Real and Monetary Shocks to Exchange Rates: The Evidence

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Contents

1 Introduction

This paper is a largely empirical effort directed toward understanding and explaining an empirical regularity that has defied explanation for decades—the substantial and persistent variation of real exchange rates that cannot be explained by macroeconomic fundamentals such as money and income growth and changes in interest rates. As Baxter and Stockman noted, transitions from fixed to floating exchange rate regimes are accompanied by sharp increases in nominal and real exchange rate variability without corresponding changes in the variability of fundamental macroeconomics variables.[1] More recently, this puzzle has been given a thorough examination in two important papers by Flood and Rose.[2] While, as shown by Chari, Kehoe and McGrattan, monetary shocks can generate exchange rate variability of the magnitudes observed, it cannot generate the persistence.[3] The problem is further analysed in papers by Duarte and Duarte and Stockman.[4]

The analysis here is based on the insight that a country's real exchange rate is the relative price of domestic output in terms of foreign output, which immediately suggests that the focus should be on the factors that determine these relative prices in a world undergoing technological change and capital accumulation. Basic economic intuition suggests a range of factors that should be correlated with these relative price movements and an OLS regression analysis of the relationship of these factors and the real exchange rates of Canada, the United Kingdom, Japan, France and Germany with respect to the United States is pursued. While taking care to avoid the spurious regression problem, it is established that the major observed real exchange rate variations since 1974 can be explained in substantial

[1]M. Baxter and Allan C. Stockman, "Business cycles and the Exchange Rate Regime: Some International Evidence", *Journal of Monetary Economics*, Vol. 23, Issue 3 (May), 1989, 377-400.

[2]Robert P. Flood and Andrew K. Rose, "Fixing Exchange Rates: A Virtual Quest for Fundamentals", *Journal of Monetary Economics*, Vol. 36, Issue 1 (August), 1995, 3-37, and "Understanding Exchange Rate Volatility without the Contrivance of Macroeconomics", *Economic Journal*, Vol. 109, Issue 459 (November), 1999, 660-72. See also Maurice Obstfeld and Kenneth Rogoff, "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause", *NBER Macroeconomics Annual*, 15, 2000.

[3]V. V. Chari, Patrick Kehoe and Ellen McGrattan, "Can Sticky Price Models Generate Volatile and Persistent Exchange Rates?" *Review of Economic Studies*, Vol. 69, No. 3, July 2002, 533-63

[4]Margarida Duarte, "Why Don't Macroeconomic Quantities Respond to Exchange Rate Variability," *Journal of Monetary Economics*, Vol. 50, No. 4, May 2003, 889-913, and Margarida Duarte and Allan C. Stockman, "Rational Expectations and Exchange Rates", *Journal of Monetary Economics*, Vol. 52, Issue 1 (January), 3-29, 2005.

part by variables such as world prices of oil and other commodities, relative terms of trade changes, real net capital inflows, government consumption expenditures relative to GDP, and domestic and U.S. real GDP. Substantial effort is also devoted to explaining the relationship, often present, between domestic relative to U.S. interest rate differentials and real exchange rates.

This broadening of the range of 'fundamentals' that can explain exchange rate movements beyond those considered by Baxter and Stockman and Flood and Rose, combined with the fact that the real technology and capital accumulation variables considered here have been much more variable under flexible exchange rates than they were under the post-war Bretton-Woods system, suggests that it was precisely because of these factors that the fixed exchange rate regime broke down. Otherwise, these shocks would have affected domestic price levels, and output and employment, instead of nominal exchange rates, a politically unacceptable result.

While it is found that observed real exchange rate movements are explained in large measure by real shocks of the sort just noted, evidence is also uncovered that real exchange rate movements are in small measure also related to demand for money shocks although no evidence was found of a relationship between unanticipated money supply shocks and real exchange rate changes of the sort that would be created by domestic monetary policies that were independent of U.S. monetary policy. This suggests that the domestic authorities continually adjust credit conditions to avoid obvious overshooting effects of money demand or supply shocks on their exchange rates and thereby maintain 'orderly markets'. Although overshooting effects of monetary shocks can be detected, these are too small to be visible in plots of real and nominal exchange rates and domestic relative to U.S. price levels on the same chart. The fact that the effects of small monetary policy differences are present suggests that the authorities of countries other than the U.S. occasionally, either deliberately or inadvertently, 'lean' against their exchange rates with the U.S. To the extent that the U.S. does not care about exchange rates, this suggests that the United States in a fundamental sense 'runs' world monetary policy.

2 The Determinants of the Real Exchange Rates

Our first step is to present a simple clear theoretical analysis of the basics of real exchange rate determination.[5] The place to start is with the general equilibrium forces at work when all prices are flexible and the economy is continually at full employment. These assumptions will, of course, be

[5]There is an extensive literature here. Much early work arose from attempts to test the purchasing-power-parity theory—see Paul A. Samuelson, "Theoretical Notes on Trade Problems," *Review of Economics and Statistics*, Vol. 46, No. 2, May 1964, 145-54, Bela Balassa, "The Purchasing Power Parity Doctrine: A Reappraisal," *Journal of Political Economy*, Vol. 72, No. 6, December 1964, 584-96, and Lawrence H. Officer, *Purchasing Power Parity and Exchange Rates: Theory, Evidence and Relevance*, London and Greenwich Connecticut, JAI Press, 1982. See also Peiter Korteweg, "Exchange Rate Policy, Monetary Policy, and Real Exchange Rate Variability," *Princeton Essays in International Finance*, No. 140, Princeton University Press, 1980 and Irving Kravis and Robert Lipsey, "Toward an Explanation of National Price Levels," *Princeton Studies in International Finance*, No. 52, Princeton University Press, 1983. Subsequently the emphasis shifted towards representative agent models—see Allan C. Stockman, "A Theory of Exchange Rate Determination," *Journal of Political Economy*, Vol. 88, No. 4, August 1980, 673-698, and "Real Exchange Rates Under Alternative Real Exchange Rate Regimes," *Journal of International Money and Finance*, Vol. 2, No. 2, August 1983, 147-66, Allan C. Stockman and Lars E. O. Svensson, "Capital Flows, Investment and Exchange Rates," *Journal of Monetary Economics*, Vol. 19, No. 2, March 1987, 171-202, Elhanan Helpman, "An Exploration in the Theory of Exchange Rate Regimes," *Journal of Political Economy*, Vol. 89, No. 5, October 1981, 865-90, Elhanan Helpman and Assaf Razin, "Dynamics of a Floating Exchange Rate Regime," *Journal of Political Economy*, Vol. 90, No. 4, August 1982, 728-754, and Sebastian Edwards, *Real Exchange Rates, Devaluation, and Adjustment*, MIT Press, 1989. Most recently, the focus has been on 'new open-economy' models, starting with Maurice Obstfeld and Kenneth Rogoff, "Exchange Rate Dynamics Redux," *Journal of Political Economy*, Vol. 103, No. 3, June 1995, 624-60, with empirical work by Charles Engel "Real Exchange Rates and Relative Prices: An Empirical Investigation," *Journal of Monetary Economics*, Vol. 32, No. 1, August 1993, 35-50, and Charles Engel and John H. Rogers, "How Wide is the Border," *American Economic Review*, Vol. 86, No. 5, December 1996, 1112-1125. For the most recent theoretical contributions, see Michael B. Devereux, "Real Exchange Rates and Macroeconomics: Evidence and Theory," *Canadian Journal of Economics*, Vol. 30, No. 4, November 1997, 773-808, Caroline Betts and Michael B. Devereux, "Exchange Rate Dynamics in a Model of Pricing-to-Market," *Journal of International Economics*, Vol. 50, No. 1, February 2000, 215-44, Charles Engel, "Optimal Exchange Rate Policy: The Influence of Price Setting and Asset Markets," *Journal of Money, Credit, and Banking*, Vol. 33, No. 2, Part 2, May 2001, 518-541, Michael B. Devereux and Charles Engel, "Exchange Rate Volatility, Exchange Rate Pass-Through, and Exchange Rate Disconnect," *Journal of Monetary Economics*, Vol. 49, No. 5, July 2002, 913-40, V. V. Chari, Patrick Kehoe and Ellen McGrattan, "Can Sticky Price Models Generate Volatile and Persistent Exchange Rates?" *Review of Economic Studies*, Vol. 69, No. 3, July 2002, 533-63, and Margarida Duarte, "Why Don't Macroeconomic Quantities Respond to Exchange Rate Variability," *Journal of Monetary Economics*, Vol. 50, No. 4, May 2003, 889-913.

relaxed as the discussion proceeds.

2.1 General Equilibrium Issues

The real exchange rate is the relative price of domestic output in terms of foreign output, defined as

$$Q = \frac{\Pi P_d}{P_f} \tag{1}$$

where Q is the real exchange rate, Π the nominal exchange rate defined as the foreign currency price of domestic currency, P_d the domestic price level and P_f the foreign price level. Although the price levels are viewed conceptually as indices of the respective countries' output prices, it will be convenient in subsequent empirical analysis to use consumer price indices.

While it has been traditional to separate the goods produced in each country into traded and non-traded goods, we must be careful because there is substantial evidence that traded goods typically sell for different prices, measured in the same currency, in different countries—that is, that the law of one price does not hold.[6] A more sensible procedure is to divide each good, and hence the output of each country, into traded and non-traded components. For example, a chair that retails for $100 might well have been purchased for $30 at a foreign factory, and could probably be purchased at a domestic factory for a competitive price of $30 plus the cost of transporting the chair from abroad. The difference between the cost at the factory and the retail cost is the services of wholesaling and retailing the product plus the costs of arranging transportation, getting it through customs, etc. These latter costs are the non-traded component while the traded component is the $30 plus the traded component of the transport costs. A 10% devaluation of the domestic currency resulting entirely from real forces unrelated to the chair market will cause the price of the traded component to rise from $30 to $33, leaving the non-traded component unchanged, with the result that the retail price of the chair will rise by only 3% once firms along the supply chain get around to adjusting their markups. Since the non-traded component consists entirely of labour services, some of which are embodied in capital,[7] the same chair would retail for much less than $100 in a country

[6] See, for example, Charles Engel, "Real Exchange Rates and Relative Prices: An Empirical Investigation," *Journal of Monetary Economics*, Vol. 32, No. 1, August 1993, 35-50, and Charles Engel and John H. Rogers, "How Wide is the Border," *American Economic Review*, Vol. 86, No.5, December 1996, 1112-1125.

[7] For example, although a building is traditionally defined as physical capital, a substantial fraction of its value is embodied labour used in its construction.

in which labour productivity and real wages are lower.

While the division of the range of goods produced in a country into their traded and non-traded components is an empirical nightmare, all that will be necessary here is to assume that the non-traded component of aggregate domestic output is substantially positive. On this basis the domestic and foreign price levels can be expressed as the geometric indices

$$P_d = P_{N_d}^{\alpha} P_{T_d}^{1-\alpha} \tag{2}$$

and

$$P_f = P_{N_f}^{\hat{\alpha}} P_{T_f}^{1-\hat{\alpha}} \tag{3}$$

where $\alpha > 0$ and $\hat{\alpha} > 0$ are the fractions of domestic and foreign output represented by non-traded components. Equation (1) can now be rewritten

$$Q = \frac{\Pi\, P_{N_d}^{\alpha} P_{T_d}^{1-\alpha}}{P_{N_f}^{\hat{\alpha}} P_{T_f}^{1-\hat{\alpha}}}. \tag{4}$$

Although the traded components of domestic and foreign output typically will not involve the same goods because the countries may trade with different third countries as well as with each other, we can nevertheless express the domestic traded component in the foreign country's currency by replacing P_{T_d} with $P_{T_{df}}/\Pi$ where $P_{T_{df}}$ is the foreign currency price of the domestic traded component of output. The above equation then becomes

$$\begin{aligned} Q &= \frac{\Pi\, P_{N_d}^{\alpha} (P_{T_{df}}/\Pi)^{1-\alpha}}{P_{N_f}^{\hat{\alpha}} P_{T_f}^{1-\hat{\alpha}}} = \frac{(\Pi/\Pi^{1-\alpha})\, P_{N_d}^{\alpha} P_{T_{df}}^{1-\alpha}}{P_{N_f}^{\hat{\alpha}} P_{T_f}^{1-\hat{\alpha}}} \\ &= \left[\frac{(\Pi P_{N_d})^{\alpha}}{P_{N_f}^{\hat{\alpha}}}\right] \left[\frac{P_{T_{df}}^{1-\alpha}}{P_{T_f}^{1-\hat{\alpha}}}\right] \end{aligned} \tag{5}$$

As can be seen from the above equation, the long-run equilibrium effects of world technological change and capital accumulation on a country's real exchange rate with respect to some other country will depend on the effects of these forces on the price of domestic relative to foreign traded output-components and the price of domestic relative to foreign non-traded output-components, where all prices are measured in a single currency.

Consider first the effects of real income growth and the associated rise in labour productivity in the two economies. Since the non-traded components of output are primarily labour services and are less amenable to increases in labour productivity than the traded-components, the relative price of the non-traded components should tend to rise as real income expands leading us to expect that the real exchange rate of the more rapidly growing country will tend to rise. That is, other things equal, the real exchange rate should be positively related to the ratio of domestic to foreign real income.[8]

A second force leading to real exchange rate movements is changes in the allocation of world investment among countries. As technology advances the resources of different countries become favoured for development and world investment shifts to those locations. The implications can be usefully analysed from the perspective of the standard textbook relation between income and expenditure. Domestic output can be expressed as the sum of three aggregates

$$X = C' + I' + E' \tag{6}$$

where C', I' and E' are the domestic outputs of consumption, investment and export goods respectively, and X is aggregate output produced by resources in the domestic economy, or gross domestic product. These aggregates include production arising within both the private and government sectors. Adding and subtracting imports denoted by E_{rw} (i.e., rest-of-world exports to the domestic economy)

$$E_{rw} = E_{C_{rw}} + E_{I_{rw}} + E_{E_{rw}} \tag{7}$$

where $E_{C_{rw}}$, $E_{I_{rw}}$ and $E_{E_{rw}}$ are the domestic imports of consumption, investment and re-export goods, respectively, the above equation becomes

$$\begin{aligned} X &= C' + I' + E' - E_{rw} + E_{C_{rw}} + E_{I_{rw}} + E_{E_{rw}} \\ &= C + I + E - E_{rw} \\ &= C + I + B_T \end{aligned} \tag{8}$$

where C and I are total domestic consumption and investment of both domestic and imported goods, E is total domestic exports including re-exports of imported goods and $B_T = E - E_{rw}$ is the domestic balance of trade. Adding to both sides of (8) the excess of income received on domestically owned capital employed abroad over income paid abroad on

[8]This is the well-known Balassa-Samuelson hypothesis—see Paul A. Samuelson, "Theoretical Notes on Trade Problems," *Review of Economics and Statistics*, Vol. 46, No. 2, May 1964, 145-54, and Bela Balassa, "The Purchasing Power Parity Doctrine: A Reappraisal," *Journal of Political Economy*, Vol. 72, No. 6, December 1964, 584-96.

foreign owned domestically employed capital, referred to as the debt service balance and denoted by DSB, the equation becomes

$$Y_d \;=\; X + DSB \;=\; C + I + B_T + DSB \tag{9}$$

where Y_d is total income earned by domestic residents, or GNP. Subtracting $C + I$ from both sides of the above equation we obtain

$$Y_d - C - I \;=\; S - I = \; NCO \;=\; B_T + DSB \tag{10}$$

where S is gross domestic savings, $S - I = NCO$ is the domestic net capital outflow and $B_T + DSB$ is the domestic current account balance. Domestic savings and investment will depend on the domestic real interest rate, denoted by r_d, domestic real income and exogenous shift factors which we can aggregate into the shift-variable Ψ_{S-I}. The domestic balance of trade will depend upon domestic and foreign incomes and on the domestic real exchange rate with respect to the rest of the world, which we denote by Q_{rw}, and the exogenous shift variable Ψ_{B_T}. The debt service balance is determined by past domestic savings and investment and is therefore unaffected by the current-period levels of other variables. Equation (10) thus becomes

$$N(Y_d, r_d, \Psi_{S-I}) \;=\; B_T(Y_d, Y_f, Q_{rw}, \Psi_{B_T}) + DSB \tag{11}$$

where $N()$ is the function determining the net capital outflow and $B_T()$ is the function determining the balance of trade. Equation (11) and, equivalently, (8) and (9) can be viewed as the condition of equilibrium in the domestic real goods market—the condition that the aggregate supply of domestic output must equal the aggregate demand for it.

The interest parity condition requires that domestic and rest-of-world nominal interest rates, i_d and i_{rw}, be related according to

$$i_d - i_{rw} \;=\; \Phi + \rho_c \tag{12}$$

where Φ is the forward discount on domestic currency on the foreign exchange market and ρ_c is the country-specific risk premium on domestic assets. Foreign exchange market efficiency—i.e., rational behaviour of market participants—implies that

$$\Phi \;=\; -E_{\Pi}^{rw} + \rho_x \tag{13}$$

where E_{Π}^{rw} is the expected relative change in the value of the domestic currency in terms of a weighted average rest-of-world currencies and ρ_x

is the corresponding foreign-exchange risk premium on domestic currency. Substitution of (13) into (12) yields

$$i_d \;=\; i_{rw} - E_{\Pi}^{rw} + \rho_x + \rho_c \;=\; i_{rw} - E_{\Pi}^{rw} + \rho \tag{14}$$

were ρ is the combined risk premium on domestic assets. To obtain a corresponding relationship between domestic and rest-of-world real interest rates we simply substitute for each nominal interest rate the respective real interest rate plus the expected inflation rate to obtain

$$\begin{aligned} r_d &= r_{rw} - E_P^d - E_{\Pi}^{rw} + E_P^{rw} + \rho \\ &= r_{rw} - E_Q^{rw} + \rho \end{aligned} \tag{15}$$

where E_P^d and E_P^{rw} are the expected rates of inflation in the domestic economy and the rest of the world and E_Q^{rw} is the expected rate of change in the domestic real exchange rate with respect to the rest of the world. Expressions equivalent in structure to equations (12) through (15) can be written for the domestic economy with respect to any foreign country—all one needs to do is appropriately modify the superscript ^{rw}.

As is clear from equation (15), the domestic real interest rate in equation (11) will be determined by conditions in the rest of the world and by the risk of holding domestic as compared to foreign assets together with expectations about the future course of the real exchange rate. Under our full-employment-price-flexibility assumption, domestic and foreign real incomes at any point in time will depend on past savings and technology and real interest rates will be determined by risk conditions and the productivity of capital in the domestic and foreign economies at the full-employment levels of output and investment. The only variable that can respond to a disequilibrium between aggregate supply and aggregate demand is Q_{rw}, the relative price of domestic output in the world (including domestic) market. Given a reallocation of world investment toward the domestic economy, Ψ_{S-I} will fall, reducing the left side of (11) and expanding aggregate demand. Assuming that no offsetting change in Ψ_{B_T} occurs,[9] the real exchange rate Q_{rw} must rise, either through an increase in the domestic price level or a rise in the nominal exchange rate, to expand imports relative to exports and reduce equivalently the right side of (11), bringing aggregate demand for domestic output back into line with aggregate supply. A technology induced shift of world investment into the domestic economy increases aggregate demand

[9] Here we abstract from any changes in risk and the productivities of capital in the domestic and foreign economies associated with the shift of Ψ_{S-I}.

for domestic output which, if unaccompanied by a corresponding inflow of capital goods, will cause the relative price of domestic output to rise. The fact that investment spending in the domestic economy has increased with not all of it being spent on traded output components means that the price of domestic non-traded output components will rise relative to the price of non-traded components in the rest of the world. In analysing the effects of shifts of world investment on the real exchange rate of one country with respect to another we should therefore look at the real net capital inflow (or the negative of the current account balance) of the recipient country as a fraction of its output in comparison with the real net capital inflow of the trading partner as a fraction of that country's output. Other things equal, we would expect the real exchange rate of the country experiencing the largest real net capital inflow (or smallest real net capital outflow) as a percentage of output to rise.

Another potential cause of real exchange rate changes is shifts of residents' preferences among goods having different traded and non-traded output components. Although private preferences are impossible to model in this context, it would seem that shifts in government output as a fraction of domestic real income might well lead to real exchange rate changes in that governments tend to be biased toward the purchase of domestic goods rather than goods imported from abroad. As a consequence we might expect that the bigger the fraction of output consisting of government expenditure in the domestic relative to the foreign economy, the higher will be the demand for domestic relative to foreign non-traded output components and the higher will be the domestic real exchange rate.

Then there are a whole range of factors that might be expected to change the domestic relative to the foreign prices of traded components of output. An obvious example relevant to the Canadian economy is the trends in world commodity prices, Canada having been historically a producer of base metals, coal, grains and other such commodities. To the extent that commodities are a bigger fraction of domestic output than that of a trading partner one would expect that a fall in world commodity prices would reduce the domestic real exchange rate with respect to that partner. Of course, there are a myriad of goods with high traded components and on-going technological change would be expected to bring about changes in the relative prices of these components, causing the real exchanges rates of producing countries to change in ways that will be very difficult to predict. Assuming that countries' export components of output constitute higher fractions of output than import components of output, it would seem reasonable to expect that a rise in its terms of trade relative to that of another country would result in an increase in its real exchange rate with respect to that country. And clearly, a rise in the terms of trade of a country with respect to a particular trading partner should result in an increase in its real exchange rate with respect to that partner.

The above analysis has ignored market imperfections that are an important focus of the modern literature.[10] These distortions should not be of importance in the broad framework outlined above. The long-run equilibrium real exchange rate would be expected to depend on real net capital inflows, real income growth, and the time paths of world prices of particular traded components of output even in the face of the usual distortions in the relative price structure. Market imperfections become important, as emphasised in the modern literature, with respect to short-term variations in real exchange rates around their long-run equilibrium levels, issues to which we now turn.

2.2 Overshooting

The response of real exchange rates to monetary shocks can be best understood by focusing on the conditions of monetary and, more generally, asset equilibrium.[11] The domestic demand function for money can be written in the form

$$M_d \;=\; P_d\, L(i_d, Y_d, \Psi_M) \tag{16}$$

where M_d is the domestic nominal money stock and Ψ_M is an exogenous demand-for-money shift variable. This equation plus a rest-of-world counterpart, plus equation (14), reproduced here for convenience,

$$i_d \;=\; i_{rw} - E_{\Pi}^{rw} + \rho \tag{14}$$

constitute the basic conditions of world asset equilibrium. When (16) holds domestic residents are holding their desired stock of money balances, and their desired stock of non-monetary assets as well since an excess demand or supply of non-monetary assets implies an excess supply or demand for money balances—all domestic wealth must be held in one form or the other.

[10] For a clear discussion of the role of market imperfections in real exchange rate determination, see Michael B. Devereux, "Real Exchange Rates and Macroeconomics: Evidence and Theory," *Canadian Journal of Economics*, Vol. 30, No. 4, November 1997, 773-808.

[11] For a more extensive elaboration of the issues covered in this section, see John E. Floyd, "Exchange Rate Overshooting," Unpublished Manuscript, University of Toronto, February 18, 2002.

Equality of the demand and supply of money by rest-of-world residents indicates that they too hold their desired quantities of non-monetary assets.[12] Equation (14) must hold to ensure that world residents be willing to hold in their portfolios the existing mix of domestic and rest-of-world non-monetary assets—an excess demand for domestic non-monetary assets assets, and corresponding excess supply of rest-of-world non-monetary assets, will cause the price of domestic assets to rise relative to rest-of-world assets and the domestic interest rate to fall relative to interest rates abroad.

Now let there be a once and for all increase in the domestic nominal money supply. If prices are perfectly and instantaneously flexible, which will require at a minimum full knowledge of everyone in the economy that the money stock has increased, the domestic price level will rise in the same proportion as the money supply and both sides of (16) will increase by the same amount. Suppose, however, that prices are not perfectly flexible. In a Fleming-Mundell world where prices cannot change in the short-run, domestic income rises in response to the devaluation of the domestic currency that occurs as domestic residents try to re-establish portfolio equilibrium.[13] The domestic interest rate is unaffected because it is tied to the rest-of-world rate by the condition of free international capital mobility. The resulting rise in income will be sufficient to increase desired money holdings by the same amount that the actual money stock has increased, thereby preserving asset equilibrium. But the increase in domestic income results from a shift of world demand onto domestic goods as a result of the decline in the domestic nominal, and real, exchange rate and the resulting fall of the relative price of domestic goods in world markets. It is unreasonable to expect these changes in trade flows to occur immediately—time will be required for firms and consumers to make the necessary adjustments. If the price level, real income and the interest rate cannot change, there is no way that asset equilibrium can be re-established—the right side of equation (16) will exceed the left side regardless of how much the nominal and real exchange rates depreciate.

To facilitate the analysis, substitute equation (2) together with $P_{T_{df}} =$

[12] The fact the asset holders typically hold equilibrium quantities of foreign as well as domestic money balances is ignored here for convenience—the results will not be changed by relaxing this assumption.

[13] See J. Marcus Fleming, "Domestic Financial Policies Under Fixed and Under Floating Exchange Rates," *International Monetary Fund Staff Papers*, Vol. 9, No. 3, November 1962, 369-79, and Robert A. Mundell, "Capital Mobility and Stabilisation Policy Under Fixed and Flexible Exchange Rates," *Canadian Journal of Economics and Political Science*, Vol. 29, No. 4, November 1963, 475-85.

$P_{T_{drw}}/\Pi^{rw}$ into (16) to express the domestic price level in terms of its non-traded and traded components:

$$M_d \;=\; P_{N_d}^{\alpha}(P_{T_{drw}}/\Pi^{rw})^{1-\alpha} L(i_d, Y_d, \Psi_M) \tag{17}$$

where $P_{T_{drw}}$ is the price of the domestic traded-component of output and Π^{rw} the price of domestic currency in terms of a weighted average of rest-of-world currencies. Assuming that foreign-currency price of the traded-component of domestic output is fixed by conditions abroad and the prices of the non-traded components of domestic output are fixed in the short-run, the above equation reduces to

$$M_d \;=\; (1/\Pi^{rw})^{1-\alpha} L(i_d, Y_d, \Psi_M) \tag{18}$$

where the constant price variables are normalised at unity. Taking the relative change of both sides of the above equation, assuming Y_d constant, we obtain

$$\frac{\Delta M_d}{M_d} \;=\; -(1-\alpha)\frac{\Delta\Pi^{rw}}{\Pi^{rw}} + \eta\,\Delta i_d + \frac{\Delta\Psi_M}{\Psi_M} \tag{19}$$

where the units of Ψ_M are chosen so that

$$\frac{\Psi_M}{L}\frac{\partial L}{\partial \Psi_M} \;=\; 1 \qquad \text{and where} \qquad \frac{1}{L}\frac{\partial L}{\partial i_d} \;=\; \eta \;<\; 0$$

is the domestic interest semi-elasticity of demand for money. We can now substitute in the change in equation (14) for Δi_d, reducing (19) to

$$\frac{\Delta M_d}{M_d} \;=\; -(1-\alpha)\frac{\Delta\Pi^{rw}}{\Pi^{rw}} - \eta\, E\left\{\frac{\Delta\Pi^{rw}}{\Pi^{rw}}\right\} + \eta\,\Delta\rho + \frac{\Delta\Psi_M}{\Psi_M} \tag{20}$$

where

$$E\left\{\frac{\Delta\Pi^{rw}}{\Pi^{rw}}\right\} \;=\; E_{\Pi}^{rw}$$

is the expected future rate of change in the domestic nominal exchange rate with respect to the rest of the world and di_{rw} is zero by assumption.

During the time interval during which domestic real income cannot change, the relative change in the nominal exchange rate is

$$\frac{\Delta\Pi^{rw}}{\Pi^{rw}} \;=\; -\frac{1}{1-\alpha}\left[\frac{\Delta M_d}{M_d} - \frac{\Delta\Psi_M}{\Psi_M} + \eta\, E\left\{\frac{\Delta\Pi^{rw}}{\Pi^{rw}}\right\} - \eta\,\Delta\rho\right]. \tag{21}$$

It is easily seen from the above that an exogenous shock to the money supply, assuming for the moment that the risk premium and expected future rate of change in the exchange rate are unaffected, will cause the exchange rate to devalue by a multiple $1/(1-\alpha)$. Essentially, equilibrium must be brought about by a rise in the domestic price level proportional to the increase in the money stock and only the prices of the traded components of output contribute to the price level increase—the exchange rate, and the prices of traded components of output, must therefore rise more than proportionally than the increase in the money stock, by an the amount depending inversely on $1-\alpha$, the share of the traded-components in output. Since in the long run the nominal exchange rate must depreciate, and the domestic prices of all goods must rise, in the same proportion as the increase in the money stock, the exchange rate will clearly overshoot its long run equilibrium level in the short run. If investors realize this they will expect the exchange rate to return towards that level in the future. The expected appreciation will create an expected capital gain on domestic assets causing their prices to rise and domestic interest rates to fall, reducing the cost of holding money balances. This will increase desired money holdings and thereby reduce the degree of overshooting required to maintain current-period asset equilibrium.[14]

Let the expected future change in the nominal exchange rate be some proportion $-\gamma$ of the excess of the current-period change over the long-run change that will result from current-period monetary shocks. Then, keeping in mind that in the long-run a positive money supply shock must be associated with an equal proportional negative change in the nominal exchange rate,

$$E\left\{\frac{\Delta\Pi^{rw}}{\Pi^{rw}}\right\} \;=\; -\;\gamma\;\left[\frac{\Delta\Pi^{rw}}{\Pi^{rw}}+\frac{\Delta M_d}{M_d}-\frac{\Delta\Psi_M}{\Psi_M}-\eta\;\Delta\rho\right] \tag{22}$$

This, when substituted into (21), implies an equilibrium current-period change in the exchange rate of

$$\frac{\Delta\Pi^{rw}}{\Pi^{rw}} \;=\; -\,\frac{1-\eta\,\gamma}{1-\alpha-\eta\,\gamma}\left[\frac{\Delta M_d}{M_d}-\frac{\Delta\Psi_M}{\Psi_M}-\eta\;\Delta\rho\right]. \tag{23}$$

Since $\eta < 0$, the influence of a greater response exchange-rate expectations to overshooting is to increase the denominator proportionally more than the numerator of the term immediately to the right of the equal sign and thereby reduce the degree of overshooting.

