot rates very well but show much less variability than spot rates. And forward discounts perform poorly as predictors of subsequent changes in spot rates.[3] The theory also explains why real exchange rates have traditionally shown less low-frequency variability under fixed as opposed to flexible exchange rate regimes.

These phenomena are ascribed to the maximizing behavior of central banks, each pursuing similar objectives, in a world where information about the future course of economic activity and the timing of the influence of central bank policy upon it is extremely poor. Central banks, given the limited information available to them, are induced to set paths of monetary growth that will neutralize the effects of international portfolio shocks on domestic exchange rates while allowing exchange rate movements that result from changes in technology, oil shocks, the terms of trade, and other real forces to go through unopposed. The result is a similarity of credit conditions across countries leading to world-wide variations of output and inflation rates.

[1] This fact was noted early on by Michael Mussa, "Empirical Regularities in the Behavior of Exchange Rates and Theories of the Foreign Exchange Market," in Karl Brunner and Allan H. Meltzer, eds., *Carnegie-Rochester Conference Series on Public Policy*, Vol. 11, (*Policies for Employment, Prices, and Exchange Rates*), North Holland, 1979, pp. 9–57.

[2] See Arthur Burns and W.C. Mitchell, *Measuring Business Cycles*, New York: National Bureau of Economic Research, 1941, Victor Zarnowitz, "Recent Work on Business Cycles in Historical Perspective: A Review of Theories and Evidence," *Journal of Economic Literature*, Vol. 23, June 1985, 523–80, David K. Backus, Patrick J. Kehoe and Finn E. Kydland, "International Real Business Cycles," Working Paper, Leonard N. Stern School of Business, New York University, February 1991, and Marianne Baxter and Allan C. Stockman, "Business Cycles and the Exchange Rate Regime: Some International Evidence," *Journal of Monetary Economics*, Vol. 23, May 1989, 377–400.

[3] See again the paper by Michael Mussa cited above.

This monetary coordination in response to exogenous local and world-wide stochastic shocks suggests an appropriate name of the theory: *Stochastic Monetary Interdependence.*

In providing a coherent explanation of how world monetary policy works, both monetary shocks and speculative bubbles are ruled out as factors explaining recent major (though not minor) real exchange rate movements. The results indicate why purchasing power parity has not been a useful empirical model of exchange rate behavior and explain the tendency of forward discounts to grossly under-predict, and often wrongly predict, future movement in spot rates.[4] And a new perspective is presented on the old question of whether fixed or flexible exchange rate systems are best by establishing the circumstances under which it will pay a country to adopt one regime rather than the other. This brings us a bit closer to a theory of optimal currency areas.

The results developed here are in sharp contrast with the literature on the international coordination of economic policies pioneered by Oudiz and Sachs[5] and Canzoneri and Henderson.[6] That literature explores the logical consequences of maximizing behavior of individual countries' authorities when they know the parameters governing the time-paths of their economies and concludes that substantive attempts at coordination are rare; this paper explores the consequences when the maximizing authorities know the signs but not the magnitudes of the parameters and cannot forecast dynamic paths, and suggests that coordination is inadvertent but widespread. This difference in the assumed information sets of the authorities also distinguishes this present work from the old targets and indicators literature.[7]

[4]See, Kenneth Rogoff, "The Purchasing Power Parity Puzzle," *The Journal of Economic Literature*, 34, 2 (June), 1996, 647–668. See also, Bennett T. McCallum, "A Reconsideration of the Uncovered Interest Parity Relationship," *Journal of Monetary Economics*, 33, 1994, 105–132.

[5]Gilles Oudiz and Jeffrey Sachs,, "Macroeconomic Policy Coordination Among the Industrial Economies," *Brookings Papers on Economic Activity*, 1, 1984, 1–77.

[6]Matthiew Canzoneri and Dale W. Henderson, *Monetary Policy in Interdependent Economies: A Game Theoretic Approach*, MIT Press, 1991.

[7]See William C. Brainard, "Uncertainty and the Effectiveness of Monetary Policy," *American Economic Review, Papers and Proceedings*, 57, May 1967, 411–25, William Poole, "Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model," *Quarterly Journal of Economics*, 84, 1976. 631–40, Stephen J. Turnovsky, "The Relative Stability of Alternative Exchange Rate Systems in the Presence of Random Disturbances," *Journal of Money, Credit and Banking*, 8, February, 1976, pp. 29–50, Russel S.

Finally, the model developed here has important implications for evaluating and extending recent work on the extent and timing of the transmission of monetary shocks to economic activity. The substantial literature on observed dynamic empirical responses to the U.S. Federal Reserve System's policy actions is broadly consistent with the results of this investigation, although loose ends remain in interpreting the observed responses of exchanges rates to monetary shocks.[8] Measurements of the responses of output, employment and prices to central bank policy in smaller economies using empirical techniques suitable for measuring the effects of U.S. policy, however, are clearly shown to be misleading. On other details of the transmission process the results here also suggest that a number of current perspectives need to be revised, particularly those involving the relationship between interest rates and exchange rates and the relevance of interest rate targeting for the operation of monetary policy in small countries.[9]

2 The Model

The analysis focuses on the problem of a small country that faces domestic technology and demand for money shocks and operates in an international economy in which there are also technology, demand for money, and supply of money shocks. The basic model is a two-country one, consisting of the small country and a big country which can be treated, as the situation requires, either as a rest-of-world aggregate or as a major component of that aggregate. When the rest-world-aggregate consists entirely of small countries that do not cooperate explicitly in the setting of monetary policy, the solution of the individual country's policy problem defines world monetary policy. When the rest of the world consists of the big country and a collection of small countries, world monetary policy involves an interaction between the big country and many small countries identical to the one modeled.

Boyer, "Optimal Foreign Exchange Market Intervention," *Journal of Political Economy*, Vol. 86, No. 6 (December), 1978, 1045–55, and Warren Weber, "Output Variability Under Monetary Policy and Exchange Rate Rules," *Journal of Political Economy*, Vol. 89, No. 4 (August), 1981, 733–751.

[8]This empirical response literature is surveyed in Lawrence J. Christiano, Martin Eichenbaum, and Charles Evans, "Monetary Policy Shocks: What Have We Learned and to What End?" Unpublished Manuscript, Northwestern University, 1997.

[9]See John B. Taylor, "The Monetary Transmission Mechanism: An Empirical Framework," *The Journal of Economic Perspectives*, Vol. 9, No. 4, Fall 1995, pp. 11–26.

When full employment is continually maintained the foreign (big) economy produces an output consisting of Y_{ft}^* units of a single world consumption characteristic and the domestic (small) economy produces $Q_{ft}Y_{ft}$ units, where Y_{ft} is domestic output and Q_{ft} is the number of units of the world consumption characteristic yielded by each unit of domestic output. Q_{ft} thus represents the full-employment real exchange rate defined as the relative price of domestic output in terms of foreign output when the two economies are fully employed. The full-employment output levels Y_{ft} and Y_{ft}^* are assumed to vary stochastically around logarithmic trend values determined by ongoing technological change. The logarithm of the full-employment real exchange rate, q_{ft}, is assumed to be a random walk determined by both technology and tastes.[10] The big country's full-employment riskless real interest rate on securities denominated in the world consumption characteristic, denoted by r_{ft}^*, is also determined by technology and varies stochastically. All the stochastic shocks taken as proportions of their trend levels, or of the previous period's level in the case of q_{ft}, have zero means and constant variances. The analysis that follows assumes that neither private agents nor governments observe the current period shocks to the full-employment real exchange rate, output levels and real interest rate, although they eventually learn about the variances of the stochastic shocks and the logarithmic trends of the domestic and foreign output levels. The full-employment real interest rate r_{ft}^* is assumed to have zero trend.

Outputs are determined by short-run aggregate supply curves of the form

$$y_t = y_{ft} + \theta\,\gamma\,(p_t - E_{t-1}p_t) + \lambda\,(y_{t-1} - y_{f(t-1)}) \qquad (1)$$

$$y_t^* = y_{ft}^* + \theta^*\gamma^*\,(p_t^* - E_{t-1}p_t^*) + \lambda^*\,(y_{t-1}^* - y_{f(t-1)}^*) \qquad (2)$$

where y_t is the logarithm of current output, y_{ft} is the logarithm of full-employment output, p_t is the logarithm of the actual price level and $E_{t-1}p_t$ the expected log price level based on information in the previous period. A superscript $*$ indicates that the parameter or variable applies to the rest of the world. Neither private agents nor governments observe current-period price levels.

[10] This assumption is a rough but convenient approximation to the true behaviour of the full-employment real exchange rate which is now generally regarded as a stationary but highly persistent process. (See Kenneth Rogoff, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, Vol.34, (June 1996), pp. 647–668.) The argument put forward here depends only upon the exchange rate having a high degree of persistence and not upon whether or not it is technically a random walk.

When these equations are interpreted in a rational expectations framework following Lucas, the parameters θ and θ^* vary inversely with the variance of the current price level about its mean conditioned on past history and the parameters γ and γ^* are the limiting values of the respective aggregate supply curves as the general price levels approach stability.[11] Since agents use all available information in setting wages, the expected price levels are those that will produce full employment if information about money, technology and other exogenous variables turns out to be correct. Output deviates from its full-employment level as the result of price level surprises. The fact that the previous period's price level is observed would suggest that price-setting errors can be corrected each period, so that deviations of output from its full-employment level would show no persistence. But current output will be affected by past price-level surprises because of irreversible past investment decisions based on them. Also, wage settings may be locked into contracts written in previous periods so that the unemployment rate will vary persistently even though previous periods' price levels are observed by agents. The inclusion of the lagged deviation of output from its full-employment level introduces some rudimentary dynamics to create appropriate persistence in the time-path of unemployment. The parameters θ and θ^* will not be constant across different monetary regimes because agents' information about the variance of unexpected price level shocks will affect their behavior. Given our assumption that the authorities and private agents know the signs but not the magnitudes of the parameters and do not observe agents' expectations and the learning process that causes them to change, there is no basis for effective discretionary policy initiatives.[12]

Agents are assumed to be free to exchange ownership of existing stocks of capital, and finance new capital formation, across international borders. World asset or portfolio equilibrium is thus determined by the demand func-

[11] Robert E. Lucas Jr., "Some International Evidence on Output-Inflation Tradeoffs," *American Economic Review*, 63, June 1973, pp. 326–334.