We must now incorporate the effects of market imperfections noted in the modern literature. It is argued that because of imperfect competition

[14] This insight first appeared in Rudiger Dornbusch, "Expectations and Exchange Rate Dynamics,", *Journal of Political Economy*, Vol. 84, No. 6, December 1976, 1161-76.

among firms and two-part monopoly pricing it can be usefully assumed that traded components of output are often priced in the currency of the buyer, with the result that the prices of these components do not respond to short-term movements of the nominal exchange rate. This pricing-to-market feature can be easily incorporated into equation (23) by simply multiplying the term $(1-\alpha)$ by a parameter that can take a value between zero and unity, representing the fraction of the traded component of output that is *not* priced in the currency of the buyer. Letting this parameter be ψ, we can write (23) as

$$\frac{\Delta\Pi^{rw}}{\Pi^{rw}} \quad = \quad -\,\frac{1-\eta\,\gamma}{\psi(1-\alpha)-\eta\,\gamma}\left[\frac{\Delta M_d}{M_d}-\frac{\Delta\Psi_M}{\Psi_M}-\eta\;\Delta\rho\right]. \qquad (24)$$

If there is complete pricing to market, $\psi = 0$ with the result that, η being negative, the term immediately to the right of the equal sign becomes larger negatively than otherwise. Indeed, if it also happens that expectations of the future level of the nominal exchange rate are independent of its current level, as would be the case if the exchange rate were a random walk, γ will equal zero and current-period equilibrium will not be possible—the exchange rate will go to zero or infinity in response to an exogenous monetary shock.

We must also take a broader view of monetary shocks, regarding them as excess-money-supply shocks that could occur as a result of exogenous changes in the demand for money as well as the money supply. The term in brackets on the right side of equation (24) indicates three sources of excess-money-supply shocks: exogenous shocks to the money supply, exogenous shocks to the demand for money represented by the relative change in Ψ_M and exogenous changes in the risk discount on domestic assets represented by changes in ρ.

To understand why the latter is a monetary shock, consider a situation in which the market comes to believe that domestic assets are more risky than previously thought. The resulting flight from domestic assets does not in itself put pressure on the nominal exchange rate because net sales of domestic assets cannot occur—the existing stock must be held by somebody.[15] Domestic asset prices and domestic interest rates must adjust until the unchanged existing stock is willingly held. But the rise in the domestic interest rate associated with the resulting increase in ρ increases the cost of holding money, causing the quantity demanded of it to decline. Given the new levels of domestic and rest-of-world interest rates, the resulting attempt to

[15] Keep in mind that the creation of new domestic intermediate assets involves the simultaneous creation of new liabilities of equal amount with the result that the net stock of domestic assets does not change.

convert domestic money holdings into non-monetary assets will necessarily result in an excess supply of domestic currency on the international market. The nominal exchange rate will have to decline until domestic residents are again willing to hold the existing stock of money.

Finally, we need to examine the real exchange rate changes associated with the above monetary shocks. Interpreting domestic exchange rates in equation (5) as with respect to the rest of the world rather than a particular foreign country and taking relative changes, normalising the prices of all non-traded components of output and foreign prices of traded components of domestic output at unity, we obtain

$$\begin{aligned} \frac{\Delta Q^{rw}}{Q^{rw}} &= \alpha \, \frac{\Delta \Pi^{rw}}{\Pi^{rw}} \\ &= [1-(1-\alpha)] \, \frac{\Delta \Pi^{rw}}{\Pi^{rw}} \end{aligned} \tag{25}$$

which can be modified to incorporate pricing to market as follows:

$$\frac{\Delta Q^{rw}}{Q^{rw}} = [1-\psi\,(1-\alpha)] \, \frac{\Delta \Pi^{rw}}{\Pi^{rw}}. \tag{26}$$

If all traded-components of domestic output are priced in home currency, irrespective of the exchange rate, $\psi = 0$ and

$$\frac{\Delta Q^{rw}}{Q^{rw}} = \frac{\Delta \Pi^{rw}}{\Pi^{rw}}. \tag{27}$$

If none of these components are so priced, $\psi = 1$ and

$$\frac{\Delta Q^{rw}}{Q^{rw}} = \alpha \, \frac{\Delta \Pi^{rw}}{\Pi^{rw}}. \tag{28}$$

In either case, it is clear from equation (1) that in the long run when all prices adjust

$$\frac{\Delta \Pi^{rw}}{\Pi^{rw}} = \frac{\Delta P_d}{P_d}$$

so that

$$\frac{\Delta Q^{rw}}{Q^{rw}} = 0$$

and the real exchange rate, which falls to the extent that the nominal exchange rate overshoots its long-run equilibrium, must always eventually return to its original level.

For reasonable values of the parameters it would seem likely that monetary shocks will lead to very substantial temporary movements in nominal and real exchange rates. Based on evidence summarised by David Laidler, -0.2 would represent a reasonable upper bound on the short-run elasticity of demand for money.[16] If we set the interest cost of holding money at 5%, the resulting interest semi-elasticity of demand for money will be -4.0. Although real exchange rates are not random walks, the degree of mean reversion is extremely small in that 50% of the full adjustment to temporary shocks will take from 3 to 5 years.[17] Accordingly, γ will be between .014 and .019.[18] If we set the share of non-traded output components in total output equal to 0.6 and assume that 90% of the traded component is priced to market we must conclude that a 1% excess money supply shock will cause the exchange rate to devalue by around 10%. And in the very short-run—say, a few days—when traded-goods prices in domestic currency and desired money holdings will be virtually unchanged, the overshooting effects of money shocks will be many times greater.

2.3 Interest Rates and Exchange Rates

The positive relationship between expected inflation and interest rates clearly suggests that devaluations of the domestic exchange rate consequent on domestic inflation will be positively associated with domestic relative to foreign nominal interest rates. There is also a literature that suggests, and finds, a positive relationship between interest rates and real exchange rates.[19] Care must be exercised, however, in interpreting such a relationship.

One interpretation is clearly incorrect. It is sometimes argued that the domestic central bank conducts monetary policy by raising and lowering interest rates. When it raises rates, so the argument goes, capital investment in the domestic economy becomes more attractive with the result that the net capital inflow increases, which in turn causes the domestic currency to appreciate. There are two problems with this argument. First, capital flows do not respond in the aggregate to changes in domestic relative to foreign interest rates. On the contrary, domestic/foreign interest differentials must continually adjust to ensure that world wealth holders are willing to hold the

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[16] David E. W. Laidler, *The Demand for Money*, Second Edition, New York: Dun-Donnelly, 1977, p. 133.

[17] See Kenneth Rogoff, "The Purchasing Power Parity Puzzle," *The Journal of Economics Literature*, Vol. 34, No. 2, June) 1996, 647-668.

[18] $\gamma = (1 - .5)^{1/n}$ where n is the number of months until 50% adjustment is achieved.

[19] See Royal Bank of Canada, "Drivers of the Canadian Dollar and Policy Implications", *Current Analysis*, 2, Royal Bank of Canada, 1988.

existing stocks of domestic and foreign assets. This is evident from equation (14).[20] The second problem with the argument is that unless a country is a large fraction of the world, its central bank can have virtually no influence on rest-of-world interest rates and, to the extent that domestic assets are imperfect substitutes for foreign assets, can only change domestic interest rates by changing the risk premium on the domestic assets—assuming for the moment that the market views the domestic exchange rate as a random walk.

The domestic central bank can, of course, increase the quantity of domestic non-monetary assets in portfolios, making them less desirable at the margin, but a 1% contraction of the domestic monetary base will create a trivial excess supply of domestic non-monetary assets as a fraction of the existing stock.[21] The money base is a small fraction of the stock of money which is, in turn, less than half the size of domestic income, which at a real interest rate of 5% is only one-twentieth of domestic wealth. So while the domestic central bank may have considerable control over the interest rate at which commercial banks loan reserves to each other on an overnight basis, it is difficult to imagine it having much effect on the general level of domestic interest rates. An exception would arise where the market expects nominal exchange rate movements to quickly reverse themselves—where the exchange rate is not a random walk. In this case, a contraction of the domestic stock of base money, which will lead asset holders to sell non-monetary assets for money, resulting in an appreciation of the domestic currency, will generate expectations of a future exchange rate depreciation (i.e., a fall in the value of domestic output, and hence capital, in the world market) and thereby cause domestic interest rates to rise in expectation of a future capital loss. The problem with this argument is that the real exchange rate, and the nominal rate at given inflationary expectations, are very close to being

[20]To a casual observer it may seem obvious that when a country's interest rates rise relative to those in the rest of the world individual wealth holders, given unchanged attitudes toward risk, will adjust their portfolios to include more of that country's assets. But there is a fallacy of composition here. When all asset holders try to buy the country's assets and sell an equivalent amount assets in their home countries, its interest rates will fall relative to those in the rest of the world until the existing mix of world assets is willingly held—world residents cannot buy more of a country's assets because the stock of those assets is fixed at each point in time.

[21]When the central bank reduces the money supply by selling domestic government bonds it increases both the supply of government bonds held by the public and future tax liabilities by the same amount. Even if the public does not feel wealthier it will have to sell assets to foreigners to reestablish its desired nominal money holdings and a higher fraction of these asset sales will consist of domestic assets than the mix of domestic-foreign assets foreigners will be willing to purchase at existing interest rates.

random walks—it is difficult to imagine observed day-to-day movements in the exchange rate generating expected future movements in the opposite direction of any significant magnitude.

Given that real exchange rates do mean revert in the long-run and exhibit no trend over very long periods of 100 years or so, it is plausible to expect that when real exchange rates are high relative to their historic mean the risk of future loss on holdings of domestic capital will increase relative to the possibility of future capital gain. Accordingly the country's interest rates would be expected to rise relative to those abroad—that is, ρ in equation (14) might be expected to increase. Moreover, in the presence of a substantial monetary shock that is known to be temporary and far in excess of what might normally be observed, wealth holders might well anticipate a return of the nominal exchange rate to more normal levels, causing the country's interest rates to rise relative to those abroad.

But these arguments, together with those that clearly recognise a relationship between inflationary monetary expansion and interest rates, imply that the causation runs from exchange rates to interest rates rather than from interest rates to exchange rates. This suggests that observed positive coefficients of interest rates included in regressions of real exchange rates on real incomes, real net capital flows, real commodity prices and the relative terms of trade reflect reverse causality.

Finally, another possible positive relationship between a country's real exchange rate and its interest rates might arise because a shift of world investment towards the domestic economy involves an expansion of domestic investment in risky industries, causing average real and nominal interest rates in the domestic economy to rise. This involves a simultaneous response of both real interest rates and the real exchange rate to third factors. Unless a large fraction of the country's economy is involved in the investment expansion, however, it would seem unlikely that this expansion would be reflected in the interest rates on domestic government bonds—the effect on the default risk of holding those instruments would have to be minimal.

3 Evidence Regarding the Influence of Real Shocks

Our next task is to try to determine the extent to which observed real exchange rate changes are a consequence of real shocks to technology and capital accumulation. This is, of course, a difficult undertaking because we have available no useful models of technological change. We are limited to attempting to discern whether observed real exchange rate movements can be 'explained' by factors, such as income growth, terms of trade changes, world oil and commodity price changes, shifts in world investment, differential changes in government activity, that would obviously be expected to influence countries' real exchange rates. The real exchange rates with respect to the United States of Canada, the United Kingdom and Japan for the period 1974 through 2002, France for the period 1974 through 1998, and Germany for the period 1974 through 1989 will be examined. The periods for both France and Germany are shortened to end with European exchange market unification and the German analysis is further restricted to avoid data complications resulting from the merging of East Germany with West. All data are quarterly. After the investigation of real shocks an attempt will be made in the subsequent two sections to investigate the extent to which observed real exchange rate movements have been in response to monetary shocks.

3.1 Canada vs. United States

The movements in Canada's real and nominal exchange rates with respect to the U.S. since the late 1950s along with the variations in the ratio of the Canadian to the United States price level are shown in Figure 1. Since the mid-1970s the trend has been downward, with a decline of around 25% between 1977 and 1985, a rise of more than 20% between 1985 and 1992 and a further fall of over 30% from 1992 through 2002.

The results of OLS regressions of the real exchange rate on various real variables are presented in Table 1. The excess of Canadian government consumption expenditures as a percentage of GDP over the corresponding variable in the United States is not included in the regressions shown because it is statistically insignificant. The same is true of the oil price variable, which consists of the logarithm of U.S. crude oil prices relative to an equally weighted average of U.S. export and import prices, and the logarithm of Canada's terms of trade with respect to the United States.[22] In every case

[22] The unavailability of terms of trade data for the other ccountries with respect to the United States forces us to use the logarithm of the ratio of domestic to the U.S. terms of

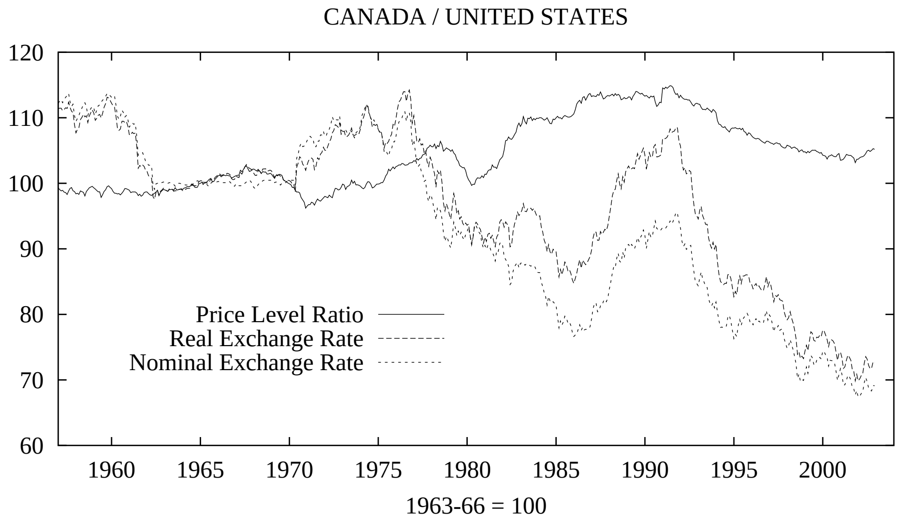

Figure 1: Real and nominal exchange rate and ratio of price levels, Canada vs. the United States. Source: *Reuters*, International Monetary Fund *International Financial Statistics.*

substantial serial correlation is present in the residuals as evidenced by LM-based tests for first-order autocorrelation and Ljung-Box Q-statistics for higher orders.[23] This is, of course, not surprising because many technological forces that are correlated with time will not be captured by the crude regression analysis that could be applied. Accordingly, heteroskedasticity and autocorrelation consistent (HAC) standard-errors were calculated and are shown in the square brackets in Figure 1 below the conventional standard errors.[24]

The regression results shown in the first column of Table 1 indicate what one would have expected. The logarithm Canadian real exchange rate with respect to the United States is positively related to the logarithm of the ratio of U.S. commodity prices (excluding energy) to an equally weighted average of U.S. export and import prices, and to the excess of the real net capital inflow into Canada over the real net capital inflow into the United States, both taken as percentages of the respective countries GDP. An increase in Canadian real GDP is associated with a rise in the real exchange

trade in those cases.

[23]The former is an F-test of the significance of e_{t-1} in the regression

$$e_t = \alpha + \mathbf{X}\beta + \gamma\, e_{t-1} + u_t$$

where e_t are the residuals and $\mathbf{X}$ the matrix of regressors in the original regression and β is a column vector. The latter is a standard test available in most commercial econometric software programs.

[24]The HAC standard errors were calculated using the formulas in James H. Stock and Mark W. Watson, *Introduction to Econometrics*, Addison Wesley, 2003, page 505, and the truncation parameter was set equal to $0.75T^{1/3}$ rounded to an integer.

Table 1: OLS Regression Analysis of Real Factors Affecting the Real Exchange Rate: Canada vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Logarithm of Real Exchange Rate					
Constant	6.733 (0.463)*** [0.785]***	6.554 (0.230)*** [0.462]***	3.878 (0.247)*** [0.341]***	5.306 (0.421)*** [0.695]***	5.199 (0.424)*** [0.706]***	5.981 (0.396)*** [0.660]***
Log of Commodity Prices	0.107 (0.053)** [0.091]		0.197 (0.052)*** [0.071]***	0.161 (0.050)*** [0.083]*	0.173 (0.051)*** [0.087]**	0.094 (0.048)** [0.075]
Real Net Capital Inflow	0.025 (0.002)*** [0.005]***	0.025 (0.002)*** [0.005]***	0.031 (0.003)*** [0.004]***	0.018 (0.002)*** [0.005]***	0.018 (0.002)*** [0.005]***	0.018 (0.003)*** [0.005]***
Log of U.S. Real GDP	-0.835 (0.173)*** [0.439]	-0.204 (0.027)*** [0.055]***		-0.152 (0.028)*** [0.051]***	-0.148 (0.028)*** [0.051]***	-0.196 (0.028)*** [0.051]***
Log of Canadian Real GDP	0.741 (0.277)** [0.491]			1-Mo. Corp. Paper	3-Mo. Treas. Bill	L-Term Gov't Bonds
Interest Rate Differential				0.018 (0.003)*** [0.005]***	0.019 (0.004)*** [0.005]***	0.038 (0.008)*** [0.013]***
Num. Obs.	116	116	116	116	116	116
R-Square	.822	.808	.744	.846	.848	.839

Notes and Sources: The commodity price variable is an index of world commodity prices in U.S. dollars divided by an equal weighted index of U.S. export and import prices. The real net capital inflow variable is the negative of the Canadian current account balance as a percentage of domestic GDP minus the negative of the U.S. current account balance as a percentage of that country's GDP. The interest rate differential is Canada minus U.S. The figures in the brackets ( ) are the standard deviations of the coefficients as conventionally calculated and the figures in the brackets [ ] are the corresponding heteroskedastic and autocorrelation adjusted standard errors with truncation lag equal to 4. Significant serial correlation is present in the residuals of all the standard regressions. The superscripts *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively according to a standard t-test. Source: International Monetary Fund, *International Financial Statistics.*

rate while an increase in U.S. real GDP is associated with a fall, as the Balassa-Samuelson hypothesis would predict. Unfortunately, the commodity price and Canadian real GDP variables do not survive the imposition of HAC standard errors. When these variables are dropped from the regression the U.S. real GDP variable assumes the entire role of accounting for trend. Replacing it with the commodity price variable, which then becomes significant and accounts for trend that cannot be explained by the net capital inflow variable, yields a somewhat poorer fit. The relationship between the real exchange rate and the real net capital inflow variable is remarkable. Figure 2 shows the effects on the real exchange rate of the real capital inflow and commodity price variable. We can conclude that, apart from trend, the excess of real net capital inflows into Canada as a percentage of GDP over real net capital inflows into the United States as a percentage of that country's GDP is the major distinctive factor explaining movements in Canada's real exchange rate with respect to the United States. In addition, it would appear that the real factors we have been able to capture in a rather crude fashion explain about 80 percent of the movements in the real exchange rate.

The right-most three columns of Table 1 add Canadian minus U.S. interest rate differentials to the regression. The addition of 1-month corporate paper rate differentials or the interest rate differentials on 3-month treasury bills resurrects the significance of the commodity price variable with HAC standard errors but the Canadian real GDP variable still does not survive. Neither the commodity price variable nor Canadian real GDP survives the addition of the interest rate differential on long-term government bonds. The interest rate differentials are everywhere significant at the 1 percent level.

As noted in the previous section, the causation when we include interest rate differentials is probably the reverse of that specified by the regressions—it is likely that interest rate differentials rather than the real exchange rate are being explained by the remaining variables. Accordingly, the interest rate differentials are made the dependent variables in the regression results shown in Table 2. In regressions explaining the two short-run interest rate differentials both real income variables are now statistically significant with U.S. real income having a negative sign and Canadian real income a positive one. The commodity price variable has a negative sign indicating that a fall in commodity prices increases the risk premium on the Canadian assets. Either but not both of the real net capital inflow and real exchange rate variables turn out to be statistically significant with the real exchange rate giving a better fit. The sign is positive, indicating that a rise in Canada's real exchange rate with respect to the United States increases the risk of

Table 2: OLS Regression Analysis of Factors Determining Canadian Relative to United States Interest Rates

Independent Variables	Dependent Variable: 1-Month Corp. Paper		3-Month T-Bills		Long-Term Govt. Bonds	
Constant	-2.915 (13.998) [19.089]	73.953 (10.435)*** [15.267]***	10.573 (12.173) [17.442]***	85.388 (8.959) [13.404]	-21.423 (6.435)*** [9.764]***	12.240 (4.706)*** [9.101]
Log of Commodity Prices	-4.513 (1.151)*** [1.470]***	-3.650 (1.194)*** (1.341)***	-3.923 (1.001)*** [1.265]***	-3.162 (1.025)*** [1.078]***	-0.761 (0.529) [0.800]	-0.411 (0.538) [0.711]
Log of U.S. Real GDP	-20.949 (5.266)*** [7.520]***	-31.037 (5.472)*** [8.438]***	-31.023 (5.479)*** (6.466)***	-40.964 (4.698)*** [7.383]***	-3.545 (2.421) [3.504]	-8.005 (2.468)*** [3.833]**
Log of Canadian Real GDP	23.637 (5.893)** [8.533]***	33.185 (6.230)*** [9.432]***	34.901 (5.125)*** (7.299)***	44.436 (5.349)*** [8.277]***	5.123 (2.709)* [3.866]*	9.388 (2.809)*** [4.152]**
Real Net Capital Inflow		11.490 (1.439)*** [1.892]***		0.374 (0.046)*** [0.065]***		0 .166 (0.024)*** [0.036]***
Log of Real Exch. Rate	11.490 (1.439)*** [1.892]***		11.199 (1.251)*** (1.740)***		5.037 (0.662)*** [0.739]***	
Num. Obs.	116	116	116	116	116	116
R-Square	.547	.495	.649	.619	.401	.358

Notes and Sources: The variables are the same as in Table 1. The figures in the brackets ( ) are the standard deviations of the coefficients as conventionally calculated and the figures in the brackets [ ] are the corresponding heteroskedastic and autocorrelation adjusted standard errors with truncation lag equal to 4. Significant serial correlation is present in the residuals of all the standard regressions. The superscripts *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively according to a standard t-test. Source: International Monetary Fund, *International Financial Statistics.*

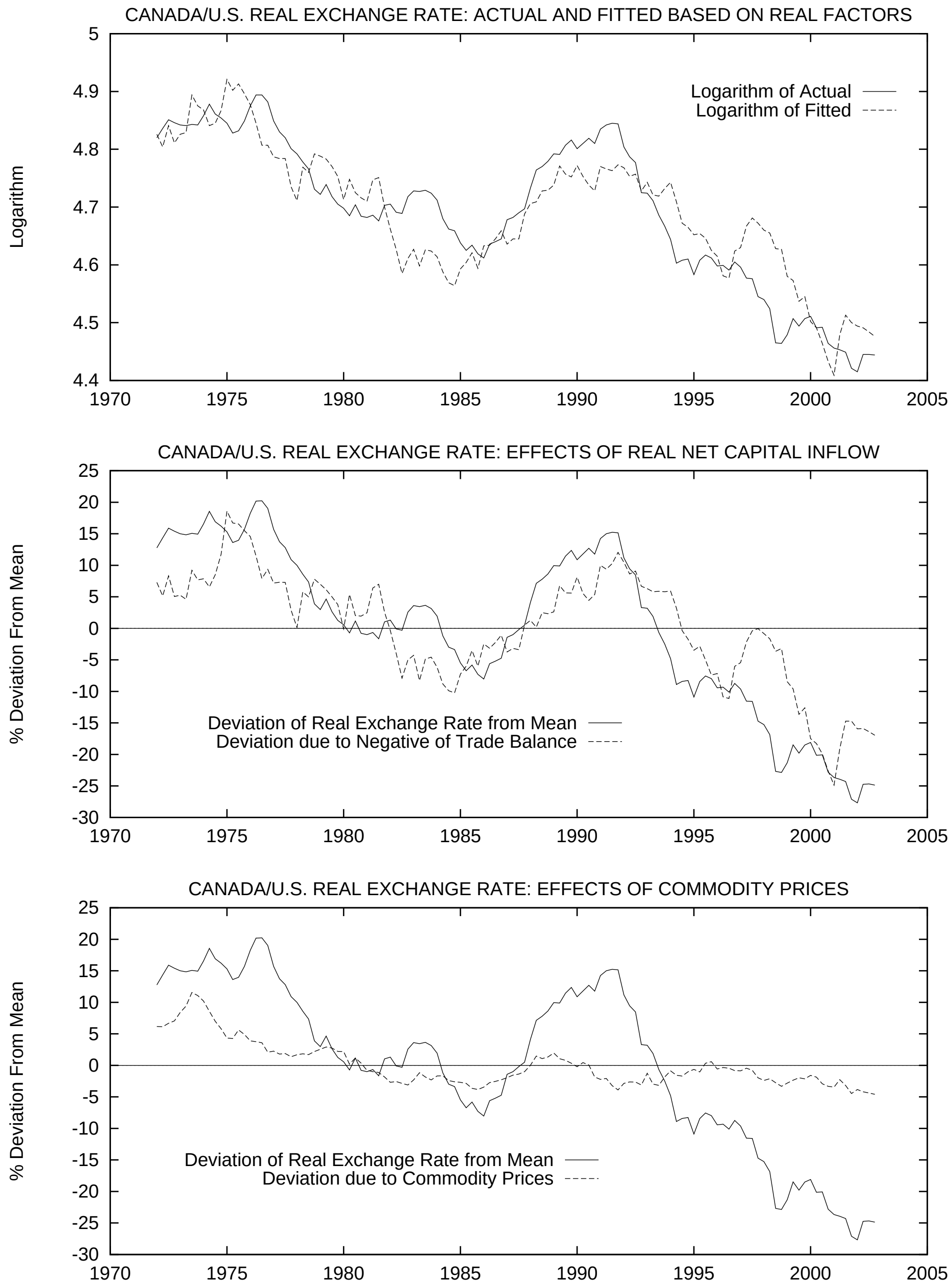

Figure 2: The effects of real net capital inflows and the prices of commodities exclusive of energy on the Canadian real exchange rate with respect to the United States. Source: International Monetary Fund *International Financial Statistics*.

holding Canadian short-term assets. This is consistent with the notion that mean reversion of the real exchange rate can be expected in the long-run. The real net capital inflow variable, which as noted above is closely related to real exchange rate movements, seems to be performing the same function as the real exchange rate in the regression, albeit more poorly. One cannot reject the notion that the forces that lead to real net capital inflows are associated with increased risk of holding domestic assets although it is difficult to imagine how the default risk on 3-month treasury bills could be affected.

The fit is considerably worse in the case where the interest rate differential on long-term government bonds is the dependent variable. The commodity price variable is always insignificant and of the two real income variables only the Canadian one survives, and then only at the ten percent level, when the real exchange rate rather than the real net capital inflow variables is included. While the fit is better when the real exchange rate is used, both income variables are significant when the real net capital inflow variable is used instead.

Although it is well-known that the expected inflation rate is a major factor determining interest rates, a variable consisting of the excess of the Canadian over the U.S. inflation rate is statistically insignificant in all cases when added to the interest rate differential regressions. This suggests that the previously included variables that were significant in determining the nominal interest rate differentials are probably also the major determinants of the inflation rate differential so that the inclusion of the latter variable adds nothing. Regressions of interest differentials on the inflation differential alone (not shown) indicate significant relationships in the case of the short-term interest rate differentials but no significant relationship in the case of long-term government bonds. Inflation differentials were apparently not of significant magnitude to have explanatory power over observed long-term interest rates. This suggests that the monetary policies of the two countries could not have been very different overall.