[12] Although the approach here follows Lucas, the qualitative results will be the same if the response coefficients of output to current unanticipated price level shocks ($\theta\gamma$ and $\theta^*\gamma^*$) are constant across regimes as we assume that central banks do not know the magnitudes of these parameters in any event. Thus, equations (1) and (2) can be alternatively treated as giving standard short-run supply responses to price level shocks. It will make no difference to the ultimate conclusions whether the output and employment fluctuations result from errors in wage setting that lead to "involuntary unemployment" or from the misperception that real wages have temporarily changed when they have not, leading to "voluntary" substitution between current and future leisure.

tions for money together with the Euler condition determining the relationship between domestic and foreign interest rates. The demand functions for money are standard with everything but interest rates expressed in logarithms.

$$p_t = m_t - \psi_t + \eta \, [r_t + (E_{t-1}p_{t+1} - E_{t-1}p_t)] - \epsilon \, y_t \tag{3}$$

$$p_t^* = m_t^* - \psi_t^* + \eta^* \, [r_t^* + (E_{t-1}p_{t+1}^* - E_{t-1}p_t^*)] - \epsilon^* \, y_t^* \tag{4}$$

where p_t is the price level, m_t is the nominal money stock, r_t is the real interest rate, ψ_t is a demand-for-money shift variable and E_{t-1} is, as before, the expectations operator based on the information available in the period $t-1$. The domestic and foreign nominal interest rates[13] are observable within period by private agents and government, but the real interest rates are not.

Each country's securities are denominated in their own output goods and the domestic real interest rate differs from the foreign real rate by a risk differential minus the expected rate of change in the real exchange rate. The latter turns out to be zero, given the random walk nature of full-employment real exchange rate movements and agents' lack of information about the structural parameters. Ignoring the risk differential, we have

$$r_t = r_t^*. \tag{5}$$

The model is thus consistent by construction with the observation that, in cases where there is not much difference between countries' inflation rates, forward exchange rates predict next period's spot rates quite well while forward discounts are poor predictors of the change in the spot rate from this period to next. When the real exchange rate is a random walk the expected rate of change in it is zero so the forward discount will reflect only the difference between the countries' expected inflation rates. At the same time, as spot exchange rates vary widely forward rates will follow them with a one-period lag so that the two series will be barely distinguishable from each other when plotted over long periods and a regression of one on the other will yield a slope coefficient insignificantly different from unity.[14]

The real exchange rate is defined in logarithms as

$$q_t = p_t - p_t^* - \pi_t \tag{6}$$

[13] These are given by $[r_t + (E_{t-1}p_{t+1} - E_{t-1}p_t)]$ and $[r_t^* + (E_{t-1}p_{t+1}^* - E_{t-1}p_t^*)]$.

[14] Although they are ignored here, time varying risk premia will also lead to differences between forward discounts and future innovations in spot rates.

where π_t is the logarithm of the nominal exchange rate (domestic currency price of foreign currency). Agents and governments observe the nominal exchange rate but not the real exchange rate in the current period. We can express the deviation of the real exchange rate from its full-employment level as

$$q_t - q_{ft} \quad = \quad -\sigma\left[(y_t - y_{ft}) - (y_t^* - y_{ft}^*)\right] \tag{7}$$

where $\sigma > 0$. The real exchange rate is at its full-employment level when output is at its full-employment level. The full-employment real exchange rate gives the relative valuation of the two countries' outputs determined by technology and tastes. When domestic output rises relative to rest-of-world output at given technology and tastes, the marginal valuation of domestic output in producing the world consumption characteristic declines, reducing the real exchange rate relative to its full-employment level.

Finally, the deviation of the rest-of-world real interest rate from its full employment level is assumed to be related to the deviation of output from its full-employment level according to

$$r_t^* - r_{ft}^* \quad = \quad \phi^*(y_t^* - y_{ft}^*). \tag{8}$$

Equations (1) through (8) solve for the eight variables y_t, y_t^*, p_t, p_t^*, r_t, r_t^*, q_t and π_t, given the stocks of and demands for money holdings in the two countries, the full-employment levels of output, interest rates and the real exchange rate, and the expected levels of prices in periods t and $t+1$ as viewed from period $t-1$.[15]

[15]Note that (7 and (8) can be rewritten as

$$y_t - y_{ft} = (y_t^* - y_{ft}^*) - \frac{1}{\sigma}(q_t - q_{ft})$$

and

$$y_t^* - y_{ft}^* = \frac{1}{\phi^*}(r_t^* - r_{ft}^*).$$

The latter equation can be interpreted as a rest-of-world IS curve where real output and the real interest rate are expressed as deviations from the full employment levels. Substituting it into the former, we obtain

$$y_t - y_{ft} = \frac{1}{\phi^*}(r_t^* - r_{ft}^*) - \frac{1}{\sigma}(q_t - q_{ft}),$$

3 Solution of the Model for the Effects of Exogenous Real and Monetary Shocks

First we consolidate the eight equations above into a four-equation system. Substituting the Lucas supply curves (1) and (2) into the respective demand for money functions (3) and (4) and utilizing the equality of domestic and rest-of-world interest rates (5) we obtain

$$\begin{aligned} p_t &= m_t - \psi_t + \eta\, r_t^* + \eta\,(E_{t-1}p_{t+1} - E_{t-1}p_t) - \epsilon\, y_{ft} \\ &\qquad - \epsilon\,\theta\,\gamma\,(p_t - E_{t-1}p_t) - \epsilon\,\lambda\,(y_{t-1} - y_{f(t-1)}) \qquad (9) \\ p_t^* &= m_t^* - \psi_t^* + \eta^*\, r_t^* + \eta^*\,(E_{t-1}p_{t+1}^* - E_{t-1}p_t^*) - \epsilon^* y_{ft}^* \\ &\qquad - \epsilon^*\,\theta^*\gamma^*(p_t^* - E_{t-1}p_t^*) - \epsilon^*\,\lambda^*\,(y_{t-1}^* - y_{f(t-1)}^*). \qquad (10) \end{aligned}$$

Rearranging the definition of the real exchange rate (6) and substituting in (7), (1) and (2) we obtain

$$\begin{aligned} \pi_t &= p_t - p_t^* - q_{ft} + \sigma\,[\theta\,\gamma\,(p_t - E_{t-1}p_t) - \theta^*\gamma^*(p_t^* - E_{t-1}p_t^*)] \\ &\qquad + \sigma\,[\lambda(y_{t-1} - y_{f(t-1)}) - \lambda^*(y_{t-1}^* - y_{f(t-1)}^*)]. \qquad (11) \end{aligned}$$

Finally, substitution of the big country's Lucas supply curve (2) into its "*IS*" curve (8) yields

$$r_t^* = r_{ft}^* + \phi^*\theta^*\gamma^*(p_t^* - E_{t-1}p_t^*) + \phi^*\lambda^*(y_{t-1}^* - y_{f(t-1)}^*). \qquad (12)$$

A system of four equations determining the expected levels of p_t, p_t^*, π_t, and r_t^* can now be obtained by passing the expectations operator through equations (9) through (12).

$$\begin{aligned} E_{t-1}p_t &= E_{t-1}m_t - E_{t-1}\psi_t + \eta\, E_{t-1}r_t^* + \eta\,(E_{t-1}p_{t+1} - E_{t-1}p_t) \\ &\qquad - \epsilon\, E_{t-1}y_{ft} - \epsilon\,\lambda\,(y_{t-1} - y_{f(t-1)}) \qquad (13) \\ E_{t-1}p_t^* &= E_{t-1}m_t^* - E_{t-1}\psi_t^* + \eta^*\, E_{t-1}r_t^* + \eta^*\,(E_{t-1}p_{t+1}^* - E_{t-1}p_t^*) \\ &\qquad - \epsilon^* E_{t-1}y_{ft}^* - \epsilon^*\,\lambda^*\,(y_{t-1}^* - y_{f(t-1)}^*) \qquad (14) \\ E_{t-1}\pi_t &= E_{t-1}p_t - E_{t-1}p_t^* - E_{t-1}q_{ft} \\ &\qquad + \sigma\,[\lambda(y_{t-1} - y_{f(t-1)}) - \lambda^*(y_{t-1}^* - y_{f(t-1)}^*)] \qquad (15) \\ E_{t-1}r_t^* &= E_{t-1}r_{ft}^* + \phi^*\lambda^*(y_{t-1}^* - y_{f(t-1)}^*). \qquad (16) \end{aligned}$$

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which can be interpreted as a domestic *IS* curve incorporating a response of domestic output to world interest rate shocks identical to the response in rest-of-world output. Equations (7 and (8) can thus be interpreted as somewhat conventional domestic and foreign *IS* curves.

To simplify notation let us define the deviation of the variables from their expected levels using the operator D. This yields expressions of the form $Dp_t = p_t - E_{t-1}p_t$ and so forth. For those variables expressed in logarithms, this is equivalent to expressing the deviations as percentages of expected levels. For r_t and r_t^* the deviations are expressed in percentage points. Subtracting (13), (14), (15) and (16) from (9), (10), (11) and (12) respectively, we obtain the following equations determining the equilibrium unanticipated shocks to the system:

$$\begin{aligned} Dp_t &= \frac{1}{1+\epsilon\,\theta\,\gamma}Dm_t - \frac{1}{1+\epsilon\,\theta\,\gamma}D\psi_t \\ &\quad + \frac{\eta}{1+\epsilon\,\theta\,\gamma}Dr_t^* - \frac{\epsilon}{1+\epsilon\,\theta\,\gamma}Dy_{ft} \end{aligned} \tag{17}$$

$$\begin{aligned} Dp_t^* &= \frac{1}{1+\epsilon^*\theta^*\gamma^*}Dm_t^* - \frac{1}{1+\epsilon^*\theta^*\gamma^*}D\psi_t^* \\ &\quad + \frac{\eta^*}{1+\epsilon^*\theta^*\gamma^*}Dr_t^* - \frac{\epsilon^*}{1+\epsilon^*\theta^*\gamma^*}Dy_{ft}^* \end{aligned} \tag{18}$$

$$D\pi_t = -Dq_{ft} + (1+\sigma\,\theta\,\gamma)Dp_t - (1+\sigma\,\theta^*\gamma^*)Dp_t^* \tag{19}$$

$$Dr_t^* = \phi^*\theta^*\gamma^*Dp_t^* + Dr_{ft}^* \tag{20}$$

The interpretation of these equations is straight forward. In (17) and (18) unanticipated increases in the nominal money stock or decreases in the demand for money unexpectedly raise the country's price level. An unanticipated rise in the world interest rate reduces the demand for money, unexpectedly raising both price levels. Unanticipated positive output-technology shocks increase the demand for money, unexpectedly lowering the country's price level. Unanticipated shocks to the natural real exchange rate are transmitted directly to the nominal exchange rate in (19) and shocks to the domestic and foreign price levels have two effects—they affect the nominal exchange rate directly at each level of the real exchange rate and they create deviations of the real exchange rate from its natural level by changing the relative domestic and foreign output levels at given technology and tastes. In (20), unanticipated shocks to the rest-of-the-world real interest rate arise either from a technology shock to the full-employment real interest rate or from unanticipated shocks to the price level and employment.