3.2 The Problem of Spurious Regression

It is well-known that when unrelated non-stationary time-series variables are regressed on each other statistically significant relationships often appear. It is necessary, therefore, to establish that the above regression results are not spurious. Dickey-Fuller and Phillips-Perron stationarity tests were performed on all variables appearing in the above regressions. The results are shown in Table 3. Three models were fit to each series:

Model 1

$$
\begin{aligned}
\text{Dickey-Fuller:} \quad \Delta y_t &= a_0 + a_1\, y_{t-1} + a_2\, t + a_3\, \Delta y_{t-1} + a_4\, \Delta y_{t-2} \\
&\qquad + \ldots\ldots + a_{p+2}\, \Delta y_{t-p} + u_t \\
\text{Phillips-Perron:} \quad y_t &= \hat{a}_0 + \hat{a}_1\, y_{t-1} + \hat{a}_2\,(t - n/2) + \tilde{u}_t
\end{aligned}
$$

Model 2

$$
\begin{aligned}
\text{Dickey-Fuller:} \quad \Delta y_t &= b_0 + b_1\, y_{t-1} + b_3\, \Delta y_{t-1} + b_4\, \Delta y_{t-2} \\
&\qquad + \ldots\ldots + b_{p+2}\, \Delta y_{t-p} + v_t \\
\text{Phillips-Perron:} \quad y_t &= \hat{b}_0 + \hat{b}_1\, y_{t-1} + \tilde{v}_t
\end{aligned}
$$

Model 3

$$
\begin{aligned}
\text{Dickey-Fuller:} \quad \Delta y_t &= c_1\, y_{t-1} + c_3\, \Delta y_{t-1} + c_4\, \Delta y_{t-2} \\
&\qquad + \ldots\ldots + c_{p+2}\, \Delta y_{t-p} + w_t \\
\text{Phillips-Perron:} \quad y_t &= \hat{c}_1\, y_{t-1} + \tilde{w}_t
\end{aligned}
$$

In all three models the null hypothesis is non-stationarity. The appropriate number of lags of Δy in the Dickey-Fuller tests is chosen on the basis of the Akaike and Bayes-Schwartz information criteria. In the first model we test whether $a_1 < 0$, $a_0 \neq 0$ and $a_2 \neq 0$ and whether $\hat{a}_1 < 1$, $\hat{a}_0 \neq 0$ and $\hat{a}_2 \neq 0$. When these three conditions all hold for the particular test we can reject the null hypothesis of non-stationarity in favour of the alternative hypothesis of stationarity around drift, indicated by a constant term significantly different from zero and around trend, indicated by a coefficient of the time-trend variable significantly different from zero. In the second model we test whether $a_1 < 0$ and $a_0 \neq 0$ and whether $\hat{a}_1 < 1$ and $\hat{a}_0 \neq 0$. When both conditions hold for a particular test we can reject the null hypothesis of non-stationarity in favour of the alternative of stationarity around drift, indicated by the constant term significantly different from zero. Finally, in the third model we simply test whether $a_1 < 0$ in the Dickey-Fuller test and $\hat{a}_1 < 1$ in the Phillips-Perron test. If so we can reject the null hypothesis of non-stationarity in favour of stationary without regard to drift and trend.[25] The results are shown in Table 3.

[25] In these tests the critical values are not those of the standard t-tests because the distributions of the statistics are non-standard when the null-hypothesis holds. Details of the tests together with the appropriate critical values can be found in Walter Enders, *Applied Econometric Time Series*, Wiley Series in Probability and Mathematical Statistics, John Wiley & Sons, 1995.

Table 3: The Results of Dickey-Fuller and Phillips-Perron Unit Root Tests of Variables in the Regressions in Table 1 and Table 2.

Model →		[1]			[2]		[3]
Variable	Test	Constant	Time	Y_{t-1}	Constant	Y_{t-1}	Y_{t-1}
Real Exchange Rate	DF						
	PP						10%
Commodity Prices / Traded Goods Prices: U.S.	DF				1%	1%	10%
	PP						
Canadian less U.S. Net Capital Inflow / GDP	DF						
	PP						
Canadian Real GDP	DF						
	PP						
U.S. Real GDP	DF	5%	1%	5%			
	PP						
Canadian less U.S. CPI Inflation Rates	DF			1%		1%	1%
	PP			1%	*nc*	1%	1%
Canada minus U.S. Interest Rate Differentials							
1-month Corporate Paper	DF			10%		5%	5%
	PP			10%	*nc*	5%	1%
3-month Treasury Bills	DF			10%	10%	10%	10%
	PP						10%
Long-Term Government Bonds	DF						
	PP				*nc*	5%	

Notes: The real exchange rate, commodity price and real income variables are in logarithms. Traded goods prices are defined as an equally weighted average of U.S. export and import prices. The percentages indicate the level at which the null hypothesis of non-stationarity can be rejected. Blank spaces indicate nonrejection and *nc* means that no calculation was recorded. DF refers to the Dickey-Fuller test and PP to the Phillips-Perron test. The calculations cover the period 1972 through 2002.

Keeping in mind that these tests are low powered—that is, they fail to reject the null hypothesis of non-stationarity very frequently when a_1 and $\hat{a}_1$ are close to 0 and 1 respectively and the series is therefore stationary with high persistence—we should reject non-stationarity when either of the tests gives a clear rejection. Accordingly, we should conclude that the commodity price variable is stationary around drift and that the logarithm of U.S. real GDP is stationary around drift and trend. The inflation rate differential and the interest rate differentials on 1-month corporate paper and 3-month treasury bills are clearly stationary. The real net capital inflow variable and the logarithm of Canadian real GDP are non-stationary. The evidence for stationarity of the log of Canada's real exchange rate with respect to the United States and the interest rate differential on long-term government bonds is weak so we should probably begin by assuming that these variables are non-stationary.

The second and third regressions from the left in Table 1 thus appear to involve the regression of a non-stationary dependent variable (the real exchange rate) on one non-stationary variable (the real net capital inflow variable) and one stationary variable (U.S. real GDP or the commodity price variable). To establish that the regressions are not spurious we need to show that the real exchange rate and the real net capital inflow variables are cointegrated. This is done using a Johansen test.

The Johansen procedure works with a VAR representation of the variables

$$\mathbf{y_t} \;=\; \mathbf{b} + \mathbf{B_1}\,\mathbf{y_{t-1}} + \mathbf{B_2}\,\mathbf{y_{t-2}} \ldots\ldots + \mathbf{B_p}\,\mathbf{y_{t-p}} + \mathbf{e_t}$$

where $\mathbf{y_t}$ is an m-dimensional vector containing the time-t values of the m variables in the VAR, $\mathbf{b}$ is a m-dimensional column vector, the $\mathbf{B_j}$ are $m \times m$ matrices of coefficients and $\mathbf{e_t}$ is an m-dimensional column vector of time-t error terms. This equation can be transformed into

$$\mathbf{\Delta y_t} \;=\; \mathbf{b} - \mathbf{Z_0}\,\mathbf{y_{t-1}} + \mathbf{Z_1}\,\mathbf{\Delta y_{t-1}} \ldots\ldots + \mathbf{Z_{p-1}}\,\mathbf{\Delta y_{t-p+1}} + \mathbf{e_t}$$

where

$$\begin{aligned}
\mathbf{Z_0} &= \mathbf{I_m} - \mathbf{B_1} + \mathbf{B_2} + \ldots\ldots + \mathbf{B_p} \\
\mathbf{Z_1} &= \mathbf{B_2} + \mathbf{B_3} + \ldots\ldots + \mathbf{B_p} \\
\mathbf{Z_2} &= \mathbf{B_3} + \mathbf{B_4} + \ldots\ldots + \mathbf{B_p} \\
\ldots &= \ldots\ldots\ldots \\
\mathbf{Z_{p-1}} &= \mathbf{B_p}
\end{aligned}$$

and $\mathbf{I_m}$ is an $m \times m$ identity matrix. For the variables to be cointegrated the rank of $\mathbf{Z_0}$, which is its number of non-zero characteristic roots or eigenvalues, must be positive. If the rank equals one there will be a single cointegrating vector which will be the eigenvector associated with the non-zero eigenvalue. If additional eigenvalues are positive there will be multiple cointegrating vectors but the total number cannot exceed $m - 1$. The Johansen procedure estimates $\mathbf{Z_0}$ and its eigenvalues along with two statistics which can be called the L-max and the Trace statistics. The L-max statistic is used to decide whether the null hypothesis of h $(0 < h < m - 2)$ cointegrating vectors can be rejected in favour of $h + 1$ cointegrating vectors. The Trace statistic is used to decide whether the null hypothesis of h cointegrating vectors can be rejected in favour of more than h cointegrating vectors.

A Johansen test of the two variables, the real exchange rate and the real net capital inflow variable yields the following result:

Cointegration Vectors Under the Null Hypothesis	Eigen-Values	L-max	Trace
0	0.135	16.768	17.645
1	0.008	0.876	0.876
Lags = 4			

The number of lags p is set at 4 based on the Akaike Information Criterion (AIC). It turns out that the Trace statistic of 17.645 is greater than the 10% critical value of 15.583 and almost equal to the 5% critical value of 17.844 while the L-max statistic of 16.768 is greater than the 5% critical value of 14.035.[26] We can therefore conclude that there is a single cointegrating vector. It turns out that this vector, normalised so that the element corresponding to the real exchange rate variable is unity, is equal to $(-1.000, 0.045)$, which implies that the real exchange rate and real net capital inflow are positively related, as consistent with the OLS regressions in Table 1 and the middle plot in Figure 2. Given that the real exchange rate and the real net capital flow variables are cointegrated, the residual from their cointegrating vector is stationary and correlated with U.S. real GDP and the commodity price variable in the second and third regressions from the left in Figure 1.

[26] Details of this test together with the appropriate critical values can be found in Chapter 6 of the book by Walter Enders cited in the previous footnote.

Given the low power of the Dickey-Fuller and Phillips-Perron tests and using basic common-sense economics, it might be more sensible to assume that the real exchange rate and net capital inflow variables are, in fact, stationary. Using annual data for the Canadian real exchange rate with respect to the U.S. for the period 1874 through 2002, we can reject the null hypothesis of non-stationarity when we allow for a trend-shift in 1974.[27] And clearly, it makes no sense to assume that the ratio of net capital inflows to GDP is boundless, as it would be under non-stationarity. But even if we assume stationarity of all variables, including Canadian real GDP, the serial correlation in the residuals cannot be ignored. Once HAC standard errors of the coefficients are used, the only variables that survive are the real net capital inflow and a trend variable related to but more encompassing than the commodity price variable. It is reasonable to argue that full confidence is possible only in the implications of the second and third regressions from the left in Table 1. Yet the real net capital inflow variable and trend, consisting significantly but not exclusively of commodity prices, can explain about 80% of the variance of the real exchange rate. The role of the real net capital inflow variable is especially startling in that the importance of this determinant of movements in the Canadian real exchange rate with respect to the U.S. has been given little emphasis in public discussion—it is the most important identifiable factor generating observed real exchange movements since 1974.

Spurious regression cannot be a correct explanation of the regression results in the left-most four regressions in Table 2. The reason is that the dependent variables are clearly stationary—non-stationary variables on the right-hand side of the equation that are not cointegrated among themselves cannot be statistically significant because they cannot explain movements in a stationary dependent variable. We have to conclude that the logarithm of Canadian real GDP is cointegrated with the real net capital inflow variable and also with the logarithm of the real exchange rate with respect to the U.S. Or, alternatively, we must conclude that all these variables are stationary. The results of separate Johansen tests on the two pairs of variables do not support the conclusion that they are cointegrated—when there is a statistically significant cointegrating vector the null hypothesis that at least one of the variables is not in it cannot be rejected, and when the variables are clearly in the would-be cointegrating vector we cannot reject the null

[27] See John E. Floyd, "Real Exchange rates, Efficient Markets and Uncovered Interest Parity: A Review," Unpublished Manuscript, University of Toronto, October 27, 2004, pages 14-16.

hypothesis that the associated eigenvalue is zero. The most sensible conclusion would seem to be that the three variables are stationary but so highly persistent that the Dickey-Fuller or Phillips-Perron tests have insufficient power to reject non-stationarity.

Turning now to the regressions that use the Canada minus U.S. interest rates on long-term government bonds as the dependent variable in the right-most two columns of Table 2, the sensible conclusion would also seem to be that all variables are stationary. The case for stationarity of the long-term interest rate differential is not as strong as that for stationarity of the short-term interest rate differentials, but the variables on the right-hand sides of the equations that are statistically significant were also statistically significant in the short-term interest differential regressions where the dependent variable was clearly stationary.

3.3 United Kingdom vs. United States

The real and nominal exchange rates of the United Kingdom with respect to the United States as will as the ratio of the U.K. consumer price index to the U.S. consumer price index are shown in Figure 3 on a base of 1963-66=100. The price level has risen substantially in the U.K. relative to the U.S. following the breakdown of the Bretton-Woods system in the early 1970s. This is reflected in a downward trend of the nominal value of the pound in terms of the U.S. dollar. The real exchange rate is highly variable but exhibits little trend.

Table 4 gives the results of Dickey-Fuller and Phillips-Perron tests of stationarity of the variables appearing in the regressions in Tables 5 and 6. Given the low power of these tests, one can conclude that all the variables are stationary—non-stationarity can be rejected at the 5% level or better in one or both tests in the cases of all but the U.K. less U.S. interest rate differential on long-term government bonds and at the 10% level in that case. Accordingly, spurious regression should not be a problem with the results presented in Tables 5 and 6.

With HAC standard errors, the only variables that survive in the regression of the real exchange rate of the U.K. vs. the U.S., shown in the left-most column of Table 5, are the commodity price, terms of trade ratio and oil price variables. Slightly under 60% of the variance of the real exchange rate can be explained by these three variables. HAC standard errors are necessary because substantial serial correlation in the residuals of the standard regression is present. This should be interpreted as evidence of unknown left-out autocorrelated variables. It is worth noting that the difference between the

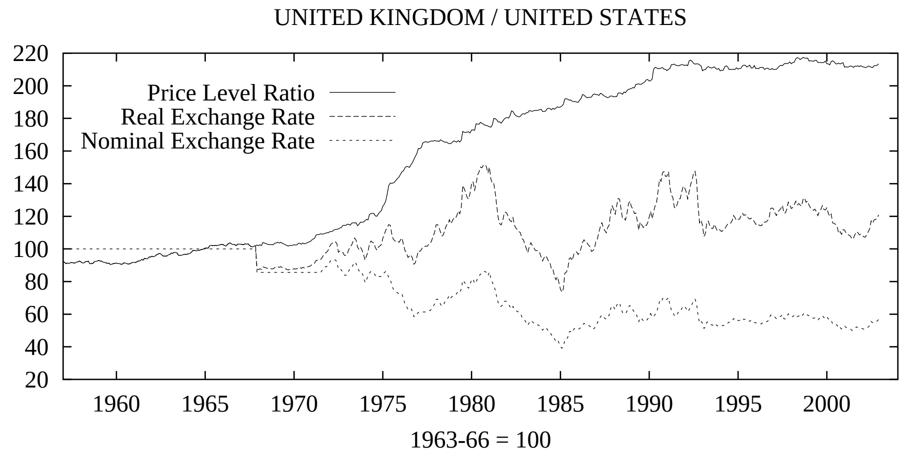

Figure 3: Real and nominal exchange rate and ratio of price levels, United Kingdom vs. the United States. Source: *Reuters*, International Monetary Fund *International Financial Statistics*.

net capital inflow into the U.K. as a percentage of GDP and the net capital inflow in to the U.S. as a percentage of GDP is not statistically significant in these regressions—evidently net capital flows do not play the role here that they played in the Canada/United States regressions. Here, as noted in Figure 4, ratio of the U.K. terms of trade to the U.S. terms of trade is clearly related to the real exchange rate between 1974 and the early 1990s, while crude oil prices appear related from the late 1980s onward as might be expected from the importance of North Sea oil during that period.

Two important predictive failures of the basic U.K./U.S. real exchange rate regression are clearly evident in the top panel of Figure 4. The downward spike of the real exchange rate centered on 1985 is unaccounted for, as is a temporary upward movement in the early 1990s. The former will be discussed subsequently in relation to the explanation of a similar spike in the real exchange rates of France and Germany with respect to the United States, and the latter will be shown in the next section as an example of an identifiable monetary shock.

The addition of the excess of U.K. over U.S. treasury bill rates to the basic regression changes very little and the added variable survives HAC standard errors only at the 10% level. The U.K. less U.S. long-term government bond rate differential reduces the coefficient of the commodity price variable by more than one-third and increases the other two coefficients slightly. And it is significant at the 1% level.

Table 4: The Results of Dickey-Fuller and Phillips-Perron Unit Root Tests of Variables in the United Kingdom Regressions in Table 5.

Model →		[1]			[2]		[3]
Variable	Test	Constant	Time	Y_{t-1}	Constant	Y_{t-1}	Y_{t-1}
Real Exchange Rate	DF				1%	5%	
	PP						
Commodity Prices / Traded Goods Prices: U.S.	DF				1%	1%	10%
	PP						
Crude Oil Prices / Traded Goods Prices: U.S.	DF				5%	5%	
	PP						
U.K. Terms of Trade / U.S. Terms of Trade	DF						1%
	PP						5%
U.K. / U.S. Govt Consumption Expenditure / GDP	DF				5%	5%	
	PP				*nc*	10%	
U.K. less U.S. Net Capital Inflow / GDP	DF				10%	5%	5%
	PP						5%
U.K less U.S. CPI Inflation Rate	DF	5%	5%	1%		5%	1%
	PP			10%			5%
U.K. minus U.S. Interest Rate Differentials							
3-month Treasury Bills	DF			10%	10%	5%	5%
	PP			5%	*nc*	1%	5%
Long-Term Government Bonds	DF						10%
	PP						

Notes: Traded goods are defined as an equally weighted average of U.S. export and import prices. The real exchange rate, commodity price and oil price variables are in logarithms. The percentages indicate the level at which the null hypothesis of non-stationarity can be rejected. Blank spaces indicate nonrejection and *nc* means that no calculation was recorded. DF refers to the Dickey-Fuller test and PP to the Phillips-Perron test. The calculations cover the period 1972 through 2002.

Table 5: OLS Regression Analysis of Real Factors Affecting the Real Exchange Rate: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Logarithm of Real Exchange Rate		
Constant	3.730 (0.325)*** [0.405]***	3.686 (0.308)*** [0.399]***	4.664 (0.375)*** [0.565]***
Log of Commodity Prices	0.493 (0.073)*** [0.111]***	0.493 (0.069)*** [0.114]***	0.295 (0.083)*** [0.119]***
Log of U.K. T.O.T. / U.S. T.O.T.	1.561 (0.132)*** [0.166]***	1.688 (0.129)*** [0.198]***	1.773 (0.133)*** (0.233)***
Log of Oil Prices	-0.256 (0.029)*** [0.058]***	-0.252 (0.027)*** [0.056]***	-0.262 (0.027)*** [0.052]***
U.K. less U.S. T-Bill Rate Differential		0.013 (0.004)*** [0.007]*	
U.K. less U.S. LT-Govt. Bond Rate Differential			0.022 (0.005)*** [0.010]***
Num. Obs.	116	116	116
R-Square	.582	.628	.638

Notes and Sources: The commodity price and oil price variables are commodity prices (excluding energy) and crude oil prices, respectively, in U.S. dollars divided by an equally weighted average of U.S. export and import prices. The figures in the brackets ( ) are the standard deviations of the coefficients as conventionally calculated and the figures in the brackets [ ] are the corresponding heteroskedastic and autocorrelation adjusted standard errors with truncation lag equal to 4. The superscripts *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Source: International Monetary Fund, *International Financial Statistics.*

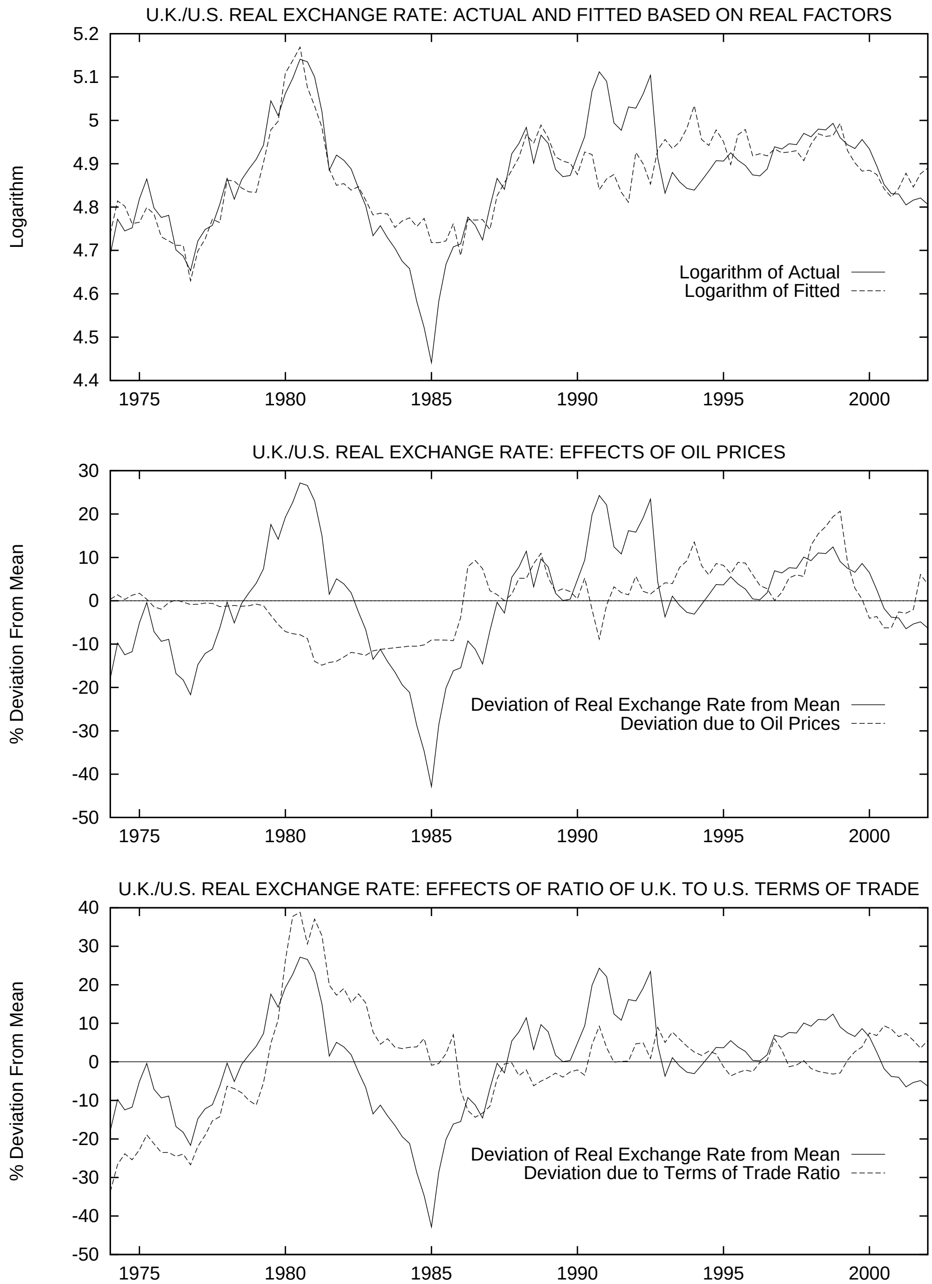

Figure 4: Actual and fitted values of the United Kingdom's real exchange rate with respect to the United States and the effects on it of oil prices and the ratio of the U.K. terms of trade to the U.S. terms of trade. Source: International Monetary Fund *International Financial Statistics*.

Table 6: OLS Regression Analysis of Factors Affecting United Kingdom Minus United States Interest Rate Differentials, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable T-Bill	T-Bill	LT-Gov-Bond	Independent Variables
Constant	27.192 (9.388)*** [15.934]*	36.429 (7.468)*** [12.512]***	-0.163 (5.900) [11.011]	Constant
Log of Commodity Prices	-6.655 (1.593)*** [2.444]***	-6.626 (1.604)*** [2.666]**	-21.591 (1.595)*** [2.704]***	Log of U.K. T.O.T. / U.S. T.O.T.
U.K. less U.K. Govt. Cons. /GDP.	-0.878 (0.200)*** [0.286]***	-0.866 (0.201)*** [0.275]***	0.531 (0.135)*** (0.183)***	U.K. less U.K. Govt. Cons. /GDP.
U.K. less U.S. NCI /GDP	0.478 (0.108)*** [0.168]***	0.487 (0.109)*** [0.179]***	-4.447 (0.453)*** [0.786]***	Log of U.S. Real GDP
U.K. less U.S. CPI Inflation	0.315 (0.051)*** [0.080]***	0.302 (0.051)*** [0.079]*		U.K. less U.S. CPI Inflation
Log of Real Exchange Rate	1.925 (1.200) [2.154]		7.906 (0.943)*** [1.573]***	Log of Real Exchange Rate
Num. Obs.	116	116	116	Num. Obs.
R-Square	.510	.499	.788	R-Square

Notes and Sources: The commodity price variable is commodity prices (excluding energy) in U.S. dollars divided by an equally weighted average of U.S. export and import prices. The figures in the brackets ( ) are the standard deviations of the coefficients as conventionally calculated and the figures in the square brackets [ ] are the corresponding heteroskedastic and autocorrelation adjusted standard errors with truncation lag equal to 4. The superscripts *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Source: International Monetary Fund, *International Financial Statistics.*

Again, a plausible interpretation of the two right-most regressions in Table 5 might be that the causation runs from real exchange rates to interest rates. The interest rate differentials are the dependent variables in the regression results shown in Table 6. The real exchange rate variable is not statistically significant in the treasury bill rate differential regression even before HAC standard errors are applied. This is consistent with the weak performance of the T-Bill rate differential in the middle regression in Table 5. And the variables that significantly explain the T-Bill rate differential are, with one exception, insignificant in the long-term government bond rate differential regression—that exception is the difference between U.K. and U.S. government consumption expenditures as percentages of the respective GDPs, which differs in sign across the two regressions. Moreover, apart from the real exchange rate and interest differential variables, only one of the three variables that was statistically significant in the right-most regression in Table 5 is also statistically significant in the right-most regression in Table 6. This fact, together with the absence of a good theoretical reason why the difference between the interest rates on U.K. and U.S. long-term bonds should have a positive effect on the real exchange rate suggests that the interest differential variable may be correlated with other real factors that, for lack of knowledge, could not be put in the real exchange rate regression.[28] With regard to the right-most regression in Table 6, the tendency of the real exchange rate to mean-revert over the long-run is consistent with a positive relationship between the risk on U.K. long-term government bonds and the real exchange rate. It is noteworthy that this regression explains about 80% of the variation in the long-term interest rate differential. It is also noteworthy that U.K. minus U.S. inflation differential is statistically significant in the T-Bill rate differential regression but not in the long-term government bond rate differential regression. It is also unclear what effect the government consumption expenditure variable is capturing—the sign is the opposite of what would be predicted on the basis of common sense.

We can conclude that real factors, particularly those related to the U.K. terms of trade with respect to the rest of the world relative to the U.S terms of trade with respect to the rest of the world, and those related to world oil prices, have significant effects on the real exchange rate of the United Kingdom with respect to the United States. Given that the R^2 is only about 60%, however, a large part of the explanation of observed real

[28] Even if one were to buy into the argument that the Bank of England can manipulate short-term real interest rates in Britain, it is difficult to imagine these effects extending to the long-term government bond rate. And, indeed, the evidence of a relationship between 3-month treasury bill rates and the real exchange rates is very weak.

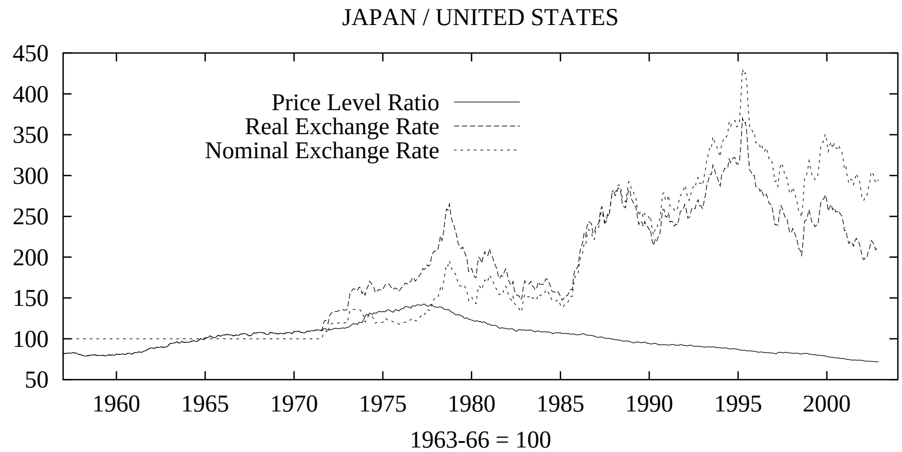

Figure 5: Real and nominal exchange rate and ratio of price levels, Japan vs. the United States. Source: *Reuters*, International Monetary Fund *International Financial Statistics*.

exchange rate movements is missing. It will be shown in subsequent sections that, with exception of the period of the early 1990s, monetary factors explain none of this missing 40%.