Note that the only rest-of-world variable that appears as a determinant of the unanticipated shock to the domestic price level in (17) is the real interest rate Dr_t^*. This demonstrates the well-known result that a flexible exchange rate insulates the domestic economy from all foreign shocks except shocks to the world interest rate. Fixing the exchange rate by setting $D\pi_t = 0$ in equation (19) destroys that insulation by imposing a rigid relationship between the unanticipated shocks to the domestic and foreign price levels.

We can now proceed to derive the unanticipated shocks to the domestic and foreign price levels that will occur under fixed as compared to flexible exchange rates.

3.1 Rest-of-World Equilibrium

Since the domestic economy is small in relation to the rest of the world changes in domestic variables have but a trivial effect on rest-of-world variables. Accordingly, equilibrium in the rest of the world is independent of whether the domestic authorities adopt a fixed or flexible exchange rate.

The equilibrium unanticipated shock to the rest-of-world real interest rate is obtained by substituting (18) into (20) and collecting the terms.

$$\begin{aligned} Dr_t^* &= \frac{\phi^*\theta^*\gamma^*}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,[Dm_t^* - D\psi_t^*] - \frac{\epsilon^*\phi^*\theta^*\gamma^*}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,Dy_{ft}^* \\ &\qquad + \frac{1+\epsilon^*\theta^*\gamma^*}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,Dr_{ft}^*. \end{aligned} \tag{21}$$

And the equilibrium unanticipated shock to the rest-of-world price level is obtained by substituting (20) into (18) and collecting the terms.

$$\begin{aligned} Dp_t^* &= \frac{1}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,[Dm_t^* - D\psi_t^*] - \frac{\epsilon^*}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,Dy_{ft}^* \\ &\qquad + \frac{\eta^*}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)}\,Dr_{ft}^*. \end{aligned} \tag{22}$$

Under the usual assumptions that the "*IS*" curves are negatively sloped the parameter ϕ^* is negative and the world interest rate is negatively affected by a positive shock to the supply of money relative to the demand for it and positively affected by positive shocks to world full-employment output and the full-employment world real interest rate. The rest-of-world price level is positively affected by unanticipated excess money supply shocks and unanticipated shocks to the full-employment real interest rate and negatively affected by unanticipated shocks to full-employment output. The shock to rest-of-world employment can be obtained by substituting (22) into (2). To eliminate fluctuations in employment the authorities must eliminate unanticipated price-level shocks.

The big-country authorities are interested not only in the unanticipated shocks to the price level and output and employment, but in shocks to the expected price level as well. If the expected price level is rising rapidly through time there is substantial on-going inflation. Even though that inflation is fully anticipated, it is generally undesirable because it causes the public to hold an inefficiently small stock of real money holdings and imposes costs of having to more frequently adjust prices, taxes and other nominal contracts to compensate for changes in the value of the currency.[16] The equilibrium expected price level in the rest of the world can be obtained by substituting (16) into (14). This yields

$$\begin{aligned} E_{t-1}p^*_t \;&=\; E_{t-1}m^*_t - E_{t-1}\psi^*_t + \eta^* E_{t-1}r^*_{ft} + \eta^*\,(E_{t-1}p^*_{t+1} - E_{t-1}p^*_t) \\ &\qquad - \epsilon^* E_{t-1}y^*_{ft} + (\eta^*\,\phi^* - \epsilon^*)\,\lambda^*\,(y^*_{t-1} - y^*_{f(t-1)}) \end{aligned} \tag{23}$$

Turning now to domestic equilibrium, which depends on whether the country is on a fixed or a flexible exchange rate, we begin with the flexible exchange rate case.

3.2 Domestic Equilibrium under Flexible Exchange Rates

The unanticipated shock to the domestic price level is obtained by substituting the equilibrium shock to the world interest rate (21) into (17), yielding

$$\begin{aligned} Dp_t \;&=\; \frac{1}{1+\epsilon\,\theta\,\gamma}\,[Dm_t - D\psi_t] - \frac{\epsilon}{1+\epsilon\,\theta\,\gamma}\,Dy_{ft} \\ &\quad + \frac{\eta\,\phi^*\theta^*\gamma^*}{(1+\epsilon\,\theta\,\gamma)(1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*))}\,[Dm^*_t - D\psi^*_t] \\ &\quad - \frac{\eta\,\epsilon^*\phi^*\theta^*\gamma^*}{(1+\epsilon\,\theta\,\gamma)(1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*))}\,Dy^*_{ft} \\ &\quad + \frac{\eta\,(1+\epsilon^*\theta^*\gamma^*)}{(1+\epsilon\,\theta\,\gamma)(1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*))}\,Dr^*_{ft}. \end{aligned} \tag{24}$$

[16] An exception would arise when the tax system is so primitive that a tax on money is the most efficient way for the government to obtain revenue.

Not surprisingly, in the special case where the unanticipated monetary and technology shocks are identical in the domestic and rest-of-world economies[17] and the economies are structurally identical except for scale, the shocks to the domestic and rest-of-world price levels are also identical. This can be seen by noting that

$$\frac{1}{1+\epsilon\,\theta\,\gamma} + \frac{\eta\,\phi^*\theta^*\gamma^*}{(1+\epsilon\,\theta\,\gamma)(1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*))} \;=\; \frac{1}{1+\theta^*\gamma^*(\epsilon^*-\eta^*\phi^*)},$$

which is the coefficient of $[Dm_t^* - D\phi_t^*]$ and ϵ^* times the coefficient of Dy_{ft}^* in (22). The identical effects of identical shocks can also be seen intuitively from the set of equations (17) through (20). The shock to the world interest rate given by (20) is the same for both countries. It is therefore obvious that if the unanticipated excess money supply and full-employment real income shocks are the same in the domestic economy as in the rest of the world and the parameters are the same at home and abroad the unanticipated price level shocks will also be the same. Given that this is true, it is obvious from (19) that the unanticipated shocks to the nominal exchange rate will entirely reflect the shocks to the full-employment real exchange rate.

The equilibrium expected level of domestic prices can be obtained by substituting (16) into (13). This yields an expression identical to (23) without the star superscripts. If we ignore deviations of output from full employment over the long run, the expected level of the nominal exchange rate becomes, from (15),

$$E_{t-1}\pi_t \;=\; E_{t-1}p_t \;-\; E_{t-1}p_t^* \;-\; q_{f(t-1)} \tag{25}$$

The nominal value of the domestic currency in terms of foreign currency will be a random walk with a drift or trend equal to the excess of the trend of the domestic price level over the trend of the price level in the rest of the world.

[17] That is, where $Dm_t - D\psi_t = Dm_t^* - D\psi_t^*$ and $Dy_{ft} = Dy_{ft}^*$.

3.3 Domestic Equilibrium under Fixed Exchange Rates

Under flexible exchange rates, the set of equations (17) through (20) solve for $Dp_t, Dp^*_t, D\pi_t$ and Dr^*_t. Under a fixed exchange rate, $D\pi_t = 0$ and the domestic nominal money stock Dm_t becomes endogenous—the domestic authorities are forced to adjust the money supply through non-sterilized foreign exchange market intervention to maintain the exchange rate at its pegged level. So the system now solves for Dp_t, Dp^*_t, Dm_t and Dr^*_t.

Fixing the exchange rate in equation (19) sets up a dependency of the domestic price level on the price level abroad and the real exchange rate. When the parameters are the same in the domestic and rest-of-world economies the unanticipated shock to the domestic price level becomes

$$Dp_t \;=\; Dp^*_t + \frac{1}{1+\sigma\,\theta\,\gamma}\,Dq_{ft}. \tag{26}$$

If there are no shocks to the real exchange rate, the domestic price level will move in unison with the foreign price level and the unanticipated shock to the domestic price level will be given by (22). Domestic unemployment will also move in unison with unemployment abroad.

The expected domestic price level is obtained from (15). When we ignore deviations of output from full employment in the long run, it becomes

$$E_{t-1}p_t \;=\; E_{t-1}p^*_t + q_{f(t-1)}. \tag{27}$$

The domestic price level will follow a random walk with drift equal to the trend in the rest-of-world price level. And given that the expected rate of change of q_{ft} is zero, the expected rate of domestic inflation will equal the expected rate of foreign inflation.

4 Conducting Monetary Policy

Assume that in each country there is an underlying desired or core inflation rate based on the willingness of the public, as revealed in the political process, to use an inflation tax to finance some part of government expenditure. The function of the country's central bank is, then, to minimize deviations of the actual inflation rate from the core inflation rate. There are three dimensions to this minimization problem. First, unanticipated period-to-period deviations of the inflation rate from core, represented by unanticipated shocks to the current-period price level, lead to associated deviations of output and employment from their full-employment levels. Second, persistent deviations of the inflation rate from core, even when fully anticipated, are costly because they signify the wrong level of monetary finance of government expenditure, imposing unwarranted costs of continually adjusting prices and taxes and other nominal contracts. Third, long-term variations the inflation rate impose costs because the institutions through which contracting takes place have to constantly adjust to accommodate changes in expected inflation.

The domestic and foreign central banks can minimize the costs of unanticipated shocks to prices and employment by minimizing

I: $Var\{Dp_t^*\}$ and $Var\{Dp_t\}$.

They can minimize the expected deviation of the long-term inflation rate from core by minimizing

$$\textit{II:}\quad E_{t-1}\{(E_{t+k-1}p^*_{t+k} - E_{t-1}p^*_t - k^*\,\alpha^*)\} \quad \text{and}$$
$$E_{t-1}\{(E_{t+k-1}p_{t+k} - E_{t-1}p_t - k\,\alpha\}.$$

where α and α^* are the domestic and foreign core inflation rates and the relevant time-horizon is k periods. Finally, they can minimize the costs of variability of their long-term inflation rates by minimizing

$$\textit{III:}\ Var\{E_{t+k-1}p^*_{t+k} - E_{t-1}p^*_t - k^*\,\alpha^*\} \qquad \text{and}$$
$$Var\{E_{t+k-1}p_{t+k} - E_{t-1}p_t - k\,\alpha\}.$$

Note the distinction between *II* and *III*. Objective *II* can be satisfied by minimizing the predicted average deviation of the inflation rate from the core rate over the succeeding k periods. To satisfy objective *III*, the central bank must minimize the variance of its error in predicting the k-period inflation rate.

Perfect monetary policies would involve manipulation of m_t^* and m_t to offset within period the effects of all shocks to the full-employment output, interest rate and real exchange rate levels and all shocks to the demand functions for money to maintain time paths of the price levels identical to the paths implied by the countries' core inflation rates. Such policies are impossible to implement, of course, when the current shocks to the full-employment levels of the relevant exogenous variables and the current shocks to the demand for money are unobservable. Moreover, if the authorities do not know the magnitudes of the economies' structural parameters, they cannot forecast the time-path of the response of the price level and output to any corrective monetary action they might take. Attempts to use discretionary policy will then be fruitless.

When the big country's monetary authority has no information about the current shocks to full-employment output and interest rate levels and the demand for money but has some information about trends in full-employment output and demand for money growth, its optimal policy will be to maintain a constant rate of money growth sufficient to produce an expected average rate of increase in the price level equal to the core inflation rate. Although objective I above must be abandoned, the other two objectives can be accomplished to the extent that the underlying growth rates of output and the demand for money are correctly perceived.

In fact, policy makers generally believe that they can obtain some information about output and demand for money shocks by observing credit conditions and nominal interest rates within period. Acting on this belief, the big country's authorities would introduce variations in m_t^* to offset some of these shocks. The potential success of such actions is a controversial issue that we will not pursue here except to note that a policy rule that would use variations in the money stock to minimize variations in the world real interest rate will be ineffective because the authorities cannot observe real interest rates within period or, in a changing inflationary environment, with any accuracy across periods.

The small country's central bank faces an even more difficult task in attempting to implement discretionary policy because it must evaluate shocks to the big country's economy as well as to its own. In compensation, however, its authorities have the additional option of fixing the exchange rate. The first question that must be considered, before attempting to wrestle with discretionary policy issues, is whether it would be better for the small country to fix the exchange rate or let it float and adopt a constant rate of domestic money growth.

4.1 Fixed Exchange Rates vs. Flexible Rates with Constant Money Growth

We begin by making three assumptions that will later be relaxed: that the big country follows constant money growth; that the full-employment real exchange rate is constant; and that the domestic and rest-of-world core inflation rates are the same. We also adopt the working assumption that the domestic and foreign economies are identical except for scale. Constancy of the real exchange rate implies from (26) and (27) that under a fixed exchange rate the time-path of the domestic price level will be identical with the time-path of the price level in the rest of the world. A fixed exchange rate regime will be preferred to a flexible exchange rate with constant growth if the variance of the unanticipated shocks to the domestic price level under flexible exchange rates with constant money growth is greater than the variance of the unanticipated price level shocks abroad. Comparing (24) and (22), this condition becomes

$$Var\{Dp_t\} \;\; > \;\; Var\{Dp_t^*\}$$

or

$$\begin{aligned} Var\{\, A\,[Dm_t - D\psi_t] \;+\; B\,[Dm_t^* - D\psi_t^*] \;+\; \epsilon\, A\; Dy_{ft} \\ +\, \epsilon\, B\; Dy_{ft}^* \;+\; \eta\, C\; Dr_{ft}^*\} \;\; > \\ Var\{\, C\;[Dm_t^* - D\psi_t^*] \;+ \epsilon^*\, C\; Dy_{ft}^* \;+\; \eta^*\, C\; Dr_{ft}^*\}. \end{aligned} \qquad (28)$$

where

$$\begin{aligned} A &= \frac{1}{1 + \epsilon\,\theta\,\gamma} \\ B &= \frac{\eta\,\phi^*\theta^*\gamma^*}{(1 + \epsilon\,\theta\,\gamma)(1 + \theta^*\gamma^*(\epsilon^* - \eta^*\phi^*))} \\ C &= \frac{1}{1 + \theta^*\gamma^*(\epsilon^* - \eta^*\phi^*)}. \end{aligned}$$

Passing the variance operator through (28) and setting all foreign parameters equal to their domestic counterparts, we obtain an expression which reduces to

$$\begin{aligned} A^2\; Var\{Dm_t - D\psi_t\} \;-\; [C^2 - B^2]\; Var\{Dm_t^* - D\psi_t^*\} \\ +\, \epsilon^2\, A^2\; Var\{Dy_{ft}\} \;-\; \epsilon^2\,[C^2 - B^2]\; Var\{Dy_{ft}^*\} \;\; > \;\; 0. \end{aligned} \qquad (29)$$

It has already been shown in the discussion following equation (24) that $A + B = C$. Since $B < 0$ as long as the rest-of-world's "IS" curve is negatively sloped, this implies that $A^2 > C^2 > C^2 - B^2$. Thus, when the variances of the money and full-employment output shocks are the same in the domestic and foreign economies the variance of the domestic price level shock will be smaller under a fixed exchange rate than under flexible exchange rates with constant money growth. This conclusion becomes stronger when we take account of the effect of the greater variance of the domestic price level on θ relative to θ^*. As Lucas argued, greater variability of the unanticipated shocks to the price level will make agents less inclined to view observed within-period price shocks in their own industries as relative price shocks, with the result that employment will fluctuate less in response to unanticipated shocks to the price level. From the definitions of A and C above, it is clear the existence of an excess of A over C at equal values of θ and θ^* will cause a decline in θ relative to θ^*, making that excess of A over C greater.[18]

It turns out that the variances of the small-country money and full-employment output shocks are likely to be many times larger than the variances of the corresponding big-country shocks. Think of the world as consisting of n equal-sized areas each with a variable S_t^i (not in logarithms) subject to random shocks. Let one of these areas be the small country and denote the magnitude of its variable by S_t^1 and let the remaining $n-1$ areas be the big country whose aggregate level of the variable is denoted by $S_t^R = \sum_{i=2}^n S_t^i$. The deviation of the big-country's aggregate variable from its initial value taken as a proportion of that initial value will equal

$$DS_t^R = \sum_{i=2}^n \left[\frac{(S_t^i - S_{t-1}^i)}{S_{t-1}^R} \right] \quad = \quad \frac{1}{n-1} \sum_{i=2}^n DS_t^i. \tag{30}$$

When the shocks in the different areas are independent and have the same variance, the variance of this aggregate shock will equal

$$Var(DS_t^R) \quad = \quad \frac{1}{(n-1)^2} \sum_{i=2}^n Var(DS_t^i) \quad = \quad \frac{1}{n-1} Var(DS_t^i). \tag{31}$$

The variance of the shock in the small country will be $(n-1)$ times the variance of the shock in the big country. By pegging its currency to the

[18]Robert E. Lucas Jr., "Some International Evidence on Output-Inflation Tradeoffs," *American Economic Review*, 63, June 1973, pp. 326–334, and "Econometric Policy Evaluation: A Critique", *Journal of Monetary Economics*, 2, 1976, Carnegie-Rochester Conference Series, Vol. 1, 1976, pp. 19–46.

large-country's currency the small country in effect pools its income and demand for money shocks with the big-country shocks—the average percentage shock over a large area will always be smaller than the percentage shocks of the individual small areas that comprise it. We call this the *pooling advantage* of fixed exchange rates. A classic example is the Canada/U.S. case. During the period 1963–70 when the Canadian dollar was pegged to the U.S. dollar the variance of the residual from an AR36 forecast of the logarithm of monthly Canadian $M1$ was ten times the corresponding residual from a similar forecast of the logarithm of U.S. $M1$.[19] During this fixed exchange rate period the Canadian money supply can be assumed to have been adjusted endogenously in response to demand for money shocks to maintain the fixed exchange rate. By tying the Canadian dollar to the U.S. dollar, the Canadians effectively pool their income and demand for money shocks with the U.S. shocks so that unanticipated domestic price changes are dependent on U.S. shocks rather than their own.

So when purchasing power parity holds a fixed exchange rate regime will always beat flexible exchange rates with constant money growth as long as the country is small in relation to the rest of the world and not too different from it in structure. This also assumes, of course, that the small country is willing to accept the big country's core inflation rate. If the core inflation rates differ, objective II will be violated and the small country's authorities will have to decide whether to sacrifice objective II in order to pursue objective I. The extent of the difference in the core inflation rates together with the relative weights of objectives I and II in the central bank's objective function will be the determining factors.

Relaxation of the assumption that purchasing power parity holds modifies these results in two ways. First, the real exchange rate variations lead to additional price level and employment variations in (26) making the fixed exchange rate regime less favorable in relation to flexible exchange rates with constant money growth. Since the coefficient of the variable Dq_t is less than unity, the variance of the full-employment real exchange rate would have to be greater than that of the excess variances of the small-country over large country income and demand for money shocks to tip the balance in favour of flexible exchange rate regime with constant money growth. In the

[19] Seasonally unadjusted data were used and seasonal dummies were included in the regressions. Running AR24 forecasts were also used, in which case the variance of the Canadian forecast error was about five times the variance of the U.S. forecast error.

Canada/U.S. case noted earlier, the first difference of the logarithm of the real exchange rate has about twice the variance of the forecast error of logarithm of the U.S. money shock. This compares with a variance of the Canadian money shock ten times larger than the variance of the U.S. money shock. The variance of the observed real exchange rate, however, will certainly be smaller than the variance of the full-employment real exchange rate because the nominal exchange rate is constant and the real exchange rate shocks, being unanticipated, will only partially affect prices and will therefore be partly absorbed by unanticipated changes in output. The residuals from an AR36 regression of Canadian industrial production have only twice the variance of the residuals from a similar forecast of U.S. industrial production[20] so it would seem rather unlikely that the variance of the full-employment real exchange rate would have exceeded the difference in the variances of the money shocks. In any case, were this condition to have consistently failed for countries in general it would be reasonable to expect that some country at some point in history would have discovered that it could benefit by adopting flexible exchange rates with constant money growth rather than fixed exchange rates. Flexible exchange rates with constant money growth have never been observed, central bank rhetoric of the 1970's notwithstanding.

A second modification of the results occurs as a result of the fact that real exchange rates are typically indistinguishable from random walks over periods as long as two or three decades. Real exchange rate shocks that are far too small to compensate for the difference between the variances of the small-country and big-country income and monetary shocks will cause the real exchange rate to wander far and wide. This means that the price level will be a random walk under a fixed exchange rate system and objective III will be unattainable. Whether this will lead the small country to prefer flexible exchange rates with constant money growth to fixed exchange rates will depend upon the size of the variance of the period-to-period innovation of the full-employment real exchange rate and the weight attached to objective III in the authorities' objective function.