3.4 Japan vs. United States

The real and nominal exchange rates and price level ratio of Japan with respect to the United States are plotted in Figure 5. Japan's price level rose about 75% relative to the U.S. price level between the early 1960s and the late 1970s and then declined continuously thereafter, falling by about 50% by 2002. The real exchange rate shows an upward trend from the early 1970s to the mid-1990s and then falls by about 40% thereafter although in 2002 is was still twice as high as in the early 1970s. As consistent with the movements of price level ratio, the nominal exchange rate rose continually relative the real exchange rate from the late 1970s.

The left-most regression in Table 7 explains more than 80% of the variation in the real exchange rate on the basis of real factors that would plausibly be expected to affect it. The positive and negative signs for the logarithms of the respective Japanese and U.S. real GDP variables are consistent with the Balassa-Samuelson hypothesis. The difference between Japanese and U.S. government consumption expenditures as percentages of the respective GDPs also has the expected sign. The ratio of the Japanese to U.S. terms of trade is positive as would be expected. Unfortunately, however, the difference between the net capital inflow into Japan and the U.S. as percentages of their respective GDPs has a negative sign which is inconsistent with what straight-forward economic analysis would predict.

Table 8 presents the results of Dickey-Fuller and Phillips-Perron unit root tests on the variables appearing in the regressions in Table 7. The null hypothesis of non-stationarity cannot be rejected at the 10% level for the logarithm of the real exchange rate, the net capital inflow variable and the logarithm of Japanese real GDP.[29] The government expenditure and terms of trade variables are clearly stationary. The fact that they are significant along with the logarithm of U.S. real GDP in the regression shown in the left-most column of Table 7 implies that the other three variables are either cointegrated or stationary after all, given the low power of the Dickey-Fuller and Phillips-Perron tests. A Johansen cointegration test of the real exchange rate, net capital flow and Japanese real GDP variables yields the following result:

Cointegration Vectors Under the Null Hypothesis	Eigen-Values	L-max	Trace
0	0.258	34.566	45.178
1	0.074	8.923	10.613
2	0.014	1.690	1.690
Lags = 5			

Appropriate lags were selected on the basis of the AIC. The 1% critical values for the Trace and L-max statistics are 35.397 and 25.521 respectively. The cointegrating vector is $(-1.000, 0.076, 1.197)$ ordered by real exchange rate, Japan less U.S. net capital inflows as percentages of the respective GDPs, and Japanese Real GDP. The null hypothesis that the individual variable is not in the cointegrating vector can be rejected at the 1% level for each variable in turn. And it turns out that in the cointegrating vector the net capital flow variable has the expected sign.

When the excess of the Japanese over the U.S. inflation rate is added to the above regression it turns out to be statistically significant with a negative sign, as shown in the second and third regressions from the left in Table 7. And when we add the difference between the Japanese and U.S. log-term government bond rates, as shown in the second regression from the left in Table 7, this variable too is statistically significant with a negative sign, a result the opposite to those obtained in the cases of Canada and the U.K. with respect to the U.S. Moreover, in this regression the net capital flow, which had the wrong sign, becomes statistically insignificant and is

[29] It is evident from Table 3 that non-stationarity of the logarithm of U.S. real GDP can be rejected at the 5% level.

Table 7: OLS Regression Analysis of Real Factors Affecting Japan's Real Exchange Rate and Interest Rate Differential on Long-Term Government Bonds with Respect to the United States 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable: Logarithm of Real Exchange Rate			Dependent Variable: Interest Rate Differential	
Constant	-4.108 (0.749)*** [1.107]***	2.618 (0.632)*** [0.784]***	-2.686 (0.595)*** [0.722]***	15.843 (4.422)*** [5.553]***	26.682 (8.028)*** [14.066]*
Log of Japan T.O.T. / U.S. T.O.T.	0.908 (0.072)*** [0.128]***	1.123 (0.067)*** (0.079)***	1.080 (0.058)*** [0.069]***	9.176 (1.590)*** [1.794]***	5.281 (0.973)*** [1.354]***
Japan less U.S. Net Cap. Flow / GDP	-0.021 (0.006)*** [0.008]***		-0.017 (0.005)*** [0.006]***	0.292 (0.059)*** [0.091]***	0.264 (0.065)*** [0.110]**
Japan less U.S. Govt. Cons. /GDP	0.069 (0.014)*** [0.019]***	0.031 (0.009)*** [0.013]**	0.051 (0.011)*** [0.018]**		
Log of Japanese Real GDP	1.987 (0.245)*** [0.331]***	1.262 (0.176)*** [0.257]***	1.610 (0.192)*** [0.322]***		-2.389 (0.647)*** [1.130]**
Log of U.S. Real GDP	-1.883 (0.327)*** [0.426]***	-1.011 (0.217)*** [0.322]***	-1.507 (0.254)*** [0.429]***		
Japan less U.S. LT-Govt. Bond Rate		-0.015 (0.005)*** [0.007]**	Log of Real Exchange → Rate	-3.983 (0.990)*** [1.224]***	
Japan less U.S. CPI Inflation		-0.016 (0.002)*** [0.003]***	-0.019 (0.002)*** [0.003]**	0.152 (0.044)*** [0.073]**	0.222 (0.035)*** [0.066]***
Num. Obs.	116	116	116	116	116
R-Square	.835	.899	.904	.688	.674

Notes and Sources: See previous tables.

Table 8: The Results of Dickey-Fuller and Phillips-Perron Unit Root Tests of Variables in the Regressions for Japan in Table 7.

Model →		[1]			[2]		[3]
Variable	Test	Constant	Time	Y_{t-1}	Constant	Y_{t-1}	Y_{t-1}
Real Exchange Rate	DF						
	PP						
Japan Terms of Trade / U.S. Terms of Trade	DF					10%	10%
	PP						5%
Japan less U.S. Net Capital Inflow / GDP	DF						
	PP						
Japan / U.S. Govt Consumption Expenditure / GDP	DF						5%
	PP						1%
Japanese Real GDP	DF						
	PP						
Japan less U.S. LT-Govt. Bond Rate	DF				10%	10%	
	PP						
Japan less U.S. CPI Inflation Rate	DF						5%
	PP						5%

Notes: The percentages indicate the level at which the null hypothesis of nonstationarity can be rejected. Blank spaces indicate nonrejection and *nc* means that no calculation was recorded. DD refers to the Dickey-Fuller test and PP to the Phillips-Perron test. The calculations cover the period 1972 through 2002.

therefore dropped. When the long-term bond rate differential is made the dependent variable, as shown in the second regression from the right in Table 7, it and the inflation-rate difference are significantly positively related. And the difference in net capital inflows relative to real GDPs is significant at the 5% level with a positive sign, suggesting that the bigger the capital inflow into (or the smaller the capital outflow out of) Japan as compared to the United States, the higher was the interest rate on long-term Japanese government bonds relative to that on long-term U.S. government bonds. When the real exchange rate is added to this regression, as shown in the right-most column of Table 7, it is statistically significant with a negative sign, the opposite of the result obtained in the interest-rate-differential regressions for Canada and the U.K. vs. the U.S. This is consistent with the negative sign of the long-term interest rate differential variable in the real exchange rate regression.

It should be noted that one of the three presumed non-stationary variables is missing in the second regression from the left and two right-most regressions reported in Table 7. Statistical significance of the stationary variables requires that the two included non-stationary variables (the real exchange rate and Japanese real GDP variables or, alternatively, the net capital flow and Japanese real GDP variables) must be cointegrated. In Johansen tests for these two pairs of presumed non-stationary variables (not shown) cointegration cannot be established. This, together with the facts that stationary variables are significant in all the regressions, that non-stationarity of the three variables can be rejected at around the 20% level, and that it makes little economic sense to assume that the true levels of the real exchange rate and net capital flow variables are boundless, suggests that all the variables in the regressions reported in Table 7 are probably stationary.

The top panel of Figure 6 plots the actual together with the fitted values of the real exchange rate resulting from the regression reported in the left-most column of Table 7. The middle panel plots the residual from that regression against the excess of the Japanese over the U.S. CPI inflation rates—a negative correspondence is evident throughout the period. Nevertheless, as the bottom panel shows the removal of the effects of inflation difference has little effect on the overall movement of the logarithm of the real exchange rate.

It appears that the effort to establish that persistent real shocks are important in explaining the Japanese real exchange rate with respect to the United States has been quite successful although it is clear that, despite an R^2 in excess of .8, substantial unaccounted for influences lurk in the

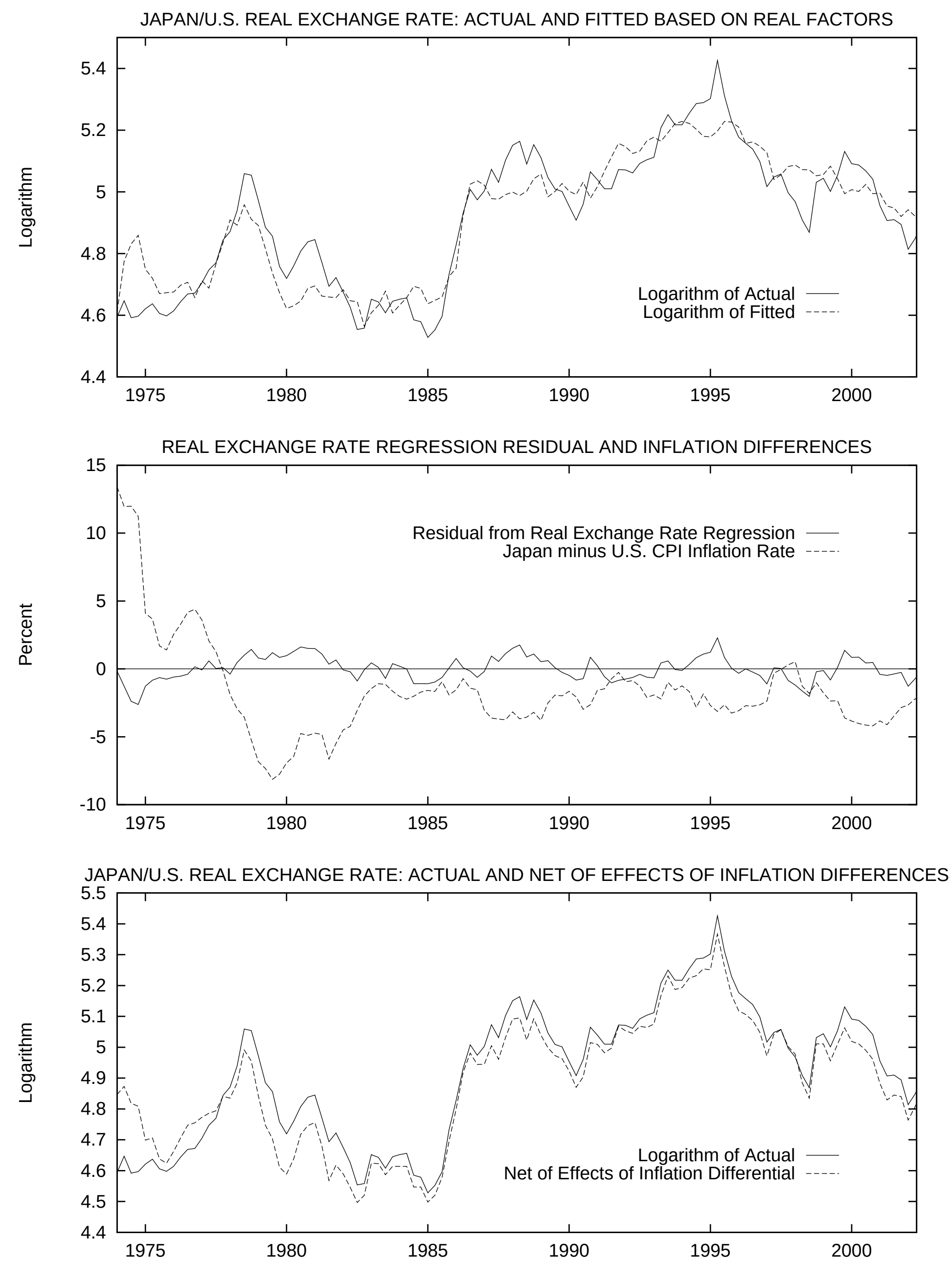

Figure 6: The real exchange rate of Japan with respect to the United States: Actual and net of the effects of inflation differences. Source: International Monetary Fund *International Financial Statistics*.

background. The best interpretation of the importance of the inflation rate and long-term bond-rate differences is that they are correlated with other unknown real forces that are at work. To the extent that the inflation rate differences reflect monetary forces, those forces must be presumed to be long-term, reflecting the effects of monetary shocks on inflation expectations.

3.5 France vs. United States

The French real and nominal exchange rates with respect to the U.S. dollar, and the ratio of the French to the U.S. consumer price indexes, are shown in Figure 7. From the mid-1970s onward the real exchange rate shows substantial variability, ranging from 80 to 145 on a base of 100, and a very slight downward trend. The price level rose in France relative to the United States by about 40 percent between the mid-1970s and the late-1980s and then fell to a level about 25% higher than the mid-1970s level. As a result, the nominal exchange rate devalued relative to the real exchange rate until the late-1980s and then appreciated with respect to it from then on.

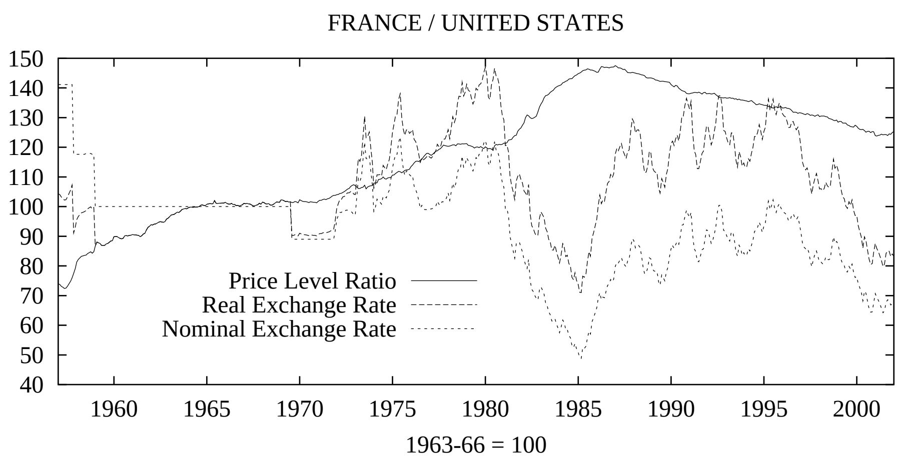

Figure 7: Real and nominal exchange rate and ratio of price levels, France vs. the United States. Source: *Reuters*, International Monetary Fund *International Financial Statistics*.

As indicated in the middle column of Table 9, about 80% of the variations in the French real exchange rate with respect to the United States can be explained by plausible real factors. French real GDP has a positive sign and U.S. real GDP a negative one, as consistent with the Balassa-Samuelson hypothesis. The effects of oil price increases are negative as might be expected and the effects of commodity price increases are positive—surprisingly since, unlike Canada, France is not a producer of commodities. An increase in net capital inflows into France as a percentage of GDP relative to the corresponding variable for the United States has, surprisingly, a negative sign. It would seem that both these latter variables are capturing the effects of other left-out variables and are not performing the role that simple-minded theory would suggest. Most importantly, a positive movement in the French terms of trade with respect to the rest of the world relative to the U.S. terms of trade with respect to the rest of the world has a positive effect on the real exchange rate as would be expected. Moreover, it turns out that, as can be seen from the bottom panel of Figure 8, the rise in the terms of trade variable in the 1970s and the major dip in the 1980s tends to explain the corresponding movements in the real exchange rate—a similar but much stronger result than was found for the U.K. real exchange rate with respect to the U.S. It turns out that the terms of trade variable is the only one for which a plot indicates obvious correspondence with the real exchange rate—the other variables together had important effects, as can be seen by comparing the bottom panel of Figure 8 with actual and fitted values in the middle regression of Table 8 shown in the top panel, but the individual effects do not stand out.

The excess of the French over the U.S. long-term government bond rates and the excess of the French over the U.S. CPI inflation rates are both significant at the 5% level when added to the basic real exchange rate regression, as shown in the left-most column Table 9. The interest rate differential has a positive sign and the inflation rate differential a negative one. This is in contrast to the Japanese case where both variables had negative signs. The interest rate differential on treasury bills is statistically insignificant when used in place of the long-term government bond rate differential and also renders the inflation rate difference statistically insignificant—this regression result is not shown.

When the long-term government bond rate differential is taken as the dependent variable, the real exchange rate and the net capital inflow variables appear, this time with the correct sign, along with the inflation rate differential, as the only variables that are statistically significant—explaining nearly 60 percent of the variance of the interest rate differential. This sug-

Table 9: OLS Regression Analysis of Real Factors Affecting the Real Exchange Rate and Long-Term Govt. Bond Rate Differential: France vs. United States, 1974:Q1 to 1998:Q4

Independent Variables	Dependent Variable: Log of Real Exchange Rate		Dependent Variable: Interest Rate Diffl.
Constant	2.658 (1.774) [2.426]	1.935 (1.108) [2.369]	-9.687 (3.145)*** [4.290]***
Log of Commodity Prices	0.477 (0.097)*** [0.132]***	0.506 (0.092)*** [0.127]***	
Log of Oil Prices	-0.085 (0.037)** [0.050]*	-0.107 (0.039)*** [0.051]**	
Log of French T.O.T. / U.S. T.O.T.	1.865 (0.233)*** [0.202]**	2.133 (0.190)*** [0.156]***	
French less U.S. Net Cap. Flow / GDP	-0.023 (0.007)*** [0.009]**	-0.016 (0.007)** [0.008]**	0.223 (0.046)*** [0.056]***
Log of French Real GDP	1.537 (0.448)*** [0.694]**	1.846 (0.463)*** [0.541]***	
Log of U.S. Real GDP	-1.487 (0.317)*** [0.641]**	-1.710 (0.325)*** [0.360]***	
French less U.S. LT-Govt. Bond Rate	0.032 (0.010)*** [0.015]**	Log of Real Exchange → Rate	2.225 (0.623)*** [0.859]***
France less U.S. CPI Inflation	-0.014 (0.007)** [0.006]**		0.229 (0.047)*** [0.059]***
Num. Obs.	100	100	100
R-Square	.822	.798	.586

Notes and Sources: See previous tables.

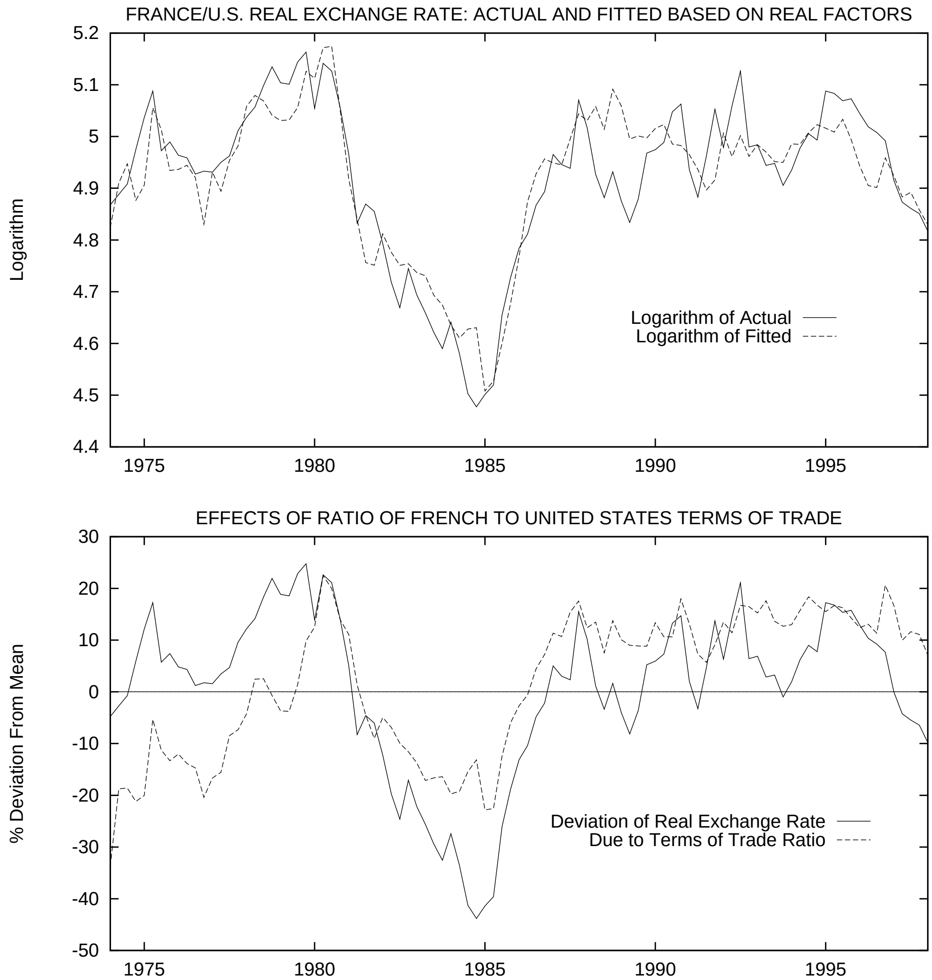

Figure 8: French real exchange rate with respect to the United States, fitted values based on real factors excluding interest and inflation rate differentials (top panel), and effects the ratio of the French terms of trade to the U.S. terms of trade. Source: International Monetary Fund *International Financial Statistics*.

gests that the market may recognise mean reversion of the real exchange rate in the very long run and that conditions under which capital is attracted to the U.S. rather than France are associated with a fall in French bond rates relative to U.S. bond rates although, as noted previously, it is difficult to imagine how the default risk on government debt would be affected.

Again, we have to worry about the possibility of spurious regression. As can be seen from Table 10, the logarithms of the real exchange rate, crude oil prices divided by an equally weighted average of U.S. export and import prices, and French real GDP, as well as the difference of the capital inflows into France and the United States as percentages of the respective GDPs, fail both the Dickey-Fuller and Phillips-Perron tests for stationarity at the 10% level. The logarithms of commodity prices relative to U.S. export and

Table 10: The Results of Dickey-Fuller and Phillips-Perron Unit Root Tests of Variables in the Regressions for France in Table 9.

Model →		[1]			[2]		[3]
Variable	Test	Constant	Time	Y_{t-1}	Constant	Y_{t-1}	Y_{t-1}
Real Exchange Rate	DF						
	PP						
Commodity Prices / Traded Goods Prices: U.S.	DF	5%		5%	1%	1%	5%
	PP						
Crude Oil Prices / Traded Goods Prices: U.S.	DF						
	PP						
French Terms of Trade / U.S. Terms of Trade	DF						
	PP				*nc*	10%	
French less U.S. Net Capital Inflow / GDP	DF						
	PP						
French Real GDP	DF						
	PP						
U.S. Real GDP	DF	5%	5%	10%			
	PP						
French less U.S. LT-Govt. Bond Rate	DF	1%	5%	1%	5%	1%	5%
	PP	5%			*nc*	5%	5%
French less U.S. CPI Inflation Rate	DF	5%	5%	1%		10%	5%
	PP						10%

Notes: The percentages indicate the level at which the null hypothesis of nonstationarity can be rejected. Blank spaces indicate nonrejection and *nc* means that no calculation was recorded. DF refers to the Dickey-Fuller test and PP to the Phillips-Perron test. The calculations cover the period 1972 through 1998.

import prices and U.S. real GDP, as well as the interest rate and inflation rate differential variables, are clearly stationary. The logarithm of the ratio of the French terms of trade with respect to the rest of the world over the U.S. terms of trade with respect to the rest of the world is stationary at 10% level of significance according to the Phillips-Perron test.

The fact that the interest rate and inflation rate differentials are clearly stationary implies that the real exchange rate and net capital inflow variables must be cointegrated—otherwise, those variables would be statistically insignificant in the right-most regression in Table 9. A Johansen test, however, indicates the contrary. When a constant is included in the cointegrating vector and no deterministic trends are included the following result is obtained:

Cointegration Vectors Under the Null Hypothesis	Eigen-Values	L-max	Trace
0	0.070	8.128	13.421
1	0.052	5.292	5.292
Lags = 5			

where the number of lags is chosen based on the AIC. The 10% critical values for the Trace and L-max statistics are 17.957 and 13.781 respectively.[30] The likely explanation of this lack of cointegration is that the two variables are in fact stationary. In an earlier study I found that the monthly French vs. U.S. real exchange rate over the period 1957-2002 was stationary at the 1% level in a Dickey-Fuller test and at the 10% level in a Phillips-Perron test.[31] As noted previously, these tests have very low power and the inability to reject non-stationarity in the quarterly data may simply be the result of too short a time period. In the tests shown in Table 10, the coefficient of the t-*1* level of the variable under the Phillips-Perron equation that included a constant term was -2.33 as compared to the 10% critical value of -2.58. In the case of the net capital flow variable the coefficients of the t-*1* level, the constant term and the trend under the Phillips-Perron test were -3.01, -2.89 and -2.78, respectively, as compared to the respective 10% critical values of

[30]Using a likelihood ratio test, the null hypothesis of no deterministic trends cannot be rejected at any reasonable significance level. In any case, when deterministic trends are included the results are no different.

[31]See John E. Floyd, "Real Exchange rates, Efficient Markets and Uncovered Interest Parity: A Review," Unpublished Manuscript, University of Toronto, October 27, 2004.

-3.15, -2.73 and -2.38.[32] Also, as noted previously, basic common-sense economics suggests that these variables should be stationary—otherwise they could vary without bound, eventually taking on ridiculously large or small values.

If we conclude that the real exchange rate variable is stationary, then the right-hand side variables in the regressions reported in the left-most two columns of Table 9 must either be stationary or cointegrated with other variables that are non-stationary. Were that not the case these variables would be statistically insignificant.

The evidence clearly supports the conclusion that a substantial fraction of movements in the French real exchange rate with respect to the United States can be explained by real variables that are related to variations in technology, capital accumulation and economic growth.

3.6 Germany vs. United States

The German real and nominal exchange rates with respect to the United States and the ratio of the German to the U.S. consumer price indexes are plotted in Figure 9. The German price level fell almost continuously relative to the U.S. price level from the mid-1960s onward. As a result the German nominal exchange rate appreciated on average throughout this period while the real exchange rate showed little trend. Both the real and nominal exchange rates, unlike the price-level ratio, varied substantially. The real exchange rate ranged from 80 to 180 on a base of 100.

The empirical analysis in the German case is truncated at the end of 1989 because of the effects on the data of German unification. As evident from the regression reported on the left in Table 11, over 90 percent of the variation in the German real exchange rate with respect to the United States is explained by a number of plausible real variables. The German and U.S. real GDPs have the signs postulated by the Balassa-Samuelson hypothesis, the ratio of the German to the U.S. terms of trade with respect to the rest of the world has the expected positive sign, as does the difference between German and U.S. government expenditure on consumption, taken as percentages of the respective GDPs. The negative sign of the logarithm of crude oil prices in U.S. dollars relative to U.S. export and import prices is as would be expected from the fact that Germany is an oil consuming country that produces no oil. As in the case of France, however, the logarithm of commodity prices in U.S. dollars relative to U.S. traded goods prices has

[32] In both these tests the truncation lag was set at 4. The results are somewhat worse when the truncation lag is set at 1. They were much worse in the Dickey-Fuller tests.

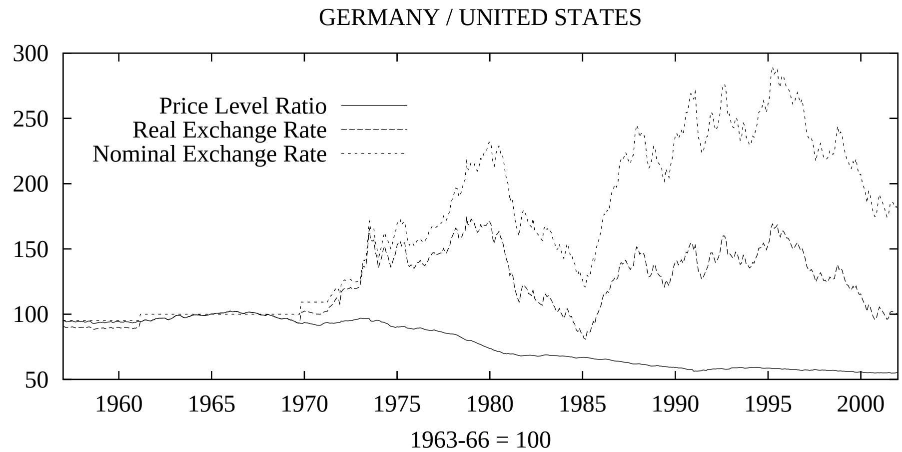

Figure 9: Real and nominal exchange rate and ratio of price levels, Germany vs. the United States. Source: *Reuters*, International Monetary Fund *International Financial Statistics*.

a positive sign that would not be expected, given that Germany does not produce these goods. The difference between German and U.S. interest rates on government bonds is not statistically significant when added to the regression, so the results are not shown.