Flexible exchange rates thus have an *insulation advantage* over fixed exchange rates in that they insulate the domestic price level from both short- and long-run variations in the full-employment real exchange rate—if it lets the exchange rate float, the small country's central bank can maintain an appropriate trend rate of inflation, and thereby achieve objectives II and

[20]Seasonally adjusted data was used in these calculations.

III regardless of movements in the full-employment real exchange rate and regardless of the core inflation rate in the big economy. This comes, of course, at the sacrifice of objective I.

If the rest-of-world authorities can abandon constant money growth and offset some of the price level shocks by clever within-period money stock adjustments they can make fixed exchange rates more desirable for the domestic economy. This assumes, quite reasonably, that the domestic authorities cannot engage in even more clever within-period departures from constant money growth under flexible exchange rates—the domestic authorities have the same access to technical expertise as their counterparts abroad and face a more difficult within-period stabilization task because they need to observe and counteract both the domestic and rest-of-world exogenous money and full-employment output shocks. The possibility that political instability in the rest of the world could result in worse performance than could be obtained with constant money growth must also be noted. Flexible exchange rates with constant money growth could insulate the domestic economy against this instability.

So the small country's authorities have to balance the insulation advantage of flexible exchange rates against the pooling advantage of fixed exchange rates in minimizing their objective function. We thus need to know the objective function to determine which regime will be chosen. But the fact that flexible exchange rate regimes are frequently adopted but no country has ever adopted constant money growth for any significant period suggests that there must be additional options available.

4.2 The Best of Both Worlds: Smoothing International Portfolio Shocks Under Flexible Exchange Rates

Under a fixed exchange rate the adjustments of the small country's nominal money supply are endogenous—the necessary consequence of fixing the exchange rate. These money supply changes finance portfolio adjustments necessitated by shocks to the domestic quantity of money demanded. When domestic residents wish to hold additional nominal money balances they reestablish portfolio equilibrium by selling assets to foreign residents in return for money. The domestic authorities must supply that money to keep the home currency from appreciating. This excess demand for money can arise from a shock to the domestic demand function for money or domestic full-employment output or from a movement of the world interest rate consequent on money and full-employment income shocks in the rest of the world. These same portfolio pressures occur under flexible exchange rates but their effect is to cause an adjustment of the nominal exchange rate and, in response, an adjustment of the domestic price level. Portfolio pressures on the exchange rate result when credit conditions become tighter or easier in the domestic economy than in the rest of the world—that is, when there are differential excess money supply shocks in the small and large countries. This is evident in the model from the fact that when the money and full-employment income shocks are the same in the small and large countries and the two countries are structurally the same except for scale, (17) and (18) become identical.

4.2.1 Portfolio Smoothing Using Current-Period Information

Now imagine the possibility that the small country authorities, from within-period observation of credit and foreign exchange market conditions, can sense when these portfolio pressures on the exchange rate are occurring and offset them with either unsterilized foreign exchange market intervention or open market operations. Such interventions would fit the conventional descriptions of "orderly markets" or "even keel" policies. They do not require that the authorities have better information about domestic economic conditions than do private agents since information about portfolio pressures on the exchange rate is useful only to the authorities, given that they alone control the stock of base money. These policies also do not require any special forecasting ability on the part of the central bank or knowledge of current-period demand function for money and full-employment output shocks—when recognizable portfolio pressure on the exchange rate, from whatever source, appears in the current period the bank simply provides the necessary finance to maintain portfolio equilibrium without the exchange rate being affected. Meanwhile, the nominal exchange rate is free to move without restriction in response to underlying shocks to the full-employment real exchange rate and differences between the domestic and foreign core inflation rates. Perfectly done, this would achieve simultaneously the pooling advantages of fixed exchange rates along with the insulation advantages of flexible rates. The small economy will follow the same cyclical pattern as its big neighbor, albeit with perhaps a different trend inflation rate.

In fact, the small country's inflation rate will be driven in this case by private sector expectations based on the underlying core inflation rate and recent inflation experience. Money holders will require increases in their holdings sufficient to finance their inflation expectations—excess or deficient holdings will lead to portfolio pressure on the exchange rate. The time path of nominal money growth in the small country would thus be determined endogenously and the credibility of the central bank's commitment to the core inflation rate would be extremely important.

It is of course visionary to suggest that the small country's central bank could perform the above portfolio smoothing operation without error. To make a regime of flexible exchange rates with portfolio smoothing viable, these errors must be insufficient to merit the adoption of either constant money growth on the one hand, or a fixed exchange rate on the other. When these smoothing errors are substantial and the underlying stochastic shocks to the full-employment real exchange rate are small, a fixed exchange rate may be the better solution, given that only small persistent deviations from the core inflation rate will likely occur under such a regime. The smoothing errors have to be greater than the domestic income and demand for money shocks to make the portfolio smoothing policy inferior to flexible exchange rates with constant money growth.

4.2.2 Managed Floating Using Past Information

There is in fact an upper bound to the smoothing errors that need be tolerated. This can be seen by approaching the smoothing process from an exchange rate management rather than a money supply management perspective. The objective is to allow the nominal exchange rate to adjust to reflect full-employment real exchange rate movements and differences between the domestic and foreign core inflation rates but to maintain it constant in response to portfolio shocks.

Suppose that the small country's authorities have no within-period knowledge of the stochastic shocks to the demand function for money and the full-employment levels of output and the real exchange rate and cannot observe from within-period foreign exchange and capital market conditions when portfolio pressures on the exchange rate are occurring. They can nevertheless approximately identify movements of the full-employment real exchange rate with a one-period lag and use this information to manipulate the nominal exchange rate to remove their long-term effects on the domestic price level. The object is to use unsterilized foreign exchange market intervention (combined with adjustments of the domestic source component of base money sufficient to maintain appropriate holdings of foreign exchange reserves) to keep the nominal exchange rate at a target level equal to the estimated current-period full-employment real exchange rate adjusted to take account the differences between the domestic and foreign core inflation rates. The target nominal exchange rate would thus equal (with everything in logarithms)

$$\bar{\pi}_t \;=\; \bar{p}_t - p^*_t - \hat{q}_{ft} \tag{32}$$

where $\bar{\pi}_t$ is the target level of the nominal exchange rate, $\bar{p}_t$ is the target domestic price level given the foreign price level and the difference between the domestic and foreign core inflation rates, and $\hat{q}_{ft}$ is the current period forecast of the full-employment real exchange rate. If the domestic and foreign core inflation rates are the same, $\bar{p}_t = p^*_t$. Otherwise they will differ by the excess of the domestic core inflation rate over the foreign core inflation rate multiplied by the number of periods, denoted by n, that have passed since some base period in which units were chosen to make the two price levels equal. And it would be natural to use the observed real exchange rate in the previous period as a forecast of that period's full-employment real exchange rate which, in turn, is the best forecast of this period's full-employment real exchange rate. Equation (32) then becomes

$$\bar{\pi}_t \;=\; n\,(\alpha - \alpha^*) - q_{t-1}. \tag{33}$$

If the authorities maintain the current-period nominal exchange rate on its target the resulting current price level follows directly from the definition of the real exchange rate. That is

$$p_t - \bar{p}_t \;=\; p_t - p^*_t - n\,(\alpha - \alpha^*) \;=\; q_t + \bar{\pi}_t - n\,(\alpha - \alpha^*) \;=\; q_t - q_{t-1}. \tag{34}$$

It can be seen immediately that the domestic price level will differ from its target level only by the change in the real exchange rate from the previous period—it will therefore follow a trend that will differ from that of the foreign price level by the difference in the core inflation rates. This trend will be unaffected by the stochastic trend of the full-employment real exchange rate. The nominal and real exchange rates and the target nominal exchange rate will be random walks.

Equation (34) can be expanded using the fact that the current level of any variable equals the level expected on the basis of the previous period's information plus the current shock together with the fact that the difference between the domestic and rest-of-world expected inflation rates equals $n(\alpha - \alpha^*)$ to obtain the unanticipated shock to the domestic price level under the above managed floating regime,

$$Dp_t \;=\; Dp_t^* + \frac{1}{1+\sigma\,\theta\,\gamma} Dq_{ft} + \frac{\sigma\,(1-\lambda)}{(1+\sigma\,\theta\,\gamma)}[Dy_{t-1} - Dy_{t-1}^*], \qquad (35)$$

assuming that the domestic and foreign economies are identical except for scale. This is the same as the unanticipated domestic price level shock under a fixed exchange rate, given by (26), except for the term

$$\frac{\sigma\,(1-\lambda)}{(1+\sigma\,\theta\,\gamma)}[Dy_{t-1} - Dy_{t-1}^*]$$

which compensates for the fact that under managed floating the nominal exchange rate target is based on the previous period's actual observed real exchange rate rather than full-employment real exchange rate.

For a small country, the managed floating regime just described will almost certainly be superior to a flexible exchange rate regime with constant money growth. The condition is essentially the same as that for superiority of fixed exchange rates over flexible exchange rates with constant money growth ignoring the trend in the real exchange rate. Managed floating is also superior to a fixed exchange rate regime to the extent that it insulates the domestic price level both from longer-term swings in the real exchange rate (i.e., the cumulative effects of the period to period shocks) and any differences between the domestic and foreign core inflation rates. Nevertheless, if the real exchange rate exhibits very little stochastic trend (i.e., the period-to-period shocks to it are small) and the domestic and foreign core inflation rates are not too different, a fixed exchange rate may be superior to managed floating in that, being automatic, it requires few resources to manage and precludes the possibility of management mistakes.

Any actual managed floating regime constructed on the above principles will differ in practical details from the above description. First, countries will not have precisely defined core inflation rates—modern central banks typically set a range in which they hope to maintain the inflation rate in the future. Also, while prices are clearly observable with a lag of at most a month or two, and observation is more accurate the further one looks back into the past, there are many competing price indexes that the authorities could contemplate stabilizing. One would expect price indexes that quickly reflect movements in real exchange rates occurring at given nominal rates to be of particular interest to the authorities as they construct a target level of domestic prices in relation to the price level abroad. This target price level will probably not be precisely defined. Manipulation of the nominal exchange rate using unsterilized intervention will nevertheless be a feasible method of keeping some appropriate measure of the domestic price level in rough alignment with the price level abroad after taking into account acceptable differences between the domestic and foreign long-term inflation rates.