As shown in the column on the right in Table 11, the commodity price variable and the difference between German and U.S. government consumption expenditure as percentages of GDP, along with the two countries' real GDPs explain about 80 percent of the variation in the interest rate differential on long-term government bonds. The difference between the German and U.S. inflation rates was insignificant when added to the explanatory variables in the regression, as was the logarithm of the real exchange rate. The signs of the coefficients in the regression seem reasonable.

Again, of course, we must establish that these regression results are not spurious. Table 12 shows the results of Dickey-Fuller and Phillips-Perron tests on the variables used in the regressions in Table 10. The lack of stationarity of the variables is impressive—only in the case of the commodity price, and government expenditure and inflation differential variables can non-stationarity be rejected and, in the case of the latter two variables only at the 10% level. In comparison with the situation of the other countries examined, a problem here is the significantly shorter time period over which the tests are made. For example, the logarithm of U.S. real GDP is not stationary here, but the identical variable was stationary over the period 1972 through 1998 and 1972 through 2002. And the German real exchange

Table 11: OLS Regression Analysis of Real Factors Affecting the Real Exchange Rate and Long-Term Govt. Bond Rate Differential: Germany vs. United States, 1974:Q1 to 1988:Q4

Independent	Dependent Variable	
Variables	Log of Real Exchange Rate	LT-Govt-Bond Rate Diffl.
Constant	6.161 (1.313)*** [1.716]***	-12.520 (12.390) [13.954]
Log of Commodity Prices	0.199 (0.084)** [0.083]**	5.610 (1.115)*** [1.374]***
Log of Oil Prices	-0.174 (0.044)*** [0.047]***	
Log of German T.O.T. / U.S. T.O.T.	1.301 (0.173)*** [0.260]***	
German less U.S. Govt. Cons. / GDP	0.057 (0.012)*** [0.018]***	-1.233 (0.161)*** [0.234]***
Log of German Real GDP	1.653 (0.483)*** [0.553]***	14.421 (5.797)** [6.492]**
Log of U.S. Real GDP	-1.635 (0.330)*** [0.344]***	-14.151 (4.398)*** [5.083]***
Num. Obs.	64	64
R-Square	.928	.836

Notes and Sources: See previous tables.

Table 12: The Results of Dickey-Fuller and Phillips-Perron Unit Root Tests of Variables in the Regressions for France in Table 11.

Model →		[1]			[2]		[3]
Variable	Test	Constant	Time	Y_{t-1}	Constant	Y_{t-1}	Y_{t-1}
Real Exchange Rate	DF						
	PP						
Commodity Prices / Traded Goods Prices: U.S.	DF				1%	1%	10%
	PP						
Crude Oil Prices / Traded Goods Prices: U.S.	DF						
	PP						
German Terms of Trade / U.S. Terms of Trade	DF						
	PP						
German less U.S. Govt. Consumption Expenditure / GDP	DF						
	PP		1%		*nc*	10%	
German Real GDP	DF						
	PP						
U.S. Real GDP	DF						
	PP						
German less U.S. LT-Govt. Bond Rate	DF						
	PP						
German less U.S. CPI Inflation Rate	DF						10%
	PP						

Notes: The percentages indicate the level at which the null hypothesis of nonstationarity can be rejected. Blank spaces indicate nonrejection and *nc* means that no calculation was recorded. DF refers to the Dickey-Fuller test and PP to the Phillips-Perron test. The calculations cover the period 1972 through 1988.

rate with respect to the United States was found in my previous work to be stationary using monthly data from 1957 through 2002.[33]

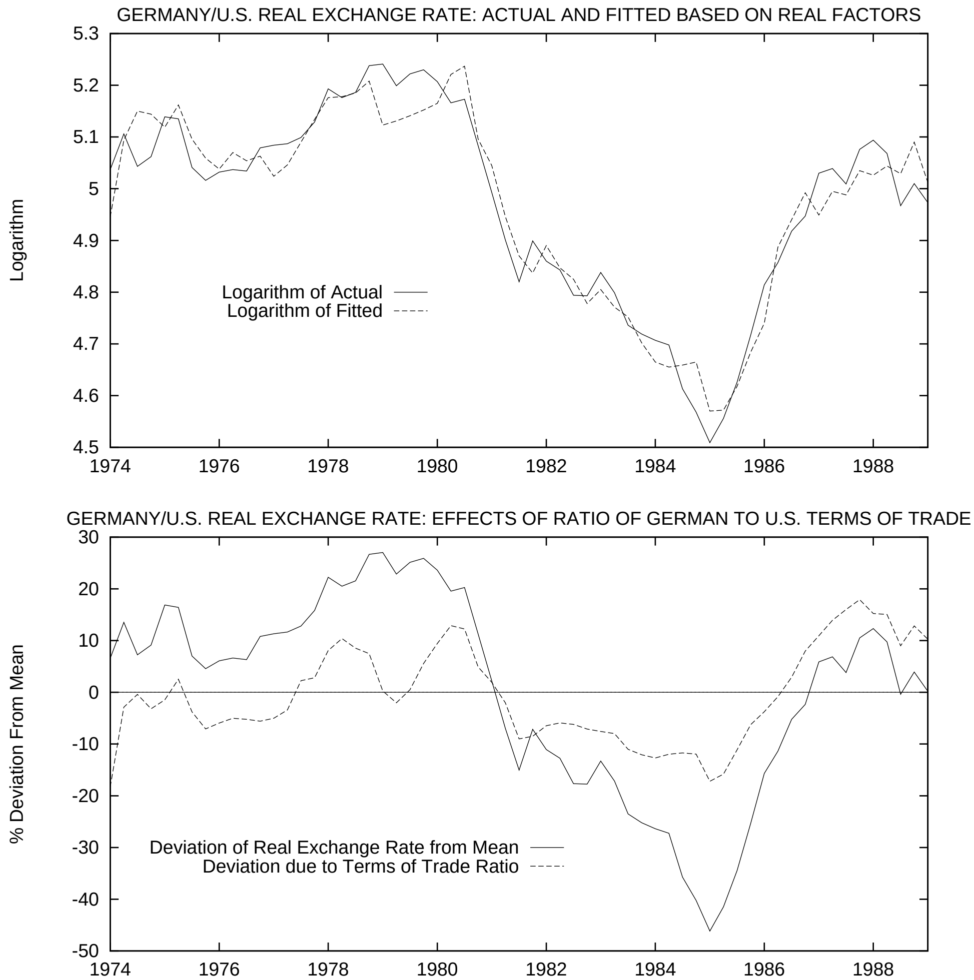

Figure 10: German real exchange rate with respect to the United States, fitted values based on real factors (top panel), and effects the ratio of the German terms of trade to the U.S. terms of trade. Source: International Monetary Fund *International Financial Statistics*.

[33] See again John E. Floyd, "Real Exchange rates, Efficient Markets and Uncovered Interest Parity: A Review," Unpublished Manuscript, University of Toronto, October 27, 2004. A unit root could be rejected at the 5% level using a Dickey-Fuller test and at the 10% level using a Phillips-Perron test.

A Johansen cointegration test of the variables in the right-most regression in Table 11, excluding the commodity price variable which is clearly stationary, yields the following result:

Cointegration Vectors Under the Null Hypothesis	Eigen-Values	L-max	Trace
0	0.372	29.735	47.785
1	0.162	11.322	18.150
2	0.101	6.828	6.829
3	0.000	0.001	0.001
Lags = 5			

The 5% critical values of the Trace and L-max statistics for the null hypothesis of no-cointegrating vectors are 47.181 and 27.169 respectively. The signs in the first cointegrating vector are the same as those of the respective variables in the regression in Table 11. And the null hypotheses that each variable in turn is not in that cointegrating vector can be rejected at the 1% level. The above test included deterministic trends and the null hypothesis of no deterministic trends can be rejected at the 5% level.

A Johansen cointegration test of the variables in the real exchange rate regression, again excluding the commodity price variable, indicated the presence of two cointegrating vectors but the null hypotheses that the oil price and government expenditure variables where not in the cointegrating vector could not be rejected in either case. When the test is performed excluding these variables the following result is obtained:

Cointegration Vectors Under the Null Hypothesis	Eigen-Values	L-max	Trace
0	0.402	32.886	59.598
1	0.224	16.211	26.712
2	0.150	10.380	10.502
3	0.002	0.121	0.121
Lags = 5			

The 1% critical values for the Trace and L-max statistics are 53.792 and 31.943 respectively for the null hypothesis of no cointegrating vectors. The null hypothesis that there is only one cointegrating vector cannot be rejected. The signs in the cointegrating vector match those in the real exchange rate regression in Table 11 and the null hypotheses that the individual variables are not in the cointegrating vector can be rejected at the 5% level or better in all cases. Here again, deterministic trends were included in the test because the null hypothesis that they are not present can be rejected.

The German real exchange rate with respect to the United States is determined by a number of real factors related to technological change and economic growth. As the top panel of Figure 10 indicates the fit on the basis of real factors alone is quite good. Moreover, as in the case of France and, to a lesser extent, the U.K., it is clear from the bottom panel of Figure 10 that the logarithm of the ratio of the German terms of trade with respect to the rest of the world to the U.S. terms of trade with respect to the rest of the world bears an important relationship to the real exchange rate. The effects of the other variables, while important as a group, do not individually stand out.

4 The Effects of Unanticipated Money Shocks

The important task is to now determine whether unanticipated shocks to the nominal money supplies are responsible for a significant fraction of the variations in real exchange rates. In this section the problem is approached by adding unanticipated domestic and U.S. money supply shocks to the above real exchange rate regressions. These shocks are calculated as the excess of the actual values over running predictions of the money stocks.

A number of alternative predictive models are used to determine the 'expected' money stock in each period. A standard one is to regress the level of the relevant nominal money aggregate on past levels of itself and nominal GDP. This is done using running regressions on the previous 10 years or 40 quarters of data, using 8 lags of both money and nominal GDP, starting in the first quarter of 1974 and ending with the fourth quarter of 2002. The unanticipated money shock is then obtained by subtracting the predicted level in each quarter from the actual for that quarter. This measure of the predicted money stock is rather crude compared to the optimal one that would be obtained by selecting for each quarter the lags of money and GDP that are statistically significant and using only those lagged values in that quarter's regression. The problem with this, of course, is the requirement that the optimal set of lags be obtained for each of the 116 quarters for the base money, M1 and M2 aggregates for each of the six countries in this study—a total of 2088 separate econometric procedures!

As an alternative, a practical procedure is to determine the optimal configuration of lags for the past 8 quarters in the 10 year periods 1966-75, 1976-85, and 1986-95, and the remaining years 1996-2002 and then use the lag patterns so established for the running regressions in the respective periods. Only the 8 regressions in 1974 and 1975 will use the lag pattern established for the 1966-75 period, and the running regressions for each subsequent 10-year period will use the lags that were significant during that period. The same procedure is then followed for the consecutive periods 1971-1980, 1981-1990 and 1991-2000 and for the period 1993-2002, with the significant lags in each period being used in the running regressions for that period. The resulting two estimates of the time path of predicted money are then averaged and subtracted, period by period, from the actual levels to obtain a 'more optimal' series of unanticipated money shocks than the one obtained by 40 period running regressions using all 8 lags of both money and nominal GDP. This is a crude way of using an approximation to the lag patterns that agents would have found had they chosen the best lag structure for each quarter's regression.

It is also possible that agents, given the costs of forecasting in relation to the benefits, will determine their expected levels of the various monetary aggregates more intuitively by looking only at past levels of the aggregate or by rough trend projections. Accordingly two additional very crude measures of unanticipated money shocks are calculated—one using simply a 40 period running OLS forecast using only 8 lagged values of the money aggregate and no lags of nominal GDP, and the other using 8 quarter running trend projections.

4.1 Canada vs. United States

Only the regressions using the crude measure of unanticipated money obtained from running regressions on 8 quarters of lags of money and nominal GDP and the so-called 'optimal' measure using selected lags in the previous 8 quarters are shown in Table 13 and Table 14. The first table gives the results when unanticipated money shocks are added to the basic real exchange rate regression shown in Table 1 while the second table gives the results when unanticipated money stocks are added to the regression determining the interest rate differential on 1-month corporate paper in Canada relative to the U.S. Using the two cruder measures of unanticipated money

Table 13: OLS Regression Analysis of the Effects of Monetary Shocks on the Real Exchange Rate: Canada vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Logarithm of Real Exchange Rate					
Constant	6.523 (0.238)*** [0.436]***	6.531 (0.230)*** [0.452]***	6.571 (0.234)*** [0.437]***	6.522 (0.228)*** [0.426]***	6.589 (0.230)*** [0.443]***	6.586 (0.235)*** [0.450]***
Can less US Net Capital Inflow /GDP	0.025 (0.002)*** [0.005]***	0.025 (0.002)*** [0.005]***	0.025 (0.002)*** [0.004]***	0.025 (0.002)*** [0.004]***	0.024 (0.002)*** [0.004]***	0.025 (0.002)*** [0.005]***
Log of U.S. Real GDP	-0.200 (0.028)*** [0.052]***	-0.201 (0.027)*** [0.054]***	-0.206 (0.027)*** [0.052]***	-0.200 (0.027)*** [0.050]***	-0.208 (0.027)*** [0.053]***	-0.208 (0.028)*** [0.053]***
Monetary Aggregate & Prediction	M1 Crude	M1 'Optimal'	M2 Crude	M2 'Optimal'	Base Crude	Base 'Optimal'
Canadian Money Shock	0.004 (0.002) [0.002]	0.004 (0.003) [0.003]	0.004 (0.006) [0.006]	0.005 (0.007) [0.007]	0.006 (0.003)** [0.003]**	0.003 (0.004) [0.004]
U.S. Money Shock	-0.001 (0.004) [0.004]	-0.003 (0.005) [0.006]	-0.010 (0.006) [0.006]	-0.019 (0.008)*** [0.009]***	-0.001 (0.005) [0.006]	0.003 (0.008) [0.009]
Num. Obs.	116	116	116	116	116	116
R-Square	.813	.813	.813	.819	.814	.810

Notes and Sources: U.S. base money aggregate is adjusted for reserve requirement changes and the money shocks are expressed as deviations of the logarithms from predicted levels. The crude prediction regresses the current log level on 8 lags of the logarithms of the money stock and real GDP, while the 'optimal' prediction regresses the log level on statistically significant past values of logarithms of the money stock and real GDP estimated over 10 year overlapping periods. Source: International Monetary Fund *International Financial Statistics.*

Table 14: OLS Regression Analysis of the Effects of Monetary Shocks on Interest Rate Differentials: Canada vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable 1-Month Corporate Paper Rate Differential					
Constant	-10.354 (14.105) [18.094]	-6.981 (13.546) [18.467]	-4.905 (13.513) [18.475]	-1.177 (13.890) [18.928]	-8.691 (13.885) [17.888]	-5.495 (13.836) [17.885]
Log of Commodity Prices	-4.194 (1.150)*** [1.338]***	-4.477 (1.198)*** [1.444]***	-4.680 (1.132)*** [1.323]***	-4.618 (1.156)*** [1.406]***	-4.894 (1.162)*** [1.336]***	-4.826 (1.177)*** [1.483]***
Log of Canadian Real GDP	23.495 (5.751)*** [7.555]***	22.682 (5.898)*** [7.830]***	25.576 (5.765)*** [7.903]***	26.876 (6.054)*** [8.020]***	22.333 (5.821)*** [7.848]***	23.626 (5.859)*** [8.124]***
Log of U.S. Real GDP	-20.539 (5.137)*** [6.714]***	-20.155 (5.239)*** [6.949]***	-22.430 (5.127)*** [7.026]***	-23.729 (5.390)*** [7.079]***	-19.570 (5.209)*** [6.920]***	-20.726 (5.236)*** [7.125]***
Log of Real Exchange Rate	12.190 (1.426)*** [1.860]***	11.918 (1.394)*** [1.893]***	12.149 (1.408)*** [1.824]***	11.891 (1.446)*** [1.886]***	12.356 (1.468)*** [1.812]***	11.958 (1.447)*** [1.825]***
Monetary Aggregate & Prediction	M1 Crude	M1 'Optimal'	M2 Crude	M2 'Optimal'	Base Crude	Base 'Optimal'
Canadian Money Shock	-0.108 (0.045)** [0.047]**	-0.176 (0.054)*** [0.066]***	-0.207 (1.113)* [1.115]*	-0.175 (0.143) [0.200]	-0.193 (0.073)*** [0.056]***	-0.218 (0.092)*** [0.079]***
U.S. Money Shock	0.133 (0.089) [0.072]*	0.115 (0.111) [0.114]	0.364 (0.128)*** [0.120]***	0.282 (0.171) [0.158]*	0.128 (0.106) [0.084]	0.127 (0.157) [0.114]
Num. Obs.	116	116	116	116	116	116
R-Square	.577	.588	.587	.564	.575	.569

Notes and Sources: See Table 13.

in these regressions does not change the basic conclusions.

As is evident from Table 13, the money shock variables have the wrong signs except for the U.S. unanticipated base money shock using the so-called 'optimal' predictive measure in the right-most column, and that coefficient is statistically insignificant. The signs of the Canadian money shocks should be negative on the grounds that an unexpected exogenous expansion of the money supply will cause domestic residents to attempt to re-balance their portfolios by purchasing assets from foreigners, driving down the value of the domestic currency in international markets. The U.S. unanticipated money shock variable should have a positive sign for the same reason—as U.S. residents re-balance their portfolios by purchasing assets abroad the U.S. dollar will devalue against foreign currencies including the Canadian dollar. The wrongly signed coefficients are statistically significant in only one case for each country. We have to conclude that there is no evidence that unanticipated money supply shocks affected the real exchange rate of Canada with respect to the United States in a direction consistent with the predictions of those who would hold exogenous monetary shocks responsible for observed real exchange rate movements.

The results in Table 14 are especially interesting because they seem to support the popular view that a positive exogenous shock to the Canadian money supply will cause interest rates in Canada to fall relative to those in the United States while, although the results are much less statistically significant, a positive exogenous shock to the U.S. money supply will cause U.S. market interest rates to fall relative to the rest of the world and hence the Canada–U.S. interest rate differential to rise.

Given that Canada is a small economy whose residents are free to buy and sell assets in the United States, an exogenous money shock will necessarily affect the exchange rate. Indeed, there is every reason to expect that the movement of the exchange rate would overshoot the long-run equilibrium that would occur after the price level has time to adjust. The fact that, as indicated in Table 13, it does not affect the exchange rate suggests that the observed negative relationship between money shocks and the interest rate differential can not be the result of Bank of Canada monetary actions. Rather, it would appear that reverse causation is the likely explanation. The last thing the Bank of Canada wants is an overshooting movement of the nominal exchange rate. Accordingly, one would expect that when interest rates in Canada are high because of greater expected inflation or perceived risk, and the private sector would be therefore induced to economise on money holdings by exchanging money for non-monetary assets, the Bank of Canada will tend to prevent this by reducing the money supply. As a result, a negative relationship will appear between changes in domestic relative to foreign interest rates and unanticipated shocks to the supply of the various monetary aggregates.

The above argument immediately raises the question of why the Canada–U.S. interest rate differential should be positively affected by unanticipated U.S. money shocks—any change in U.S. nominal interest rates as a result of monetary shocks should, other things unchanged, lead to a corresponding change in Canadian interest rates with no effect on the interest rate differential. As is evident from Table 14, however, only one of the measures of U.S. unanticipated M2 shocks is positive and statistically significant by the usual standards—the other U.S. shocks are statistically insignificant except in a couple of cases at the 10% level. Quite possibly, the U.S. M2 result is consequent on demand factors that happen to be related to U.S. nominal interest rates but are unrelated to policy actions by the Federal Reserve. Indeed, exogenous money shocks are unlikely to occur without being observable in the Base Money and M1 aggregates. In fact, in the Canadian case observed unanticipated M2 shocks do not bear a statistically significant relationship to domestic relative to U.S. interest rates.

4.2 United Kingdom vs. United States

Table 15 shows the results obtained by adding unanticipated U.K. and U.S. base money shocks to the real exchange rate regression presented in the leftmost column of Table 5. In all three cases the U.K. base money shock is statistically significant with a negative sign. The unanticipated shock to the U.S. base money aggregate, which is adjusted for the effects of reserve requirement changes, is everywhere statistically insignificant. As is clear in the top panel of Figure 11, however, the economic significance of the effects of U.K. unanticipated base money shocks on that country's real exchange rate rate with respect to the United States is trivial.

Nevertheless, it is important to explore this matter further. The middle panel in Figure 11 plots the residual from the basic real exchange rate regression in Table 5, scaled by a factor of 10, and the unanticipated U.K. base money shock as a percentage of the current-period level. A substantial negative relationship between the two series is evident in the early 1990s. The fact that the stock of base money, which had been declining relative to trend since 1980, began to decline more sharply in 1990 and then flattened out in 1993, as can be seen in the bottom panel of Figure 11, is consistent with the argument that the sharp upward movement of the real exchange rate in 1990 and downward movement in 1993 was the consequence of base money

Table 15: OLS Regression Analysis of the Effects of Monetary Shocks on the Real Exchange Rate: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Logarithm of Real Exchange Rate					
Constant	3.868 (0.326)*** [0.376]***	3.651 (0.301)*** [0.260]***	3.780 (0.319)*** [0.371]***	3.542 (0.271)*** [0.274]***	3.844 (0.323)*** [0.478]***	3.604 (0.276)*** [0.306]***
Log of Commodity Prices	0.467 (0.072)*** [0.107]***	0.513 (0.066)*** [0.089]***	0.480 (0.071)*** [0.107]***	0.549 (0.060)*** [0.089]***	0.480 (0.071)*** [0.125]***	0.537 (0.060)*** [0.097]***
Log of Oil Prices	-0.260 (0.028)*** [0.055]***	-0.261 (0.027)*** [0.049]***	-0.271 (0.028)*** [0.055]***	-0.274 (0.025)*** [0.047]***	-0.268 (0.028)*** [0.052]***	-0.275 (0.025)*** [0.046]***
Log of U.K. TOT / U.S. TOT	1.509 (0.130)*** [0.169]***	1.547 (0.119)*** [0.147]***	1.530 (0.129)*** [0.173]***	1.599 (0.110)*** [0.144]***	1.475 (0.130)*** [0.188]***	1.589 (0.112)*** [0.154]***
Monetary Aggregate & Prediction	Base Money Money Lags Only		Base Money 'Optimal' Money and GDP Lags		Base Money Running Trend Projection	
U.K. Money Shock	-0.027 (0.009)*** [0.010]***	-0.013 (0.008) [0.005]***	-0.035 (0.011)*** [0.014]**	-0.008 (0.010) [0.006]	-0.023 (0.008)*** [0.011]**	-0.006 (0.007) [0.005]
U.S. Money Shock	0.005 (0.010) [0.008]	-0.000 (0.009) [0.006]	0.013 (0.011) [0.011]	-0.001 (0.009) [0.006]	0.014 (0.006) [0.010]	0.005 (0.005) [0.007]
1990-1994 Dummy Variable		0.044 (0.020)** [0.039]		0.035 (0.018)* [0.025]		0.055 (0.018)*** [0.030]*
1990-1994 Dummy× U.K. Shock		-0.111 (0.026)*** [0.036]***		-0.163 (0.025)*** [0.030]***		-0.115 (0.018)*** [0.019]***
Num. Obs.	116	116	116	116	116	116
R-Square	.614	.679	.618	.741	.625	.743

Notes and Sources: See Table 13.

shocks that were unanticipated by the private sector. There is also an apparent negative relationship between the two series right through to the end of 1994.

Accordingly, two dummy variables for the period 1990-1994 are added to the regression—the first simply takes a value of unity during 1990-1994 and zero otherwise while the second, obtained by multiplying the money shock by the first dummy variable, is equal to the unanticipated base money shock during 1990-1994 and zero otherwise. As can be seen in Table 15, the second of these dummy variables is always statistically significant while the first is significant only when HAC standard errors of the coefficients are not imposed. It would appear that we have found a classic example of an overshooting monetary shock.

This impression is confirmed in the top panel of Figure 12 which plots the series in the bottom two panels of Figure 11 for the decade from 1988 to 1998. Unfortunately this simplistic conclusion unravels on further analysis. The bottom two panels of Figure 12 plot the real and nominal exchange rates and relative price levels of the U.K. with respect to the U.S. and the U.K. with respect to Germany for the same period. It turns out that Britain had what was essentially a fixed exchange rate with Germany during the period from the first quarter of 1990 to the third quarter of 1992 in what became a failed attempt to join the European Union's Exchange Rate Mechanism (ERM). As can be seen from the bottom panel of Figure 12, her real exchange rate with respect to Germany rose about 15% during 1990 and then gradually declined by the same amount during 1991 and 1992. This was accompanied by a rise in the British relative to the German price level during 1990 and a very slight fall during 1991 and 1992. As shown in the middle panel of Figure 12, the U.K. real exchange rate with respect to the U.S. rose about 20% in 1990, declined by about half that much in 1991 and then peaked again in the first half of 1992. These real exchange rate movements were accompanied by corresponding movements of the nominal exchange rate with respect to the United States. The British price level rose significantly relative the to the U.S. price level in 1990 and 1991 and then declined somewhat in 1992.

The fact that the U.K. exchange rate was approximately fixed in relation to the major European countries implies that British monetary policy was thereby constrained during 1990, 1991 and the first three quarters of 1992. Movements of the British nominal exchange rate with respect to the United States during this period could not have been the result of unanticipated money shocks. In fact, as can be seen from a comparison of the middle panel of Figure 12 with the top panel of Figure 13, the British and German real and nominal exchange rates with respect to the U.S. show a very similar

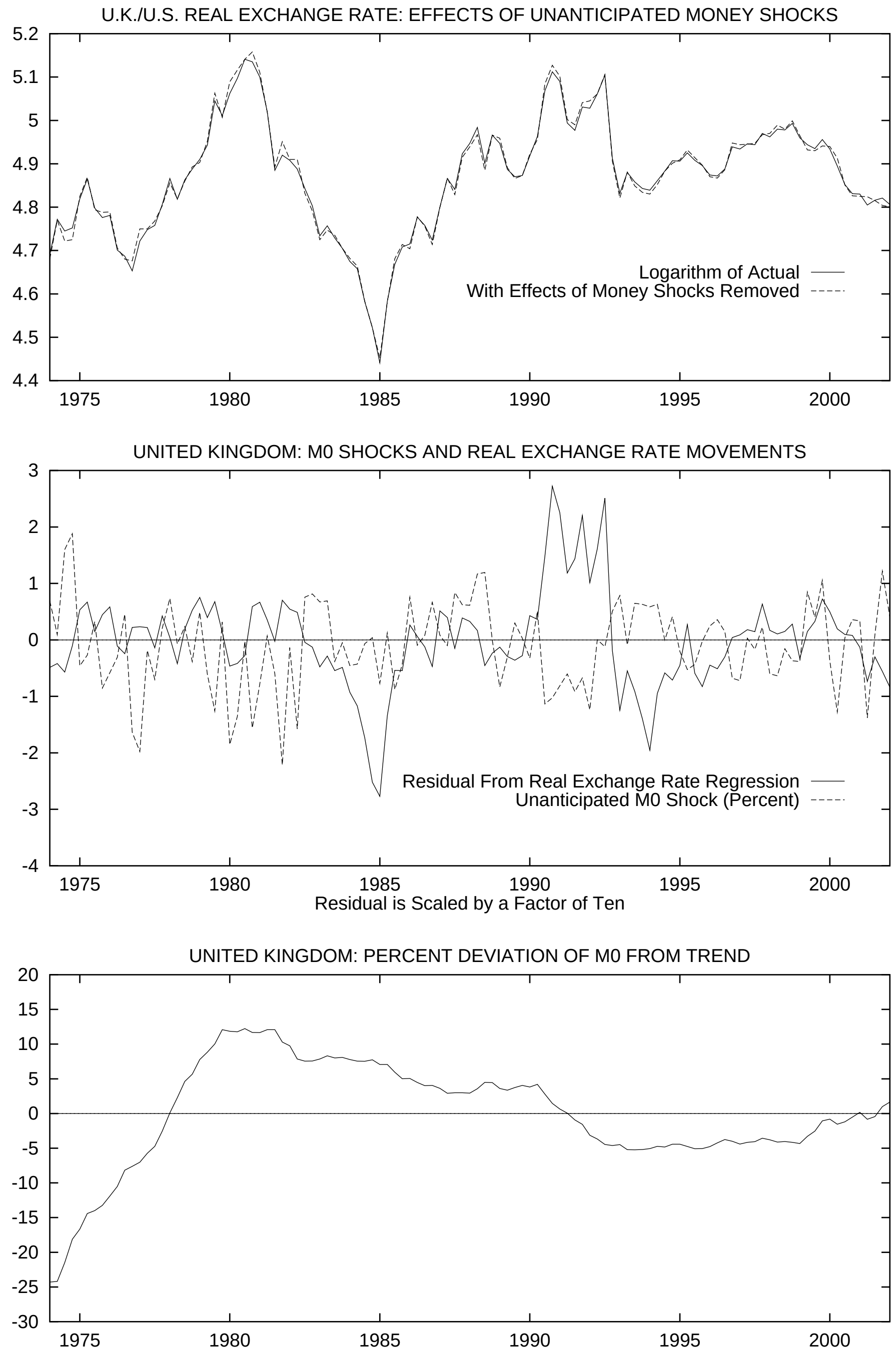

Figure 11: Unanticipated base money shocks and their effect on the United Kingdom's real exchange rate with respect to the United States. Source: International Monetary Fund *International Financial Statistics*.