Two features of this managed floating policy should be emphasized. First, the concern is with movements in domestic prices relative to foreign prices, not with movements in domestic prices alone. This is because pressure on the nominal exchange rate is being used to neutralize the effects on domestic relative to foreign prices of changes in the full-employment real exchange rate. The foreign price level, and the foreign monetary policy that ultimately determines it, are being used as an anchor. No attempt is being made to implement an independent domestic counter-cyclical monetary policy. Indeed, implementing such a policy by trying to force countercyclical changes in domestic relative to foreign prices would involve the authorities in forecasting and discretionary policy initiatives that have already been ruled out by our information assumptions.

The second noteworthy feature of the above approach to managed floating is that the authorities do not inform the private sector of their planned actions. The central bank is using nominal exchange rate adjustments to determine and engineer the appropriate change in the domestic nominal money supply. Informing private agents of its nominal exchange rate target might cause the rate to move to target more quickly but would not change the ultimate adjustment of the money supply required to keep it there. It would also create political pressures from special interest groups whose wealth positions are directly affected by exchange rate movements.

Direct management of the exchange rate has an advantage over a policy of adjusting the money supply to smooth perceived portfolio shocks in that it gives the central bank clear control over the long-term domestic inflation rate relative to the inflation rate abroad. If private agents come to expect an increase in the future inflation rate their portfolio decisions will reflect that view. When the central bank commits itself to financing these portfolio adjustments to prevent them from affecting the exchange rate, it finances these private inflation expectations and the domestic inflation rate becomes whatever private agents expect it to be. By managing exchange rate, on the other hand, allowing it to adjust only to compensate for previously observed movements in the full-employment real exchange rate or deviations of the domestic inflation rate from its estimate of the core inflation rate, the central bank makes its management of the money supply independent of any changes in private inflationary expectations.

A small country's authorities can, of course, use a combination of managed floating and portfolio smoothing. Together with the underlying core-inflation rate targets, such an approach could be termed *disciplined discretion*.[21] And both strategies can be implemented with respect to a basket of currencies, not just the currency of a particular large trading partner. In a world of many countries this will lead to pooling of income and demand for money shocks over a wider currency area than possible when countries peg to single key currencies. One could indeed imagine a world consisting entirely of small countries, each of which implements some combination of managed floating and portfolio smoothing policies with reference to the basket of all other world currencies. In this case the big country in the above analysis would consist of an aggregate of small countries identical to the one analyzed. The rate of world money growth in such a currency system will reflect the average of the core inflation rates of the respective countries augmented by unforeseen aggregate shocks to the world quantity of money demanded.

The above policies of managed floating explain the observation that real and nominal exchange rates move together and show much less variability than the ratios of the respective countries' price levels. The relatively smooth solid lines in Figure 1 can be interpreted as evidence that countries follow similar monetary policies—the price level ratios show no cyclical pattern and the differences in their trends can be ascribed to differences in the countries' core inflation rates.[22] At the same time, the nominal exchange rates (dotted lines) adjust to compensate for the swings in the real exchange rates (dashed

[21] This term is used in a somewhat different but not necessarily inconsistent fashion by Thomas Lauback and Adam S. Posen in "Disciplined Discretion: Monetary Targeting in Germany and Switzerland", *Essays in International Finance*, No. 206, Princeton University, December 1997.

[22] The price levels are consumer price indexes with the rest-of-world price level being an index of all other countries' CPI's using 1980 output shares as weights. The real exchange rate is the ratio of the domestic CPI to a 1980 output-weighted average of the CPI's of all other countries after all CPI's have been multiplied by the U.S. dollar prices of the individual countries' currencies.

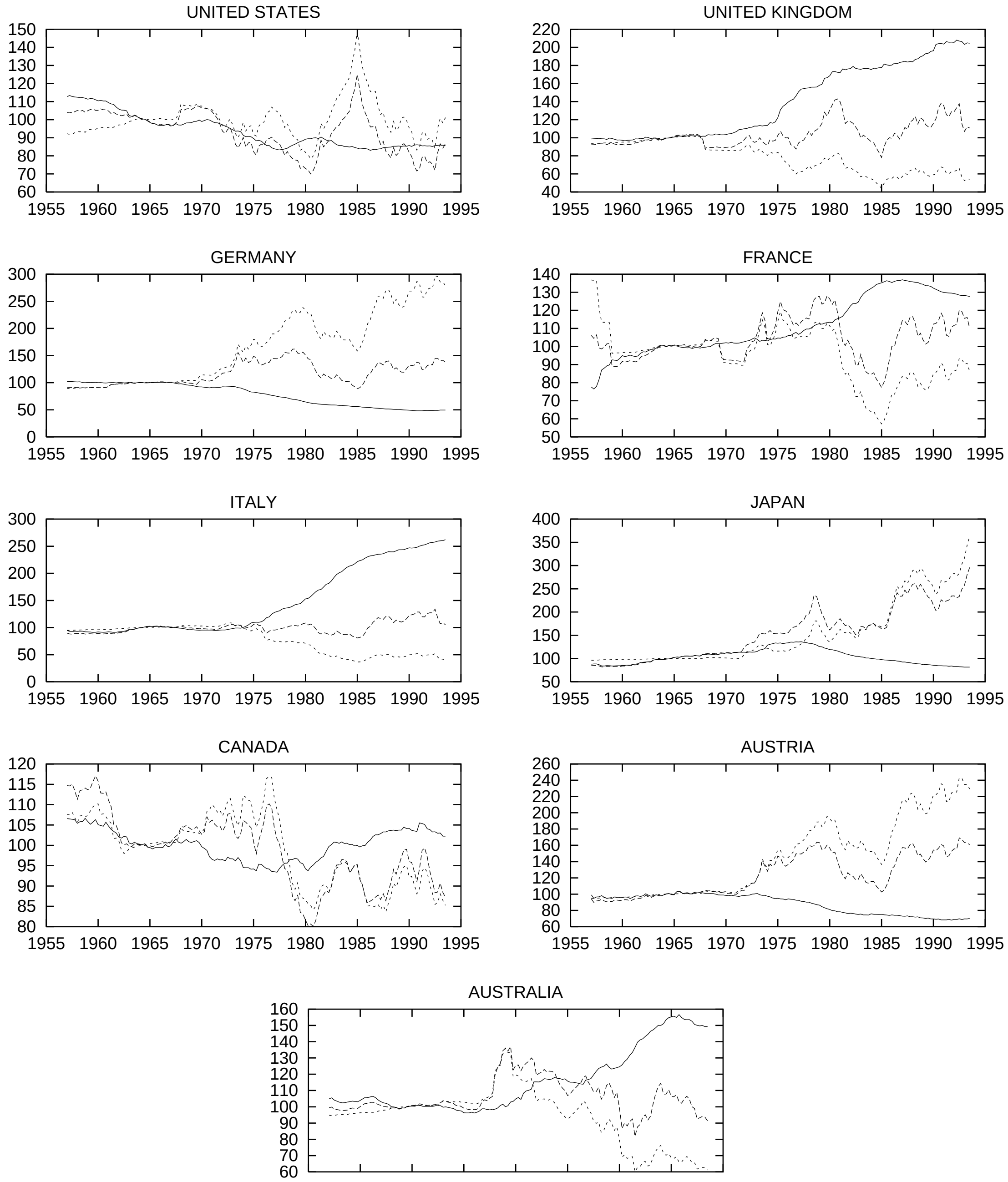

Figure 1: Real exchange rate (*dashed line*), nominal exchange rate (*dotted line*) and ratio of the domestic to rest-of-world price levels (*solid line*) for selected countries, 1957–1993, 1980 = 100. Source: *International Financial Statistics*.

lines) differing from them by little more than the trends in the respective price level ratios.

4.2.3 The Case for Fixed Exchange Rates

Whether the authorities attempt to observe and smooth portfolio shocks to the exchange rate or make the money supply adjustments necessary to directly manage the nominal exchange rate in a way that will accommodate underlying movements in the full-employment real exchange rate, the process will not be without error. These errors will appear as unanticipated shocks to the domestic price level and hence to domestic output and employment. By adopting a fixed exchange rate, these errors can be avoided. But the price is a failure to insulate the domestic price level from random-walk movements in the real exchange rate and an unacceptable core inflation rate in the country whose currency is being pegged to. If the shocks to the full-employment real exchange rate are small it will wander very slowly and the domestic price level will move only gradually, albeit persistently, from a path dictated by the core inflation rate of the country being pegged to. In this event, a fixed exchange rate may involve less costs that those resulting from errors in managing the float and may therefore be the best choice.

An appropriate strategy for the small open economy would thus be a fixed exchange rate when shocks to the full-employment real exchange rate are small, with abandonment of the fixed exchange rate for managed floating or portfolio smoothing when the full-employment real exchange rate shocks are sufficient to produce price level movements under a fixed exchange rate that are more costly than the smoothing errors that will result under managed floating or portfolio smoothing. A flexible exchange rate with constant money growth would appear never to be appropriate when the country is very small in relation to the rest of the world.

This suggests that we should observe countries adopting fixed exchange rates in periods in which real exchange rates exhibit little trend and then abandoning them for managed floating in periods when real exchange rates vary widely. The evidence is consistent with this. Figure 2 plots the real exchange rates of Germany, France, Italy, United States, United Kingdom and Canada during the gold-standard period 1880–1913, the inter-war period 1924–38, the Bretton-Woods period 1950–71 and the managed-floating period 1973–1990. During the gold standard and Bretton-Woods periods exchange rates were fixed (except for Canada in the latter period) and during the other two periods the fixed exchange rate system broke down. For every country but Canada, low-frequency real exchange rate variability was much greater during the flexible exchange rate periods than when exchange rates were fixed. Canada's real exchange rate varied as much in the Bretton-Woods period as it did in the flexible rate periods and, as the theory predicts, that country broke ranks and maintained a flexible exchange rate during much of the Bretton-Woods period. Canada also had substantial trend real exchange rate movements during the years of prairie settlement before the First World War but the average annual change between 1897 and 1908 was still only about 3 percent. The U.S. real exchange rate had a downward trend and the real exchange rates of Italy, Germany and the U.K. upward trends for the entire period after the Second World War but, again, the trend rates of change were less than 3 percent per year and the deviations around trend were far greater after 1973 than before.

A skeptic might argue that greater variability of real exchange rates in flexible exchange rate periods is the result of erratic monetary forces rather than natural real exchange rate movements, citing monetary instability as the reason for abandoning fixed rates. But this criticism implausibly assumes an absence of price level adjustments for long periods over which low-frequency real exchange rate adjustments were occurring.[23] To argue that this greater variability was due to erratic monetary policy, one would have to postulate persistent rigidity of countries' *relative* price levels during a time when world inflation rates were changing substantially. To illustrate, consider the infamous real and nominal appreciation of the U.S. dollar during the period 1980–84. Over a four year period, the currency appreciated by more than 50 percent. Without sticky prices, a 50 percent appreciation of the U.S. real exchange rate not based on exogenous real factors would have been eliminated by some combination of a 50 percent fall in the price level in the U.S. or a 50 percent rise in the price level in the rest of the world. Yet all countries shown in Table 1 experienced substantial reductions in their inflation rates between 1980 and 1984. For a price stickiness argument to be convincing, U.S. prices would have had to be sticky downward and foreign prices sticky

[23]It might also be argued that the major reason for adopting the gold standard was to keep monetary policy out of the control of the government, so that the fixed exchange rate regimes in that period had nothing to do with pooling demand for money shocks. Further analysis of the real exchange rate movements of countries that were slow to adopt the gold standard in preference to fiduciary money—for example, Austria-Hungary, Russia and Argentina—might prove fruitful.

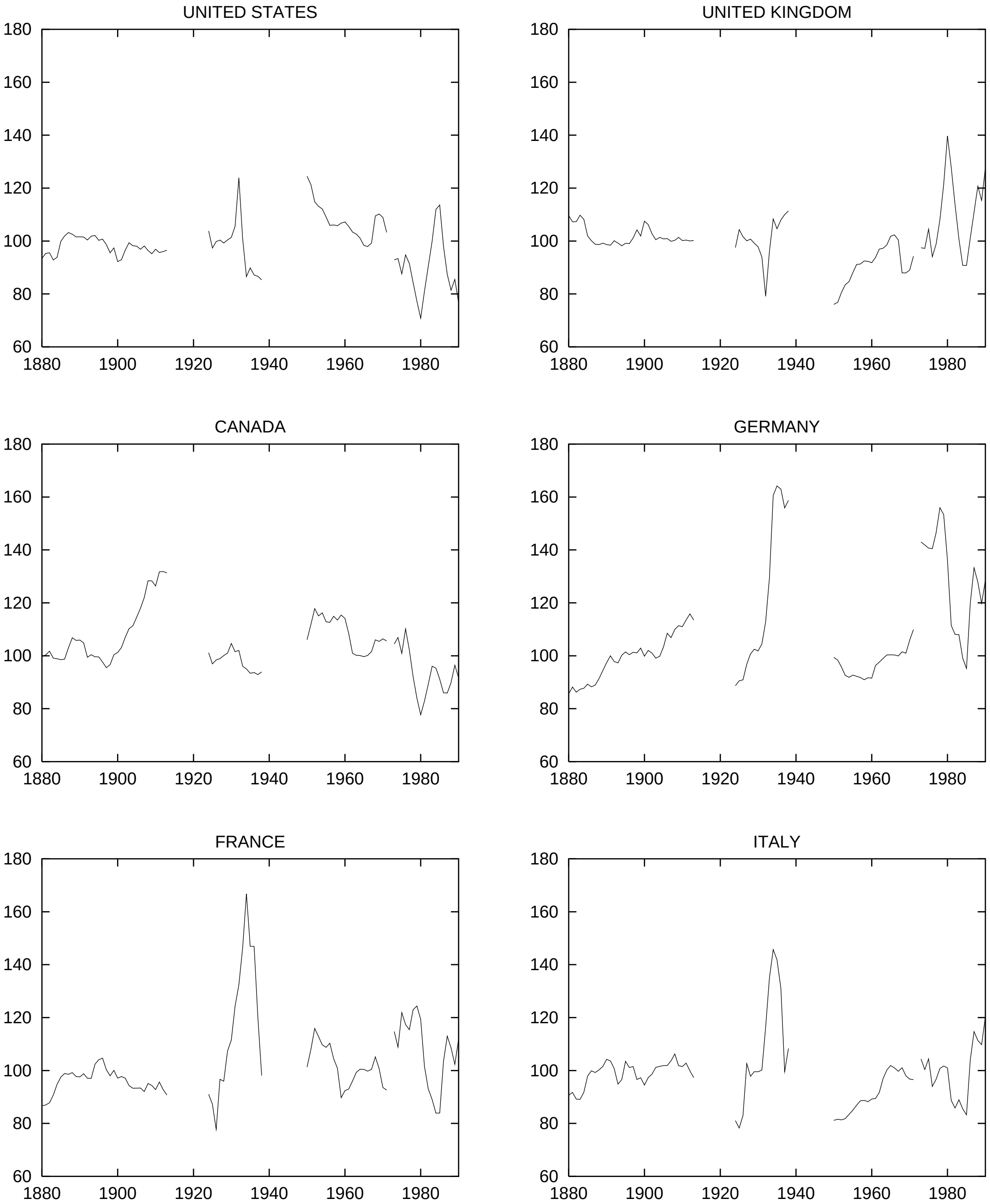

Figure 2: Real exchange rates of selected countries: 1880–1913 (1890–99 = 100), 1924–1938 (1927–29 = 100), and 1950–1971, 1973–1990 (1963–66 = 100). Source: See Appendix A.

Table 1: Inflation Rates of Selected Countries
Percent Per Year, 1980 and 1984

	1980	1984	Difference
United States	9	2	-7
United Kingdom	15	3	-12
Germany	6	0	-6
France	12	3	-9
Italy	17	5	-12
Sweden	14	4	-10

Sources: *Cansim* for Canada, *Citibase* for the U.S. and IMF, *International Financial Statistics* and OECD, *Main Economic Indicators* for the remaining countries.

upward, but the fall in the foreign inflation rates implies downward rather than upward pressure on foreign prices.

When there is no reason to expect that the full-employment real exchange rate will ever move significantly and the large country has a stable monetary policy and acceptable core inflation rate the costs of operating a foreign exchange market can be avoided by simply adopting the big country's currency. This, of course, forecloses the possibility of allowing nominal exchange rate movements to insulate the domestic price level from any future full-employment real exchange rate changes that may occur. It also binds the country irrevocably to the monetary policy and core inflation rate of the larger currency area.

5 Implications for Estimating the Effects of Monetary Policy

Over the past decade a substantial literature has developed dealing with the process by which monetary policy is transmitted to the economy and the timing of its effects on economic activity. One important strand of that literature uses vector autoregression analysis to empirically measure the response of various aggregates such as output, employment, the price level, long-term interest rates, etc., to monetary shocks defined in various ways.[24] This literature has been developed largely within a closed economy framework and applied principally to the United States, although open-economy extensions are well under way.[25]

The analytical framework developed here has important implications for the interpretation and future development of this line of research. It is clearly inappropriate to apply closed economy techniques directly to small open economies. A more complex question is whether these theoretical and empirical models are even appropriate for analyzing the (big?) U.S. economy in an environment where countries' monetary policies are stochastically interdependent. The problem is to interpret the empirical results that are emerging from these studies within the framework developed here. The vector autoregression results for the U.S. and at least some of the results for Canada and other smaller countries are consistent with the standard implications of traditional closed-economy-focused macroeconomics. The onus is therefore on

[24]This literature is very ably surveyed by Lawrence J. Christiano, Martin Eichenbaum, and Charles Evans in "Monetary Policy Shocks: What Have We Learned and to What End?" Unpublished Manuscript, Northwestern University, 1997. It builds on a number of important papers by Chrisopher Sims, among them "Macroeconomics and Reality," *Econometrica*, Vol. 48, 1980, pp. 1–48, and "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy," *European Economic Review*, Vol. 36, No. 5, 1992, pp. 975–1000. See also Eric M. Leeper, Christopher A. Sims and Tao Zha, "What Does Monetary Policy Do?" *Brookings Papers on Economic Activity*, Vol. 2, 1996, pp. 1–63, and David B. Gordon and Eric M. Leeper, "The Dynamic Impacts of Monetary Policy: An Exercise in Tentative Identification," *Journal of Political Economy*, Vol. 102, 1994, pp. 1228–1247.

[25]See, for example, David O. Cushman and Tao Zha, "Identifying Monetary Policy in a Small Open Economy Under Flexible Exchange Rates," *Journal of Monetary Economics*, Vol. 39, 1997, pp. 433–448, and Richard Clarida and Mark Gertler, "How the Bundesbank Conducts Monetary Policy', in Christina D. and David H. Romer, eds., *Reducing Inflation: Motivation and Strategy*, University of Chicago Press, pp. 363–406.

the model developed here to explain both this evidence and its consistency with traditional ideas.

One feature of contemporary research on the operation and transmission of monetary policy that seems especially at variance with the approach developed in this paper is the widespread view that the main instruments of monetary policy are the federal funds rate in the U.S. and the correspondingly defined interest rates in other countries that are alleged to operate through their effects on a wide class of short-term, and ultimately long-term, interest rates and hence on investment. Although exchange rate effects of monetary policy are also considered, they are not given the same emphasis as the interest rate effects. This would seem at variance with the theory developed here which postulates a single world interest rate from which individual countries' interest rates will differ only by risk premia. It makes little sense to argue that monetary policy operates by changing risk premia since the latter, according to modern capital asset pricing theory, are determined by the covariance structure of output and asset returns and not by the most recent shocks to the demand or supply of money. Moreover, the notion that monetary policy affects interest rates through its effects on actual relative to expected exchange rates ignores the well-known fact that the real exchange rate is a near random walk and the best forecasts of tomorrow's real exchange rate tends to be today's rate.[26] Observed interest rates and exchange rates also reflect inflation expectations as well as the effects of monetary policy, making it difficult to disentangle the latter's influence. Identification problems are further compounded by the difficulty of disentangling the effects of long-term real forces on exchange rates from the influence of monetary shocks.

We begin the discussion with three extreme assumptions that will be relaxed in due course: a) the world consists of many small countries that are identical except for scale, b) all these countries' monetary authorities perfectly smooth the effects of portfolio shocks on their nominal exchange rates, and c) there are no exogenous shocks to the full-employment real interest rate.