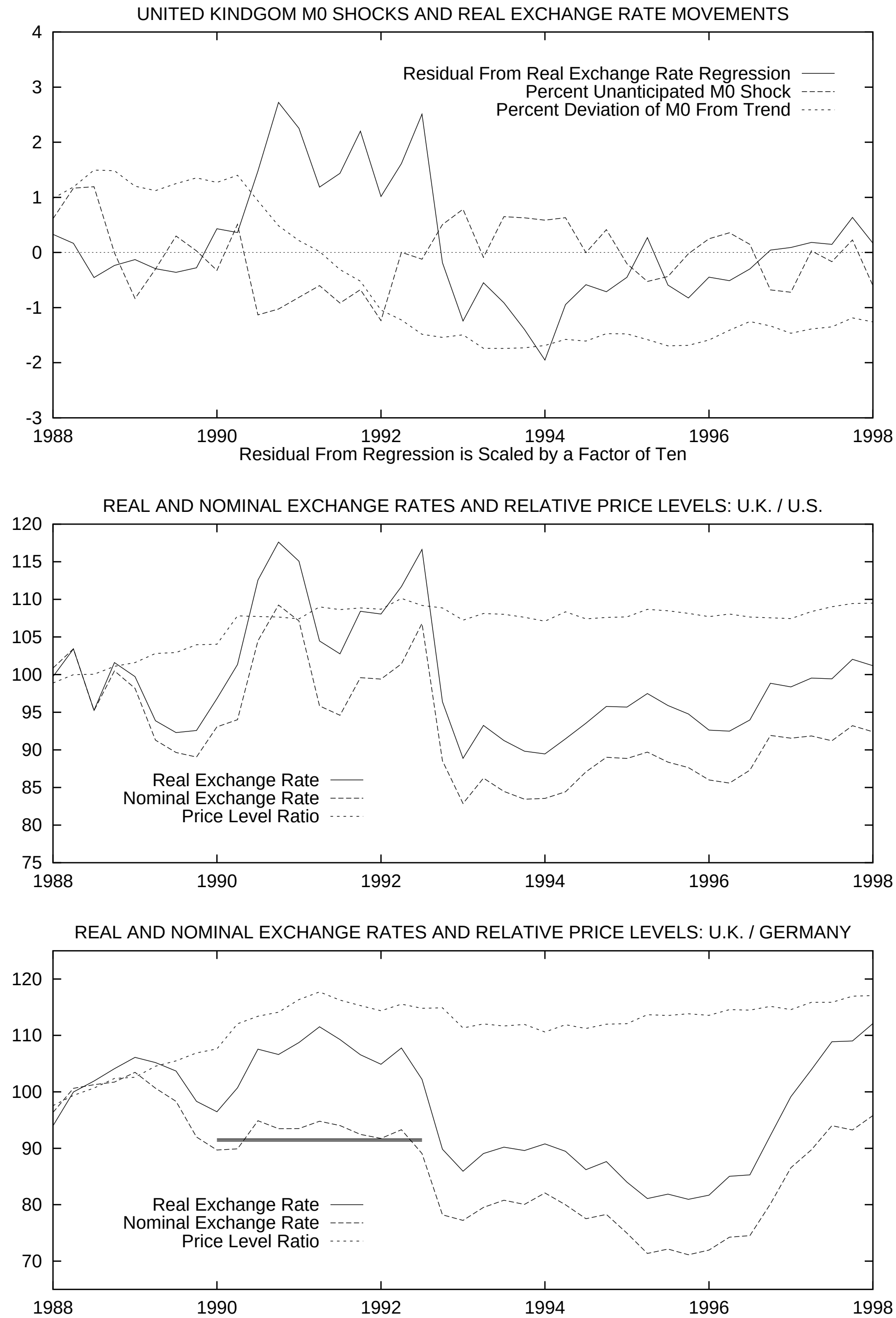

Figure 12: Real and nominal exchange rate and price level ratio movements of the United Kingdom with respect to Germany and the United States, along with United Kingdom base money shocks. The thick line in the bottom chart is the pegged level of the nominal exchange rate. Source: International Monetary Fund *International Financial Statistics*.

pattern, with peaks around the beginning of 1991 and the middle of 1992. These real exchange rate movements could not have been the result of British monetary policy—they must have been caused by real forces affecting both the U.K. and Germany relative to the United States.

The situation with respect to Britain in 1992 is a classic example of one of the two main causes of currency crises. As is clear from the bottom panel of Figure 12, the British real exchange rate with respect to Germany, and hence other ERM countries, fell by more than 20% during 1992. The government of Great Britain had essentially two choices—let the exchange rate decline and thereby leave the ERM, or allow the British price level to fall relative to the European price level by around 20%.

Any speculator with even a modest understanding of British politics could easily predict what the authorities would do.[34] The crisis of late 1992 resulted in Britain's abandonment of membership in the Exchange Rate Mechanism.

How then can we account for the negative relationship between unanticipated British base money shocks and the real exchange rate? Evidently, the decline of the percent deviation of base money from its trend between 1990 and 1993 was a consequence of something other than exogenous policy developments. Perhaps it was the result of structural changes in British monetary institutions.

The relationship between unanticipated British base money shocks and the U.S.–U.S. interest rate differential on 3-month treasury bills is examined in the OLS regressions reported in Table 16. A similar analysis focusing on the interest rate differential on long-term government bonds is presented in Table 17. A statistically significant negative relationship between unanticipated U.K. base money shocks and the interest differential on treasury bills is clearly present, even when a dummy variable taking a value of unity in the years 1990-1994 and zero otherwise is included. This could represent evidence that quarter-to-quarter British monetary policy was accommodating changes in investors' inflation expectations that had developed as a consequence of trend money growth. A positive relationship between U.S. base money shocks and U.K.–U.S. treasury bill rate differentials is also evident in Table 16. There is no obvious explanation for this—accommodating behaviour on the part of the U.S. Federal Reserve would require that U.S. treasury bill rates be negatively correlated with the interest rate differential.

[34] The other main cause of currency crises is irresistible pressure on the government to print money to finance important politically unavoidable expenditures under circumstances where the exchange rate is fixed.

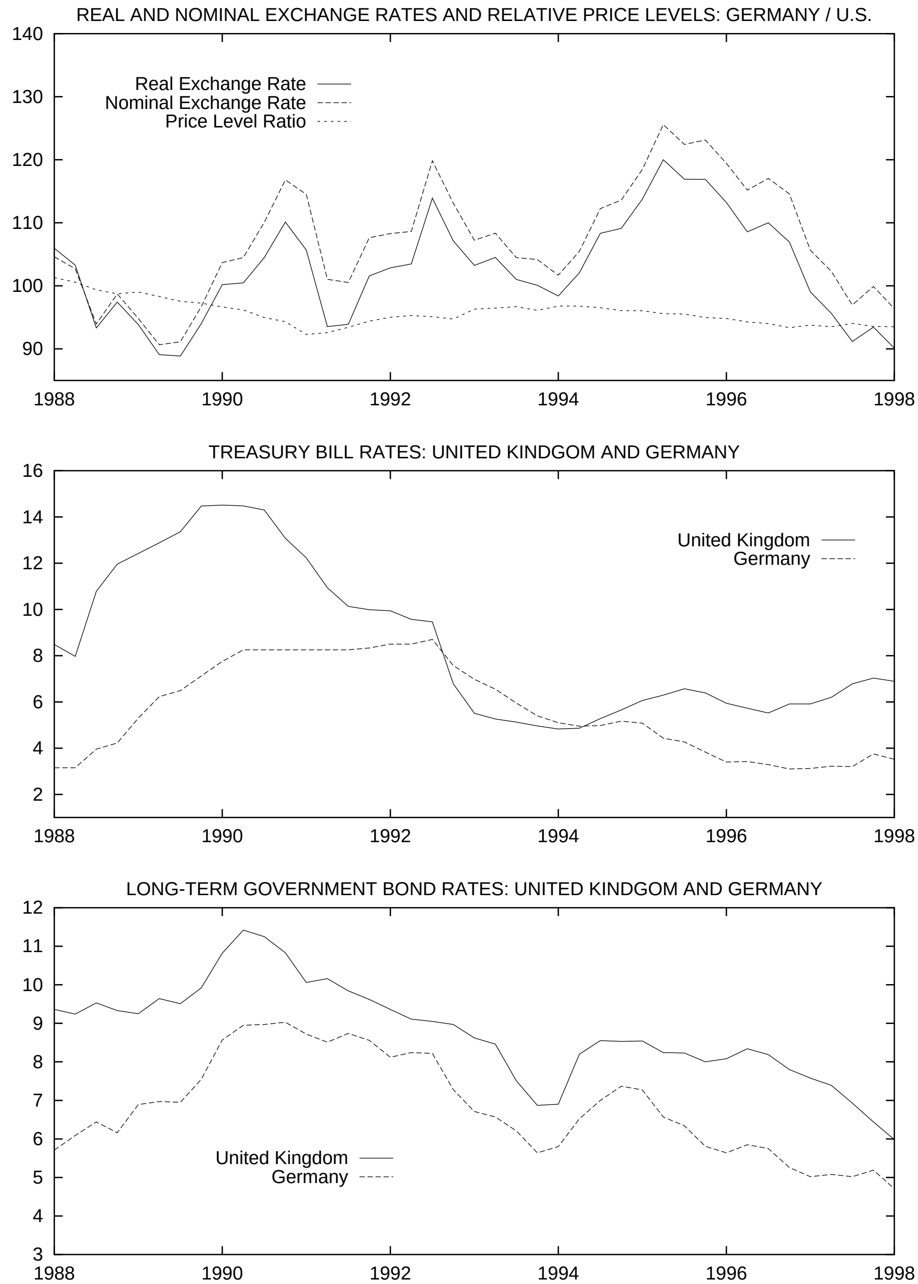

Figure 13: German real and nominal exchange rates and price level ratio with respect to the U.S., and interest rates on 3-month treasury bills and long-term government bonds in the United Kingdom and Germany. Source: International Monetary Fund *International Financial Statistics*.

Table 16: OLS Regression Analysis of the Effects of Monetary Shocks on Interest Rate Differentials I: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable 3-Month Treasury Bill Rate Differential					
Constant	34.592 (7.183)*** [10.214]***	26.114 (7.586)*** [10.032]**	31.522 (7.300)*** [10.707]***	23.389 (7.627)*** [10.579]**	31.666 (7.319)*** [12.153]***	23.228 (7.644)*** [10.920]**
Log of Commodity Prices	-6.167 (1.541)*** [2.181]**	-4.412 (1.619)** [2.125]*	-5.524 (1.568)*** [2.287]**	-3.840 (1.631)** [2.248]*	-5.601 (1.571)*** [2.622]***	-3.845 (1.634)** [2.338]
U.K. less U.S. Govt. Cons. / GDP	-0.898 (0.192)*** [0.278]***	-0.929 (0.186)*** [0.264]***	-0.895 (0.193)*** [0.275]***	-0.930 (0.188)*** [0.265]***	-0.816 (0.196)*** [0.254]***	-0.864 (0.190)*** [0.248]***
U.K. less U.S. NCI / GDP	0.544 (0.104)*** [0.169]***	0.404 (0.113)*** [0.176]**	0.520 (0.105)*** [0.166]***	0.381 (0.113)*** [0.172]**	0.526 (0.105)*** [0.158]***	0.382 (0.113)*** [0.151]**
U.K. less U.S. CPI Infl. Rate	0.236 (0.051)*** [0.076]***	0.250 (0.050)*** [0.075]***	0.241 (0.051)*** [0.075]***	0.254 (0.050)*** [0.074]***	0.238 (0.052)*** [0.078]***	0.251 (0.051)*** [0.076]***
Monetary Aggregate & Prediction	Base Money Money Lags Only		Base Money 'Optimal' Money and GDP Lags		Base Money Running Trend Projection	
U.K. Money Shock	-0.678 (0.180)*** [0.215]***	-0.603 (0.177)*** [0.220]***	-0.747 (0.219)*** [0.214]***	-0.671 (0.214)*** [0.219]***	-0.408 (0.149)*** [0.170]**	-0.381 (0.144)*** [0.166]**
U.S. Money Shock	0.261 (0.182) [0.150]*	0.239 (0.176) [0.125]*	0.417 (0.212)* [0.155]***	0.351 (0.207)* [0.126]***	0.324 (0.126)** [0.107]***	0.271 (0.123)** [0.108]**
1990-1994 Dummy Variable		1.213 (0.430)*** [0.568]**		1.233 (0.433)*** [0.522]**		1.272 (0.435)*** [0.568]**
Num. Obs.	116	116	116	116	116	116
R-Square	.559	.589	.553	.584	.546	.580

Notes and Sources: See Table 13.

Table 17: OLS Regression Analysis of the Effects of Monetary Shocks on Interest Rate Differentials II: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Long-Term Govt. Bond Rate Differential			
Constant	3.398 (6.048) [11.455]	5.488 (5.890) [11.144]	4.011 (5.960) [11.632]	4.260 (5.915) [11.301]
Log of U.K. TOT / U.S. TOT	-21.848 (1.690)*** [3.000]***	-21.533 (1.530)*** [2.661]***	-21.703 (1.559)*** [2.764]***	-21.807 (1.583)*** [2.721]***
U.K. less U.S. Govt. Cons. / GDP	0.590 (0.137)*** [0.167]***	0.534 (0.133)*** [0.148]***	0.568 (0.134)*** [0.151]***	0.570 (0.132)*** [0.150]***
Log of U.S. Real GDP	-4.536 (0.448)*** [0.816]***	-4.483 (0.443)*** [0.773]***	-4.547 (0.449)*** [0.818]***	-4.510 (0.456)*** [0.817]***
Log of Real Exch. Rate	7.261 (0.951)*** [1.729]***	6.772 (0.974)*** [1.702]***	7.169 (0.968)*** [1.794]***	7.049 (0.971)*** [1.713]***
Monetary Aggregate & Prediction	Base Money Money and GDP Lags	Base Money Money Lags Only	Base Money 'Optimum' Money and GDP Lags	Base Money Running Trend Projection
U.K. Money Shock	-0.020 (0.114) [0.120]	-0.213 (0.122)* [0.185]	-0.056 (0.148) [0.196]	-0.066 (0.104) [0.132]
U.S. Money Shock	0.083 (0.099) [0.080]	0.096 (0.125) [0.095]	0.069 (0.147) [0.116]	0.027 (0.085) [0.092]
1990-1994 Dummy Variable	0.825 (0.291)*** [0.365)**	0.862 (0.284)*** [0.362]**	0.841 (0.291)*** [0.366)**	0.870 (0.289)*** [0.367]**
Num. Obs. R-Square	116 .805	116 .810	116 .805	116 .805

Notes and Sources: See Table 13.

Table 18: OLS Regression Analysis of the Real Exchange Rate Effects of Unanticipated M2 Shocks: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Log of Real Exchange Rate			
Constant	3.797 (0.319)*** [0.376]***	3.758 (0.330)*** [0.406]***	3.750 (0.324)*** [0.392]***	3.709 (0.327)*** [0.408]***
Log of Commodity Prices	0.485 (0.071)*** [0.100]***	0.487 (0.074)*** [0.112]***	0.495 (0.073)*** [0.104]***	0.501 (0.073)*** [0.110]***
Log of Oil Prices	-0.263 (0.028)*** [0.056]***	-0.225 (0.029)*** [0.059]***	-0.262 (0.029)*** [0.058]***	-0.260 (0.029)*** [0.059]***
Log of U.K. TOT / U.S. TOT	1.541 (0.130)*** [0.154]***	1.545 (0.134)*** [0.171]***	1.557 (0.134)*** [0.157]***	1.581 (0.134)*** [0.175]***
Monetary Aggregate & Prediction	M2 Money and GDP Lags	M2 Money Lags Only	M2 'Optimum' Money and GDP Lags	M2 Running Trend Projection
U.K. Money Shock	-0.001 (0.002) [0.002]	0.002 (0.002) [0.003]	-0.003 (0.003) [0.004]	-0.001 (0.002) [0.003]
U.S. Money Shock	-0.024 (0.009) [0.016]	-0.010 (0.012) [0.010]	-0.016 (0.012) [0.016]	-0.008 (0.007) [0.010]
Num. Obs.	116	116	116	116
R-Square	.608	.585	.596	.587

Notes and Sources: See Table 13.

Table 19: OLS Regression Analysis of the Effects of Unanticipated M2 Shocks on Interest Rate Differentials I: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable 3-Mo Treasury Bill Rate Differential			
Constant	35.900 (7.523)*** [12.682]***	37.278 (7.640)*** [12.889]***	35.825 (7.575)*** [12.463]***	39.634 (7.693)*** [12.997]***
Log of Commodity Prices	-6.509 (1.617)*** [2.707]**	-6.803 (1.641)*** [2.748]**	-6.504 (1.629)*** [2.662]***	-7.299 (1.659)*** [2.791]***
U.K. less U.S. Govt. Cons. / GDP	-0.862 (0.203)*** [0.276]***	-0.868 (0.203)*** [0.275]***	-0.853 (0.204)*** [0.277]***	-0.885 (0.208)*** [0.292]***
U.K. less U.S. NCI / GDP	0.480 (0.110)*** [0.182]***	0.497 (0.111)*** [0.182]***	0.486 (0.111)*** [0.178]***	0.518 (0.110)*** [0.176]***
U.K. less U.S. CPI Infl. Rate	0.293 (0.052)*** [0.079]***	0.305 (0.052)*** [0.080]***	0.297 (0.052)*** [0.079]***	0.327 (0.055)*** [0.082]***
Monetary Aggregate & Prediction	M2 Money and GDP Lags	M2 Money Lags Only	M2 'Optimum' Money and GDP Lags	M2 Running Trend Projection
U.K. Money Shock	-0.042 (0.043) [0.042]	0.031 (0.048) [0.044]	-0.040 (0.053) [0.053]	0.077 (0.043) [0.042]
U.S. Money Shock	0.039 (0.183) [0.169]	0.032 (0.226) [0.200]	-0.119 (0.240) [0.297]	0.068 (0.161) [0.218]
Num. Obs.	116	116	116	116
R-Square	.503	.501	.503	.514

Notes and Sources: See Table 13.

Table 20: OLS Regression Analysis of the Effects of Unanticipated M2 Shocks on Interest Rate Differentials II: United Kingdom vs. United States, 1974:Q1 to 2002:Q4

Independent Variables	Dependent Variable Long-Term Govt. Bond Rate Differential			
Constant	0.127 (5.824) [10.616]	-0.443 (5.857) [11.199]	0.379 (5.925) [10.608]	0.512 (6.018) [10.555]
Log of U.K. TOT / U.S. TOT	-21.025 (1.595)*** [2.509]***	-21.383 (1.585)*** [2.678]***	-21.059 (1.671)*** [2.416]***	-21.321 (1.635)*** [2.651]***
U.K. less U.S. Govt. Cons. / GDP	0.514 (0.134)*** [0.174]***	0.528 (0.134)*** [0.172]***	0.507 (0.138)*** [0.170]***	0.498 (0.145)*** [0.203]***
Log of U.S. Real GDP	-4.581 (0.457)*** [0.732]***	-4.525 (0.451)*** [0.780]***	-4.494 (0.464)*** [0.743]***	-4.487 (0.459)*** [0.791]***
Log of Real Exch. Rate	8.109 (0.943)*** [1.608]***	8.108 (0.943)*** [1.587]***	7.899 (0.941)*** [1.603]***	7.863 (0.951)*** [1.484]***
Monetary Aggregate & Prediction	M2 Money and GDP Lags	M2 Money Lags Only	M2 'Optimum' Money and GDP Lags	M2 Running Trend Projection
U.K. Money Shock	-0.052 (0.028) [0.027]	-0.044 (0.032) [0.029]	-0.060 (0.036)* [0.032]*	-0.006 (0.029) [0.033]
U.S. Money Shock	0.185 (0.128) [0.127]	0.255 (0.152)* [0.138]*	0.105 (0.171) [0.160]	0.084 (0.104) [0.130]
Num. Obs.	116	116	116	116
R-Square	.797	.795	.793	.789

Notes and Sources: See Table 13.

The OLS regressions reported in Table 17 indicate no relationship between either U.K. or U.S. unanticipated base money shocks and the U.K.–U.S. interest rate differential on long-term government bonds, although the 1990-1994 dummy variable is everywhere statistically significant.

There is no up-to-date M1 series available for the United Kingdom. The effects of unanticipated M2 shocks on the British real exchange rate with respect to the U.S., shown in the OLS regressions reported in Table 18, are statistically insignificant for all four alternative measures of expected levels. The same is true of the effects of unanticipated M2 shocks on the U.K.–U.S. 3-month treasury bill interest rate differential, reported in Table 19, and on the long-term government bond rate differential which are reported in Table 20.

4.3 Japan vs. United States

An OLS regression analysis of the effects of unanticipated money supply shocks on the Japanese real exchange rate with respect to the United States based on the 'optimal' measure of predicted levels, and extending the basic regression reported in the left-most column of Table 7, is presented in Table 21. The unanticipated money shock variables have opposite signs to those expected—that is, a positive Japanese money shock leads to a real appreciation of the yen while a positive U.S. money shock leads to a depreciation. The coefficients of Japanese unanticipated money are significant at the 5% in the case of base money and M2 and at the 10% level in the case of M1. The U.S. money shock is significant at the 5% level in the case of base money (here adjusted for reserve requirement changes) and M1 only when HAC coefficient standard errors are imposed and in the case of M2 when HAC standard errors are not imposed. When the difference between the Japanese and U.S. inflation rates and both it and the difference between Japanese and U.S. long-term government bond rates are added to the regressions the results (not shown) indicate that all unanticipated money coefficients become statistically insignificant in the cases of M1 and M2 while the Japanese base money shock coefficients retain their statistical significance.

When the analysis is further expanded to test the effects of the alternative measures of unanticipated money shock for the three monetary aggregates, significant coefficients are obtained for the Japanese money shock only for M1 in the case where the predicted level is determined by a running regression on 8 lagged values of the respective money variable and nominal GDP and in none of the cases for M2. Japanese base money shock coefficients remain statistically significant under HAC standard errors in most

Table 21: OLS Regression Analysis of the Effects of Unanticipated Monetary Shocks on the Real Exchange Rate: Japan vs. United States, 1974:Q1 to 2001:Q4

Independent Variables	Dependent Variable Logarithm of Real Exchange Rate		
Constant	-3.965 (0.771)*** [1.033]***	-3.932 (0.752)*** [1.015]***	-2.974 (0.810)*** [0.999]***
Log of Japan T.O.T. / U.S. T.O.T.	0.888 (0.072)*** [0.128]***	0.854 (0.073)*** [0.124]***	0.968 (0.074)*** [0.105]***
Japan less U.S. Govt. Cons. / GDP	0.060 (0.014)*** [0.019]***	0.063 (0.014)*** [0.017]***	0.066 (0.014)*** [0.019]***
Japan less U.S. NCI / GDP	-0.018 (0.006)*** [0.008]**	-0.018 (0.006)*** [0.008]**	-0.014 (0.006)** [0.008]*
Log of Japanese Real GDP	1.778 (0.267)*** [0.321]***	1.829 (0.260)*** [0.320]***	1.761 (0.258)*** [0.362]***
Log of U.S. Real GDP	-1.595 (0.356)*** [0.425]***	-1.671 (0.345)*** [0.419]***	-1.681 (0.339)*** [0.460]***
	Base	M1	M2
Japanese Money Shock	0.003 (0.002) [0.001]**	0.008 (0.004)* [0.004]*	0.023 (0.009)** [0.010]**
U.S. Money Shock	-0.018 (0.013) [0.008]**	-0.015 (0.008)* [0.007]**	-0.028 (0.013)** [0.016]*
Num. Obs.	112	112	112
R-Square	.845	.850	.854

Continued on Next Page ....

Table 21 Continued:

Notes and Sources: The unanticipated monetary shocks are estimated as deviations from predicted values based on those lags of the money variable and GDP that give the 'best' fit in running regressions, where the 'optimal' lags are selected on the basis of overlapping 10 year periods. See also the notes for previous tables. Source: International Monetary Fund, *International Financial Statistics.*

cases. The U.S. unanticipated money coefficients remain statistically significant only when predicted levels are determined by running 8-quarter trend projections in the cases of M1 and M2 shocks and, again, in most cases of adjusted base money shocks.

One must conclude that there is no evidence that unanticipated monetary expansion causes the domestic real exchange rate to fall as implied by standard theory. The fact that the unanticipated money shock variables have the wrong signs in a vast majority of cases, and are in a number of cases statistically significant, and that the inflation rate differential is significantly negatively related to the real exchange rate suggests that a general equilibrium investigation of the Japanese case beyond what is possible here is appropriate. This is all the more important because the Japanese unanticipated base-money shock series, which is plotted along with the unanticipated M1 and M2 shock series in Figure 14, shows a substantial increase in variability after the late 1990s. While shortening the sample period to remove these quarters does not alter the above conclusions about the effects of base money shocks on the Japanese real exchange rate, there are, barring as yet undiscovered data problems, obvious changes in the Japanese monetary structure—relating to the money multipliers—that need to be addressed in a separate study.

Table 22 presents OLS regression results concerning the effects of unanticipated money shocks on the excess of Japanese over U.S. interest rates on long-term government bonds. It is evident from the regression reported in the right-most column that an unexpected increase in Japanese M2 is associated with a decline in the Japanese relative to the U.S. interest rate. The signs are also negative for unanticipated base-money and M1 shocks although only the coefficient of M1 shocks is statistically significant and then only at the 10% level. The temptation to argue that Japanese monetary expansion lowers domestic interest rates must be resisted since, given the

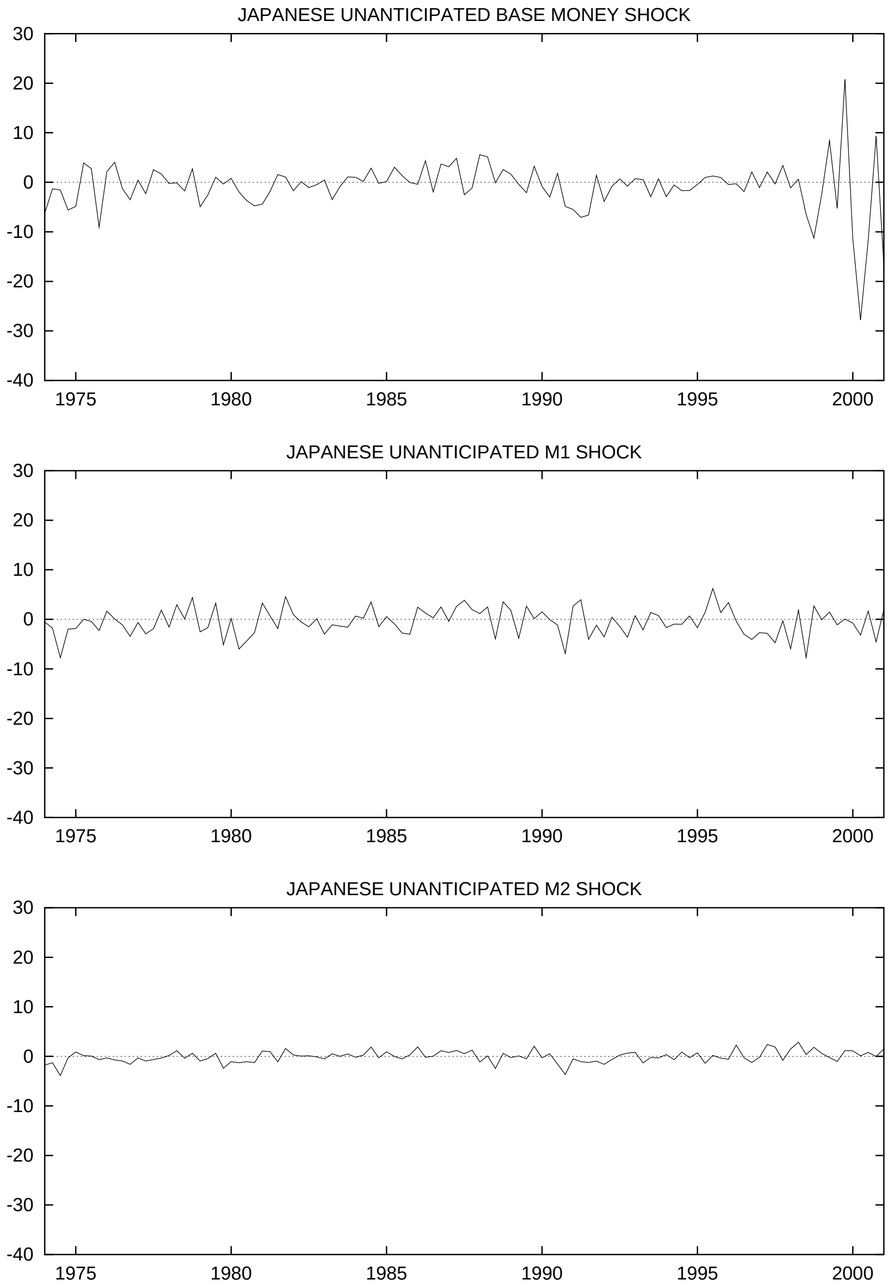

Figure 14: Japanese unanticipated monetary shocks representing deviations of actual from predicted levels based on 8 quarter lags of the monetary aggregate and GDP. Source: International Monetary Fund *International Financial Statistics*.

Table 22: OLS Regression Analysis of the Effects of Unanticipated Monetary Shocks on the Interest Rate Differential on Long-Term Government Bonds: Japan vs. U.S. 1974:Q1 to 2001:Q4

Independent Variables	Dependent Variable Interest Rate Differential		
Constant	15.514 (4.505)*** [5.428]***	15.664 (4.394)*** [5.341]***	8.425 (4.261)* [5.399]
Log of Japan T.O.T. / U.S. T.O.T.	9.233 (1.608)*** [1.703]***	10.074 (1.596)*** [0.724]***	6.928 (1.503)*** [1.779]***
Japan less U.S. NCI / GDP	0.306 (0.062)*** [0.093]***	0.287 (0.062)*** [0.086]***	0.162 (0.062)** [0.094]*
Log of Real Exchange Rate	-3.916 (1.008)*** [1.192]***	-4.011 (0.985)*** [1.169]***	-2.525 (0.944)*** [1.180]**
Japan less U.S. CPI Inflation	0.147 (0.044)*** [0.073]**	0.126 (0.044)*** [0.069]*	0.115 (0.042)*** [0.059]*
	Base	M1	M2
Japanese Money Shock	-0.024 (0.023) [0.022]	-0.112 (0.055)* [0.051]*	-0.576 (0.111)*** [0.132]***
U.S. Money Shock	0.297 (0.159)* [0.162]*	0.249 (0.107)** [0.080]***	-0.069 (0.155) [0.144]
Num. Obs.	112	112	112
R-Square	.696	.711	.754

Notes and Sources: See Table 21. Source: International Monetary Fund, *International Financial Statistics.*

absence of a negative effect on the real exchange rate, the causation probably runs the other way—that is, when interest rates fall the authorities allow the money supply to increase sufficiently to prevent overshooting exchange rate appreciation. The relationship between the interest rate differential and unanticipated U.S. M1 shocks is positive, which is consistent with the view that unanticipated U.S. monetary expansion lowers that country's long-term government bond rate. But this would imply that U.S. monetary expansion lower U.S. interest rates relative to comparable Japanese rates, which in an open capital market would have to imply that it makes Japanese long-term government bonds more risky relative to U.S. long-term government bonds, or alternatively, creates an expectation that the Yen will devalue relative to the U.S. dollar in the future, implying that unexpected monetary expansion causes the dollar to depreciate temporarily against the Yen. This then raises the question as to why the Japanese authorities do not simultaneously adjust their domestic monetary conditions to prevent this temporary appreciation of their currency. Any conclusion one might reach on why the coefficient of unanticipated shocks to U.S. M2 has a positive sign would be purely speculative.

4.4 France vs. United States

OLS regression analysis of the effects of French and U.S. unanticipated money shocks on the French real exchange rate with respect to the United States and on the excess of French over U.S. interest rates on long-term government bonds is reported in Table 23. The time period covered ends with adoption of the Euro at the end of 1998. In the regressions reported, unanticipated money shocks are defined as the excess of the actual over the predicted where the latter is calculated using the most significant lags of money and nominal GDP for a number of years bracketing the quarter estimated. As can be seen from the table, none of the coefficients of unanticipated base money, M1 or M2 shocks in the real exchange rate regressions are statistically significant. Moreover, when unanticipated money shocks are estimated from predicted levels of the three monetary aggregates using running regressions with 8 lags of money and GDP, 8 lags of money alone, or 8 quarter linear projections, the unanticipated money coefficients are always statistically insignificant.

In the interest rate differential regressions, statistically significant coefficients are obtained for the base money aggregates implying that an unanticipated increase in French base money or unanticipated decrease in U.S. base money leads to a decline in the French–U.S. interest rate differential, as

Table 23: OLS Regression Analysis of the Effects of Monetary Shocks on the Real Exchange Rate and Long-term Government Bond Rate Differentials: France vs. United States, 1974:Q1 to 1998:Q4

Independent Variables	Dependent Variable: Log of Real Exchange Rate			Dependent Variable: Interest Rate Differential		
Constant	2.429 (1.810) [2.328]	2.679 (1.792) [2.432]	2.477 (1.772) [2.320]	-9.760 (2.930)*** [4.300]***	-10.167 (3.230)*** [4.331]***	-10.131 (3.163)*** [4.108]***
Log of Commodity Prices	0.474 (0.099)*** [0.133]***	0.462 (0.103)*** [0.131]***	0.479 (0.097)*** [0.127]***			
Log of Oil Prices	-0.081 (0.038)** [0.049]*	-0.088 (0.038)** [0.050]*	-0.069 (0.038)* [0.049]			
Log French T.O.T. / U.S. T.O.T	1.792 (0.247)*** [0.221]***	1.839 (0.246)*** [0.207]***	1.922 (0.237)*** [0.199]***			
French less U.S. NCI / GDP	-0.024 (0.008)*** [0.009]***	-0.023 (0.008)*** [0.009]**	-0.025 (0.007)*** [0.009]***	0.209 (0.043)*** [0.050]***	0.223 (0.046)*** [0.055]***	0.220 (0.046)*** [0.057]***
Log of French Real GDP	1.656 (0.472)*** [0.640]***	1.597 (0.468)*** [0.665]***	1.613 (0.451)*** [0.633]**			
Log of U.S. Real GDP	-1.578 (0.338)*** [0.479]***	-1.539 (0.338)*** [0.490]***	-1.552 (0.326)*** [0.472]***			
French less U.S. LT-Govt. Bond Rate	0.036 (0.011)*** [0.015]**	0.032 (0.010)*** [0.015]**	0.035 (0.010)*** [0.015]**			
French less U.S. CPI Inflation	-0.016 (0.007)** [0.007]**	-0.014 (0.007)** [0.006]**	-0.014 (0.007)** [0.005]***	0.236 (0.043)*** [0.048]***	0.223 (0.047)*** [0.056]***	0.234 (0.047)*** [0.057]***

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Table 23: Continued

Independent Variables	Dependent Variable: Log of Real Exchange Rate			Dependent Variable: Interest Rate Differential		
Log of Real Exchange Rate				2.262 (0.581)*** [0.862]***	2.534 (0.641)*** [0.869]***	2.343 (0.627)*** [0.822]***
French Base Money Shock	0.001 (0.002) [0.002]			-0.033 (0.013)** [0.012]***		
U.S. Base Money Shock	-0.011 (0.015) [0.015]			0.469 (0.131)*** [0.172]***		
French M1 Shock		0.001 (0.005) [0.004]			-0.019 (0.050) [0.041]	
U.S. M1 Shock		-0.003 (0.008) [0.007]			0.101 (0.076) [0.091]	
French M2 Shock			-0.005 (0.007) [0.007]			0.094 (0.070) [0.059]
U.S. M2 Shock			0.019 (0.011)]* [0.012]			-0.187 (0.105)* [0.097]*
Num. Obs.	100	100	100	100	100	100
R-Square	.824	.822	.828	.654	.595	.604

Notes and Sources: Unanticipated money shocks are the excess of the actual over predicted based on significant lags of both money and GDP. See previous tables for sources and further information.

might be anticipated by those who see monetary policy as operating through interest rates. The fact that no effects on the real exchange rate are found, however, suggests that the observed statistical relationship must be capturing other unknown forces that could not be included in the analysis. This conclusion is re-enforced by the fact that no statistically significant relationship at the 5% level or better between the interest rate differential and unanticipated M1 and M2 shocks is found—this is the case for all alternative measures of the shocks for each aggregate.

It must be concluded that there is no evidence that unanticipated money supply shocks have significantly affected the French real exchange rate with respect to the United States.

4.5 Germany vs. the United States

The OLS regression results with respect to the relationships between unanticipated money shocks and the German real exchange rate with respect to the U.S. and German minus U.S. interest rates on long-term government bonds are shown in Table 24. The time-period is truncated at 1989:Q4 because of the effects of the subsequent German unification on the data. As in the case of France, the money shocks are measured using the excess of the actual over estimated levels obtained using the most significant lags of the money aggregate and GDP for years surrounding each quarterly estimate. In all cases shown but one, the unanticipated money shock variables are statistically insignificant. The one exception is a significantly positive relationship between unanticipated U.S. M2 shocks and the long-term interest rate differential when HAC standard errors of the coefficients are imposed. An examination of cases where the money supply shocks are estimated based on alternative calculations of expected current levels indicates that the results are essentially the same. Clearly, there is no relationship between unanticipated German money supply shocks and the real exchange rate. And it can be concluded that essentially there is also no relationship between unanticipated money supply shocks and the excess of the German over the U.S. long-term government bond rate.

Table 24: OLS Regression Analysis of the Effects of Money Supply Shocks on the Real Exchange Rate and Interest Rate Differential on Long-term Government Bonds: Germany vs. the U.S., 1974:Q1 to 1989:Q4

Independent Variables	Dependent Variable: Log of Real Exchange Rate			Dependent Variable: Interest Rate Differential		
Constant	5.825 (1.418)*** [1.630]***	5.697 (1.439)*** [1.697]***	6.233 (1.389)*** [1.629]***	-8.485 (12.937) [14.306]	-14.577 (13.735) [15.152]	-15.031 (12.464) [13.515
Log of Commodity Prices	0.232 (0.090)*** [0.084]***	0.206 (0.089)** [0.079]**	0.194 (0.087)** [0.080]**	5.132 (1.168)*** [1.349]***	5.668 (1.158)*** [1.332]***	5.417 (1.101)*** [1.326]***
Log of Oil Rate	-0.168 (0.046)*** [0.048]***	-0.174 (0.046)*** [0.045]***	-0.183 (0.046)*** [0.049]***			
Log of German T.O.T. / U.S. T.O.T.	1.311 (0.174)*** [0.259]***	1.216 (0.188)*** [0.256]***	1.258 (0.186)*** [0.266]***			
German less U.S. Govt. Cons. /GDP	0.062 (0.013)*** [0.018]***	0.062 (0.013)*** [0.018]***	0.057 (0.012)*** [0.018]***	-1.323 (0.177)*** [0.178]***	-1.284 (0.171)*** (0.196)***	-1.204 (0.159)*** [0.209]***
Log of German Real GDP	1.614 (0.489)*** [0.538]***	1.771 (0.493)*** [0.527]*	1.678 (0.500)*** [0.537]***	15.107 (5.814)** [6.247]**	15.242 (5.906)** [6.723]**	14.995 (5.741)** [6.623]**
Log of U.S. Real GDP	-1.584 (0.334)*** [0.338]***	-1.689 (0.333)*** [0.322]***	-1.657 (0.339)*** [0.336]***	-14.937 (4.435)*** [4.829]***	-14.645 (4.443)*** [5.106]***	-14.257 (4.334)*** [5.087]***
	Base	M1	M2	Base	M1	M2
German Money Shock	0.002 (0.010) [0.008]	0.007 (0.006) [0.004]	-0.001 (0.010) [0.008]	0.005 (0.139) [0.119]	-0.079 (0.094) [0.098]	-0.207 (0.144) [0.141]
U.S. Money Shock	0.017 (0.016) [0.014]	-0.006 (0.008) [0.005]	-0.008 (0.010) [0.008]	-0.343 (0.245) [0.232]	0.091 (0.110) [0.094]	0.218 (0.138) [0.099]**
Num. Obs.	64	64	64	64	64	64
R-Square	.930	.930	.929	.842	.840	.847

Notes and Sources: See Table 23.

5 Evidence from a Blanchard-Quah VAR Analysis

Our OLS regression analysis of the effects of unanticipated money supply shocks on the real exchange rate failed to find any significant evidence that such shocks had the theoretically postulated negative effects on the country's real exchange rate. We would have to conclude on the basis of this evidence that the monetary authorities of the countries examined other than the United States did not aggressively pursue independent monetary policies. There is clearly no evidence of overshooting shocks to real exchange rates in response to direct actions of the authorities. But that analysis does not rule out the possibility that there could have been unanticipated demand for money shocks that the authorities did not react to by appropriately adjusting the money supply to prevent exchange rate effects.

To investigate this possibility a VAR analysis of the form developed by Blanchard and Quah is conducted using monthly real and nominal exchange rate data for the five countries with respect to the United States.[35]

Standard-form VARs were run using each country's real and nominal exchange rates with respect to the U.S. as variables, and moving-average-representations were calculated.[36] Instead of obtaining the underlying structural coefficients by a Choleski decomposition that imposes the restriction that one of the variables has no current-period effect on the other, an alternative restriction is imposed following Blanchard and Quah. The structural coefficients are restricted by the requirement that one of the two orthogonal shocks, here called the monetary shock, has no permanent effect on one of the variables, in this case the real exchange rate. The money shock has a permanent effect on the nominal exchange rate while the other shock, here called the real shock, has permanent effects on both the nominal and real exchange rates.

The resulting impulse-responses and forecast-error-variance decompositions for the five countries are plotted, along with 90% confidence intervals in Figures 15, 17, 19, 21 and 23. Historical decompositions of the real and nominal exchange rates into the movements caused by the real and nominal shocks are plotted in Figures 16, 18, 20, 22 and 24. The percentages of the forecast-error-variances of the five real exchange rates due to monetary

[35] Olivier Jean Blanchard and Danny Quah, "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, Vol. 79, September 1989, 655-73.

[36] For a review of the basics of estimation and interpretation of VARs, and appropriate references to the literature on the subject, see John E. Floyd, "Vector Autoregression Analysis: Estimation and Interpretation," Unpublished Manuscript, University of Toronto, September 19, 2005.

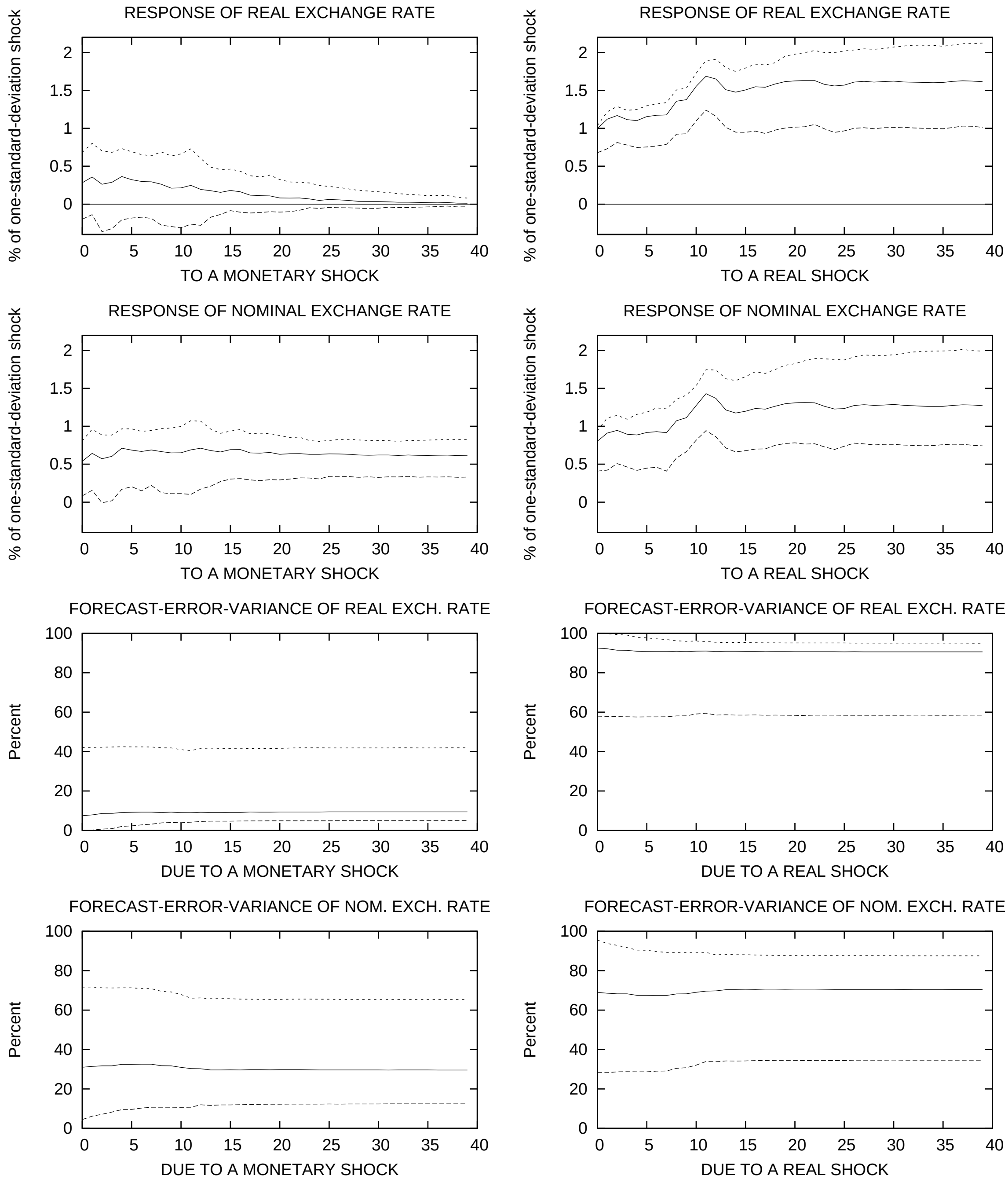

Figure 15: Blanchard-Quah VAR impulse-responses and forecast-error-variance decompositions for Canada's real and nominal exchange rates with respect to the U.S. dollar. The confidence intervals are 90 percent.

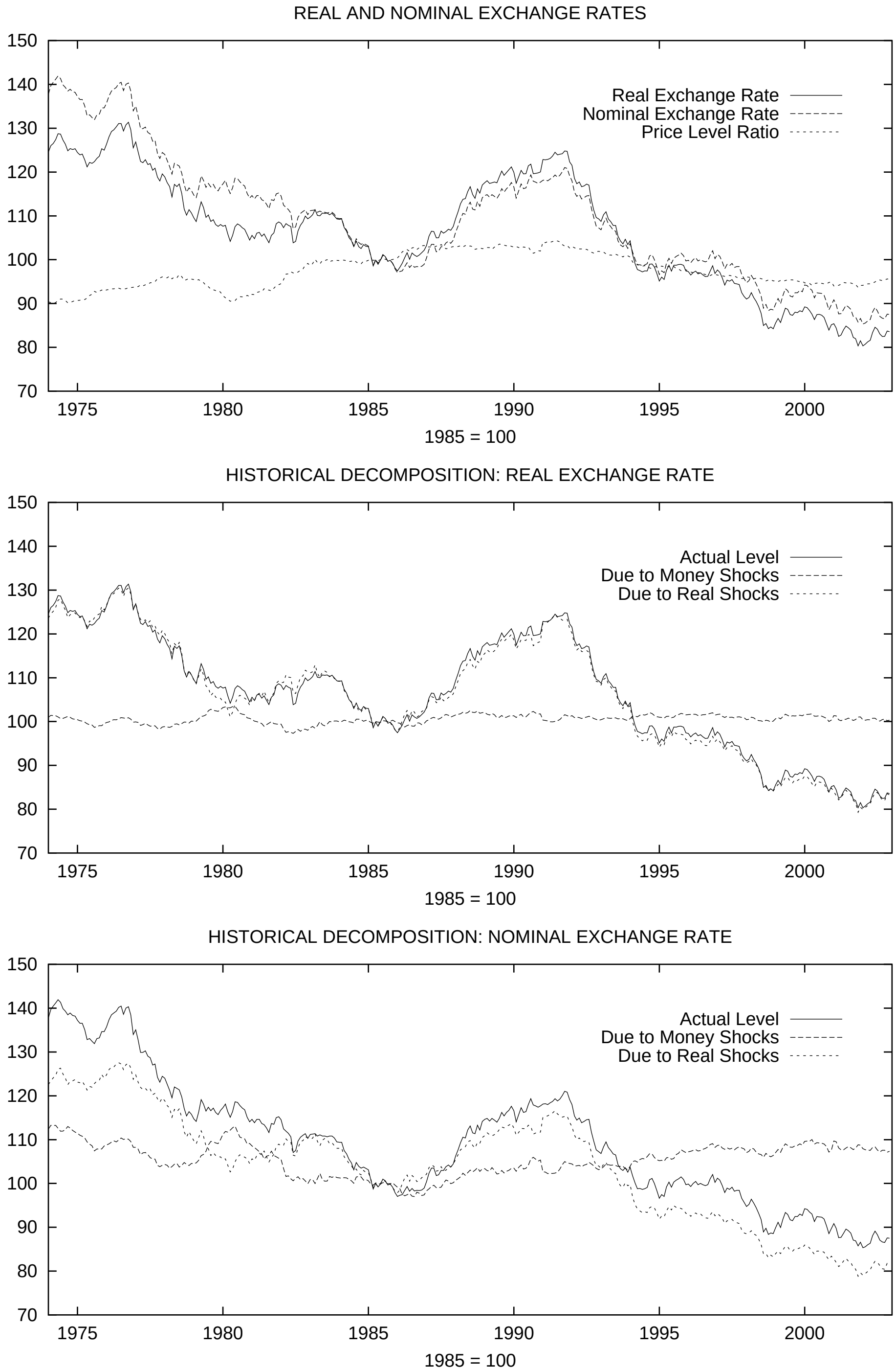

Figure 16: Blanchard-Quah-VAR historical decompositions of Canada's real and nominal exchange rates with respect to the U.S. dollar into the movements attributable to real and money shocks.

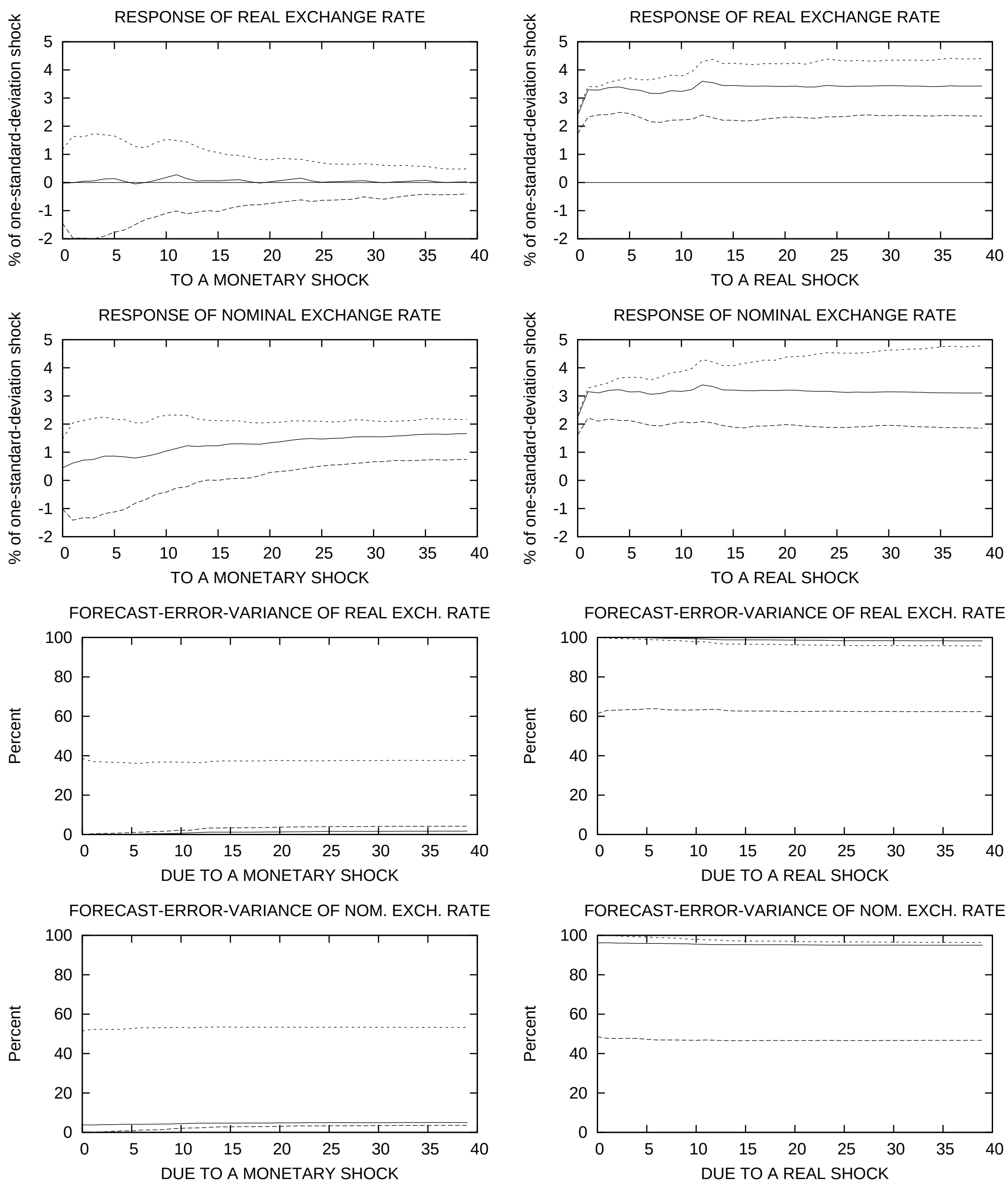

Figure 17: Blanchard-Quah VAR impulse-responses and forecast-error-variance decompositions for Britain's real and nominal exchange rates with respect to the U.S. dollar. The confidence intervals are 90 percent.

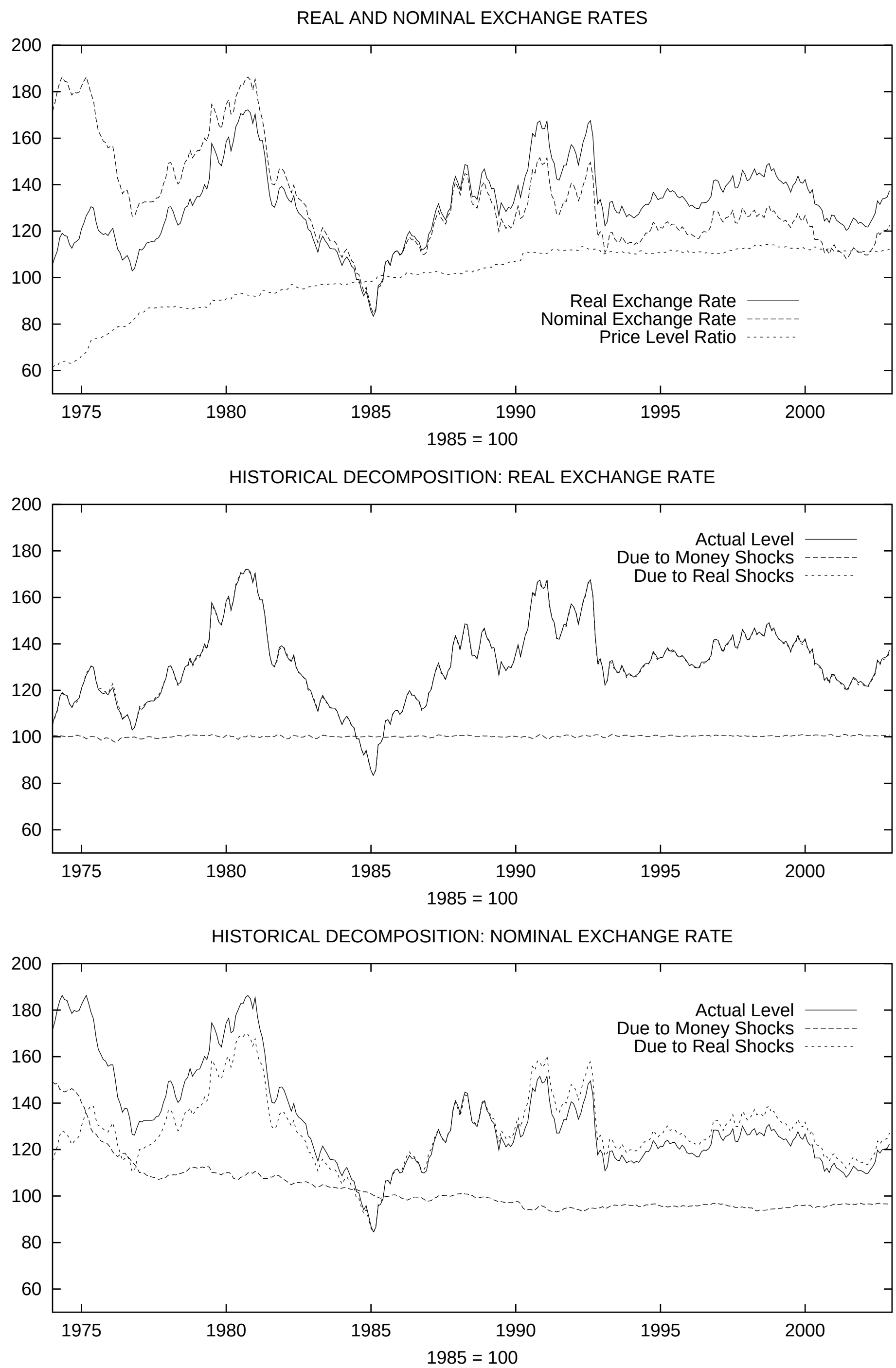

Figure 18: Blanchard-Quah-VAR historical decompositions of Britain's real and nominal exchange rates with respect to the U.S. dollar into the movements attributable to real and money shocks.