A number of basic results follow in the analytical framework developed here. First, monetary tightness can be measured by the level of the world real

[26] On these points, see John B. Taylor, "The Monetary Transmission Mechanism: An Empirical Framework," *The Journal of Economic Perspectives*, Vol. 9, No. 4, Fall 1995, pp. 11–26.

interest rate which in every country will equal the nominal interest rate minus that country's expected inflation rate. The degree of monetary tightness is thus given by (21) with $Dr^*_{ft} = 0$ under assumption c). Second, individual countries' outputs will respond cyclically to the world interest rate with the result that properly constructed single-country closed-economy-style empirical models will correctly characterize the effects of world monetary tightness, as reflected in the world interest rate common to all countries, on every country's output, employment and prices.[27] For each (unstarred) country, the relationship will be

$$y_t - y_{ft} \;=\; y^*_t - y^*_{ft} \;=\; -\rho^*(r^*_t - r^*_{ft}). \tag{36}$$

Third, the observed relationship between domestic interest rates and output and employment in each country does not yield the response of output and employment to independent domestic monetary policy, should the government choose to exercise it. Such policy would affect output only through its effect on the exchange rate. The effects of exogenous unanticipated (by the private sector) domestic nominal money supply changes can be seen by substituting (24) into (1) and setting all shocks but Dm_t equal to zero. Fourth, observed unanticipated shocks to individual countries' money supplies will, under assumption b) above, reflect shocks to their demands for money and will have no measurable effects on output and employment. When perfectly smoothing portfolio shocks to the exchange rate, each country's authorities have to supply at all points in time the quantities of money that their domestic residents wish to hold, given the country's core inflation rate. Fifth, under the above assumptions, there will also be no unambiguously positive effects of the world money stock on output and employment in any country—every country's money stock will depend on its demand for money, given its underlying core inflation rate, so the aggregate of these demands will equal the world money stock. When the demand for money increases in a number of countries simultaneously, for example, those countries will experience upward pressure on the external values of their currencies which they will offset by expanding their money supplies. The other countries will experience downward pressure on the values of their currencies which they will offset by contracting their money supplies. The monetary contractions in these latter countries will offset some of the expansion in the countries whose

[27]It is assumed here that useful estimates of expected future inflation are possible so that evidence of monetary tightness can be obtained from observed interest rates.

demand for money increased, making the expansion of the world money supply less than the initial expansion of the world demand for money. The real interest rate will rise relative to its full-employment level and there will be a world-wide contraction of output and employment.[28] An increase in the full-employment level of output will lead to an increase in the quantity of money demanded in the same way as if the relevant country's demand function for money had shifted to the right. When the world real interest rate rises, outputs in all countries will decline relative to their (in some cases increasing) full-employment output levels. Again, an observed world monetary expansion will be associated with a world-wide recession. Finally, it is evident that world business cycles—i.e., deviations of output from full-employment levels—will be caused by shocks to the world demand for money resulting from shocks either to aggregate world full-employment output or to the demand function for money that will operate through their effects on the world real interest rate. Cycles in the full-employment levels of output will arise on account of technological and other real business cycle forces.

Now relax assumption a) and consider a world consisting of many small countries plus one country large enough for shocks to its domestic money supply, output and demand function for money to affect the world interest rate. Assume that this latter country's authorities conduct monetary policy without reference to the effects of that policy on exchange rates or on output, employment and prices in any country but their own. The country, which might be taken to represent the U.S. under current real-world conditions, effectively becomes a key-currency country. If we maintain all the remaining assumptions, there will still be an negative empirical relationship between the world interest rate and output and employment in all countries. Since, based on assumption b), all countries other than the key-currency country perfectly smooth the portfolio effects of the key-currency monetary policy on the rate of exchange of their currency with the key-currency, monetary shocks in the key-currency country will be matched by equivalent induced monetary supply shocks everywhere else—the key-currency country will effectively determine the world money supply. The smoothing actions of the

[28]If the countries experiencing downward pressures on their currency values do not contract their money supplies, those countries whose demands for money are increasing will be led to increase their money supplies by the full increase in their residents' demand for money, so the world money supply will expand to fully accommodate the increase in the demand for money and an upward deviation of the world real interest rate from its full-employment level will be prevented.

peripheral countries' authorities will eliminate any relationship between the key-currency country's monetary shocks and nominal exchange rates. But there will now be a positive relationship between *excess* money supply shocks in the key-currency country and output and employment in every peripheral country.

If the peripheral countries choose not to smooth the effects of key-currency country monetary shocks on their exchange rates the magnitude of the key-currency country's effect on the real interest rate will depend on the size of the key-currency country in relation to the rest of the world. In this case, positive (negative) monetary shocks in the key-currency country will lead to a devaluation (appreciation) of the key-currency in terms of all peripheral currencies and output and employment in the peripheral countries will move in the opposite direction to output and employment in the key-currency country. Econometric estimates of the effect of the key-country's interest rate on its output and employment will provide a valid indication of that country's policy options. The observed empirical relationships between other countries' interest rates, which will equal the world interest rate, and their levels of output and employment will reflect effects of key-currency policy operating both through world interest rate induced changes in their investment and through exchange rate induced changes in their trade balances. These relationships will not measure the effects of an independent domestic policy, were one to be followed. As before, unanticipated excess money supply shocks in the peripheral countries will operate on their economies by affecting the exchange rate and will have no measurable effect on the world (and their domestic) real interest rate.

Next, we relax the assumption that countries other than the key currency country, if one exists, do a perfect job of smoothing the effects of portfolio shocks on their exchange rates. Imperfect smoothing means that there will be shocks to individual countries' outputs additional to those operating through changes in the level of world real interest rates. Risk and inflation premia will now be incorporated in the interest rates of individual countries and will vary in response to the ebb and flow of their smoothing errors. Central banks can measure domestic monetary tightness, which will be coterminous with world monetary tightness, with reference to domestic nominal interest rates, but these measures will be contaminated by changes in the risk premia and expected domestic inflation rates. And small countries still cannot affect their output and employment levels by operating on domestic interest rates because the latter are determined in the rest of the world—only by inducing changes in the external values of their currencies can they affect their domestic output, employment and price levels.

Individual countries' authorities might be able to control for short periods the interest rate on overnight borrowing of reserves by commercial banks from each other. And they can encourage commercial banks to borrow from the central bank by adjusting the "bank rate" charged on those borrowings relative to interest rates in general and thereby induce changes in the level of the domestic money supply. But they cannot affect those domestic interest rates relevant for determining the level of domestic investment.

The key-currency country's authorities can determine the level of interest rates relevant for determining that country's investment, and in doing so they determine the whole structure of world interest rates when the key-currency country is large, with the effects being stronger to the extent that the peripheral countries are at least partially successful in smoothing the portfolio effects of key-currency country policy on their exchange rates. The individual peripheral countries' exchange rates will be empirically unrelated to their unanticipated monetary shocks if they are sufficiently successful at portfolio smoothing. To the extent that all the peripheral countries successfully smooth the portfolio effects of asymmetric domestic relative to foreign monetary shocks on their exchange rates, the external value of the key-currency will also be independent of the key-currency country's unanticipated monetary shocks. The long-run effect of persistent monetary expansion in the key-currency country not matched by equivalent expansion elsewhere will, of course, be a nominal but not real devaluation of its currency. And long-run persistent monetary expansion in individual peripheral countries will also lead to nominal but not real devaluations of their currencies.

Finally, we relax assumption c) and allow for the presence of exogenous shocks to the full-employment world real interest rate. This destroys the previously clear relationship between the level of the world real interest rate and monetary tightness. Since the full-employment interest rate is never observed, neither is the deviation of the world interest rate from its full-employment level, so it is impossible to determine whether money is tight or easy by observing current interest rates even when there are no reasons for risk premia and expected inflation rates to have changed. A rise in the full-employment real interest rate will, ceteris paribus, create a situation of monetary ease. If the shocks to world full-employment real interest rate levels are small, however, and substantial excess money supply shocks are occurring in the key-currency country, a negative statistical relationship between reasonably measured world real interest rates and the key currency's output and employment would be observed. A less precisely measurable negative relationship between this world real interest rate and individual peripheral countries' output and employment levels would also be expected, provided that the latter's authorities smooth the portfolio shocks to their exchange rates.

It turns out that, when we take into consideration the arguments just noted, there is little inconsistency between the closed economy empirical results for the U.S. and the theory developed in this paper provided that the United States authorities did not conduct domestic monetary policy with reference to its effects either on the exchange rate or on economic conditions in the rest of the world. The only area where potential problems arise is in the interpretation of observed effects of U.S. policy on the exchange rate. Researchers have made substantial efforts to obtain evidence that a monetary contraction in the U.S. leads to an appreciation of the U.S. dollar in world markets, and also, that monetary contractions in other countries lead to appreciations of their currencies. These results are, on the surface, inconsistent with the notion that peripheral countries' vary their money supplies endogenously to smooth the effects of portfolio shocks on their real and nominal exchange rates. They are also inconsistent with existing evidence, based on quarterly data for nine countries including the U.S., that purely unanticipated money supply shocks have no apparent effect on current nominal exchange rates.[29] The problem is to reconcile the absence of observed short-run effects of monetary policy on real exchange rates with the presence of observed longer-term effects. One possibility is that world-wide monetary shocks, possibly initiated in the United States, by differentially affecting output and employment in different countries, could lead to deviations of real exchange rates from their full-employment levels that are contaminating VAR estimates. This would imply, however, that some country's currencies will depreciate in real terms in response to world contractions. Another possibility is that current research efforts have not yet correctly modeled the real exchange rate. Models that include the exchange rate in the set of variables the monetary authority looks at in determining its policy actions automatically include those exchange rate changes resulting from underlying random-walk

[29] See, J. E. Floyd, "Monetary Policy and the Exchange Rate: Some Evidence," Department of Economics and Institute for Policy Analysis Working Paper No. UT-ECIPA-FLOYD-98-02, University of Toronto, 1998.

full-employment real exchange rate movements. This may lead to misspecification of the relationship between monetary shocks and real exchange rates. To test the theory developed here we need to use measures of portfolio pressure on the exchange rate rather than the level of the rate itself. In any case, work in this area has just begun.

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APPENDIX A: Data Sources for Figure 4

The series for the period 1957–1995 for all countries except France before 1982 and Canada were obtained from *International Monetary Fund: International Financial Statistics*. Implicit GDP deflators (GNP in the case of Germany) were used as the price series for all countries and time periods. For the U.S. the source was Romer[30] for 1880–1929 and Friedman and Schwartz[31] for 1930–1956. The U.K. series are from Deane[32] for the period 1880–1914, and Friedman and Schwartz[33] for 1915–1956. The German Data for the period before 1957 are from *European Historical Statistics*.[34] For Italy the pre-1957 data are from compilations by Michael D. Bordo using *European Historical Statistics* and other sources. The French data for the period 1880–1982 are from Toutain.[35] The Canadian data are from Green and Urquhart[36] for the period 1880–1926 and from *CANSIM* thereafter. All of these data except for those from the IMF were brought together in the form used here by Trevor J. O. Dick.

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[30] Christina D. Romer, "The Pre-war Business Cycle Reconsidered: New Estimates of Gross National Product, 1869–1908," *Journal of Political Economy*, February 1989.

[31] Milton Friedman and Anna J. Schwartz, *A Monetary History of the United States, 1876–1960*, NBER, Princeton University Press, 1963.

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