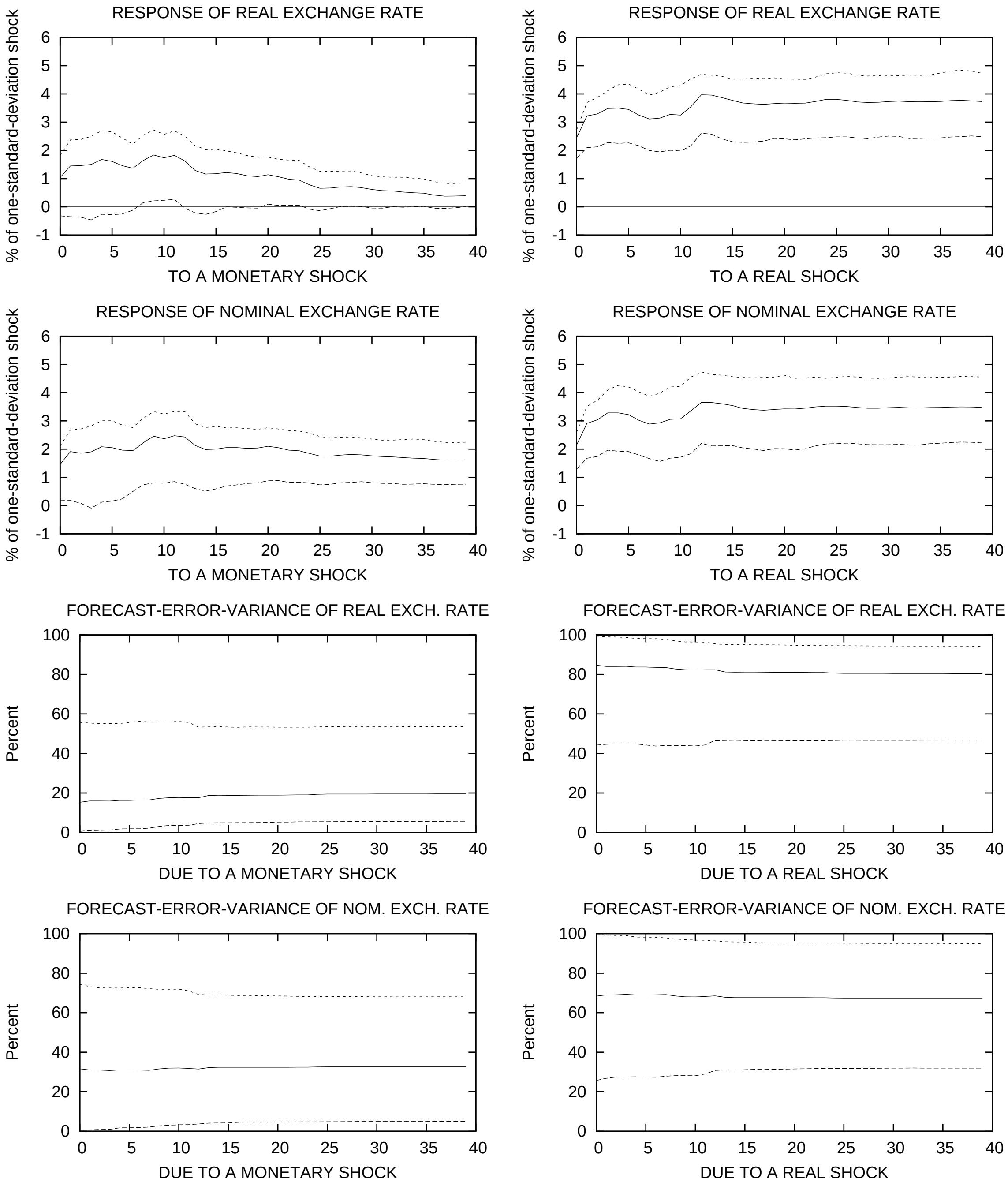

Figure 19: Blanchard-Quah VAR impulse-responses and forecast-error-variance decompositions for Japanese real and nominal exchange rates with respect to the U.S. dollar. The confidence intervals are 90 percent.

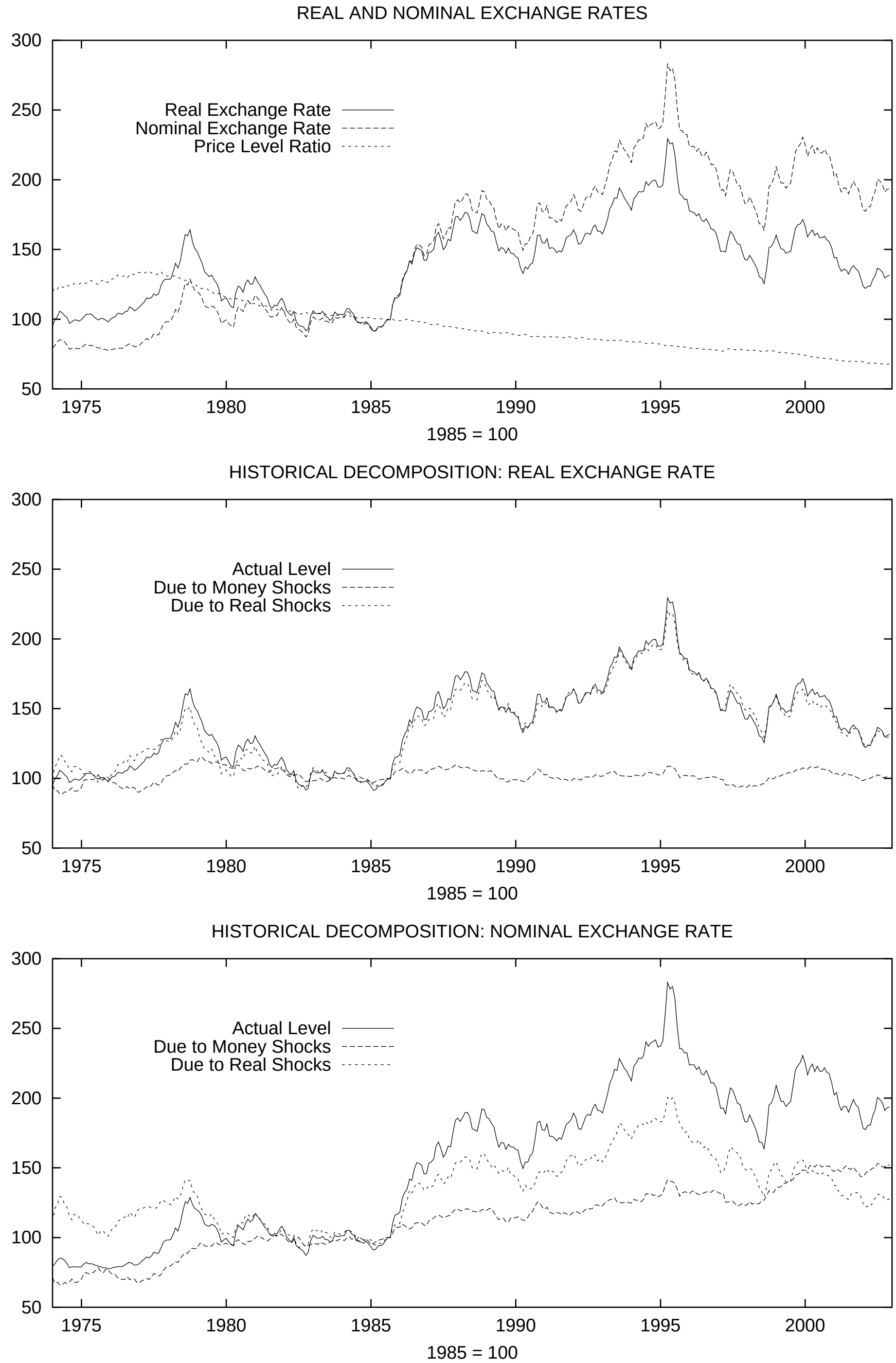

Figure 20: Blanchard-Quah-VAR historical decompositions of Japanese real and nominal exchange rates with respect to the U.S. dollar into the movements attributable to real and money shocks.

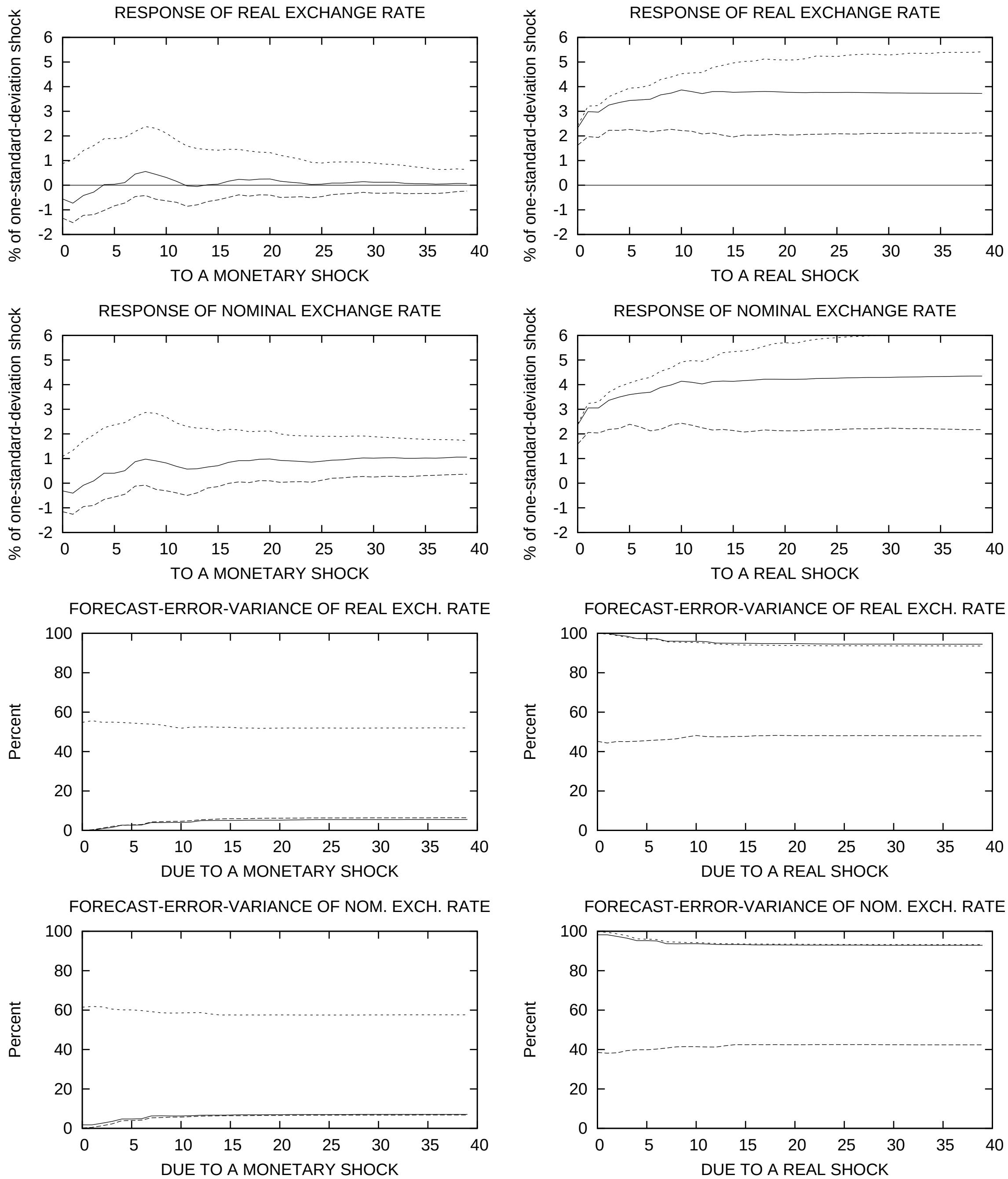

Figure 21: Blanchard-Quah VAR impulse-responses and forecast-error-variance decompositions for French real and nominal exchange rates with respect to the U.S. dollar. The confidence intervals are 90 percent.

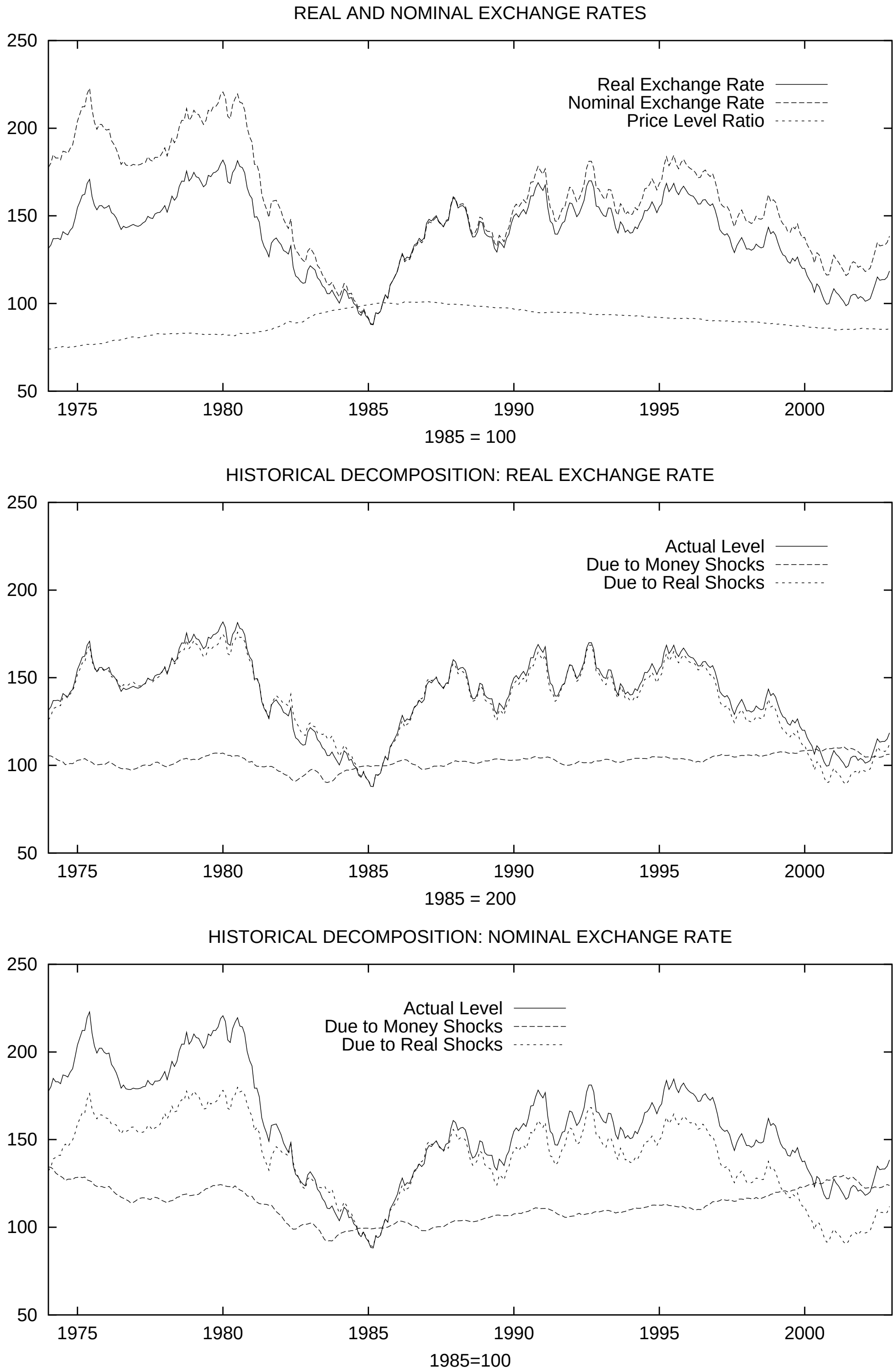

Figure 22: Blanchard-Quah-VAR historical decompositions of French real and nominal exchange rates with respect to the U.S. dollar into the movements attributable to real and money shocks.

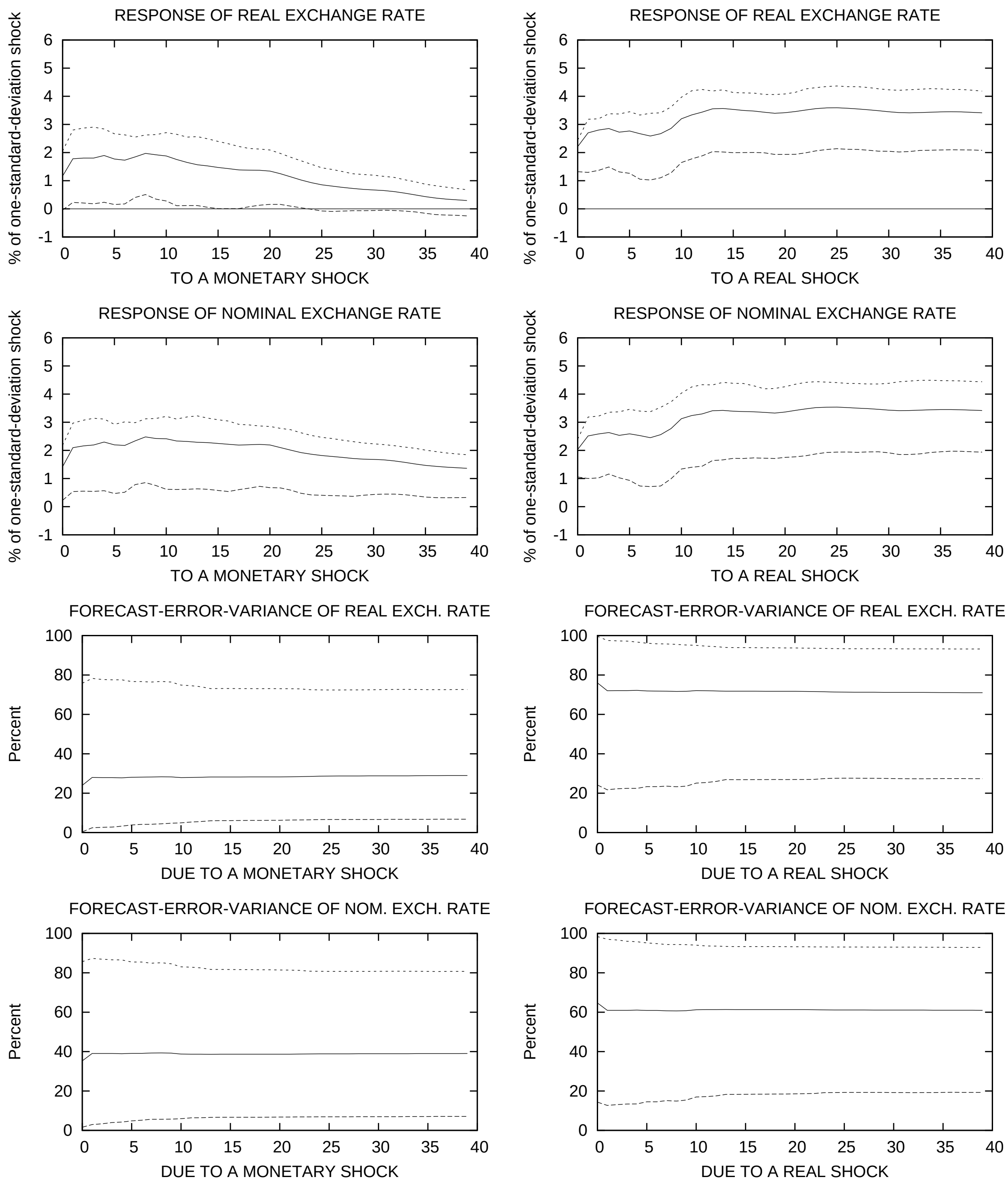

Figure 23: Blanchard-Quah VAR impulse-responses and forecast-error-variance decompositions for German real and nominal exchange rates with respect to the U.S. dollar. The confidence intervals are 90 percent.

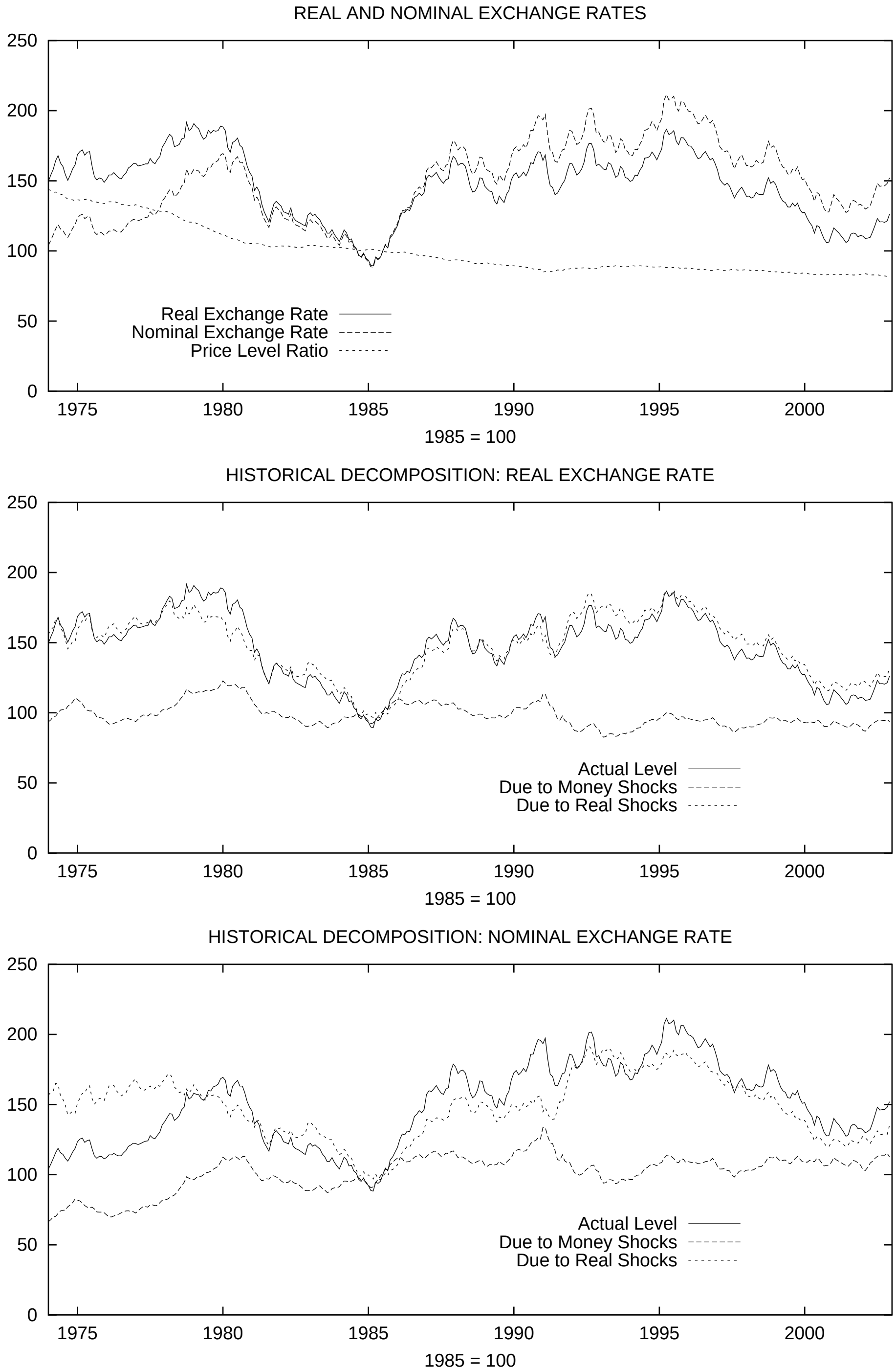

Figure 24: Blanchard-Quah-VAR historical decompositions of German real and nominal exchange rates with respect to the U.S. dollar into the movements attributable to real and money shocks.

Table 25: Percentages of the Forecast-Error-Variances of the Real Exchange Rate Due to Monetary Shocks

Horizon	U.K.	Canada	France	Japan	Germany
1	0.009	7.478	5.417	15.296	21.712
2	0.012	7.847	5.495	15.959	25.274
3	0.056	8.585	6.948	15.950	25.243
4	0.057	8.614	7.130	15.895	25.232
5	0.135	9.104	8.447	16.224	25.261
6	0.137	9.227	8.442	16.274	25.430
7	0.275	9.272	8.507	16.427	25.412
8	0.400	9.273	10.134	16.478	25.525
9	0.438	9.093	10.242	17.246	25.667
10	0.527	9.289	10.431	17.605	25.564
11	0.676	9.045	10.605	17.709	25.154
12	0.809	9.002	10.928	17.606	25.253
13	1.072	9.212	11.364	17.629	25.329
14	1.180	9.082	11.362	18.721	25.355
15	1.180	9.114	11.433	18.849	25.375
16	1.181	9.155	11.440	18.830	25.399
17	1.191	9.159	11.623	18.830	25.411
18	1.195	9.316	11.695	18.841	25.433
19	1.262	9.305	11.704	18.902	25.428
20	1.301	9.298	11.723	18.908	25.423
21	1.331	9.354	11.723	18.949	25.431
22	1.355	9.354	11.829	18.996	25.511
23	1.388	9.355	11.856	19.072	25.626
24	1.411	9.347	11.870	19.075	25.750
25	1.544	9.371	11.911	19.319	25.839
26	1.579	9.385	11.915	19.449	25.894
27	1.586	9.375	11.938	19.446	25.917
28	1.587	9.379	11.938	19.453	25.935
29	1.590	9.392	11.949	19.454	25.948
30	1.593	9.392	11.959	19.466	25.955
31	1.620	9.392	11.965	19.503	25.954
32	1.636	9.392	11.965	19.520	25.956
33	1.647	9.394	11.965	19.519	25.969
34	1.652	9.394	11.986	19.532	25.999
35	1.658	9.394	11.989	19.538	26.039
36	1.663	9.395	11.989	19.541	26.077
37	1.703	9.394	11.993	19.579	26.103
38	1.712	9.394	11.994	19.592	26.117
39	1.717	9.399	11.999	19.592	26.123
40	1.718	9.399	11.999	19.591	26.128

Notes: The forecast horizons are monthly.

Table 26: Historical Decomposition: Changes in Real Exchange Rate Levels Due to Monetary Shocks

	Maximum Level	Minimum Level	Maximum Less Minimum
Canada	102.863	96.745	6.118
U.K.	100.895	97.506	3.392
Japan	113.144	87.019	26.125
France	104.967	93.732	11.235
Germany	121.910	83.629	38.281

shocks are presented in Table 25.

As indicated in the upper left panels of the relevant figures, for Canada, Britain and France, the confidence intervals of the response of the real exchange rate to a monetary shock bracket zero. For Japan and Germany, the lower confidence interval is sometimes above zero. The plots of the historical decompositions indicate clearly that the bulk of the movements of the respective real exchange rates was the result of real shocks. In the cases of Canada, Britain and France the movements of the real exchange rates in response to monetary shocks are very small while in the case of Japan and Germany, there are clearly significant effects. This is confirmed by the percentages of the forecast-error-variances due to monetary shocks printed in Table 25. The percentages due to monetary shocks exceeded 26% for Germany and nearly 20% for Japan. For France, the percentage was below 12%, and for Canada and Britain, below 10% and 2% respectively. It is clear that, except for the U.K., the effects of monetary shocks on the real exchange rates were not trivial.

This conclusion is strengthened by the results reported in Table 26. The left-most column in that table reports the maximum levels of the historically decomposed real exchange rates reached on the basis of monetary shocks alone, given an overall average level of 100. This enables us to attach numbers to the range of variation of the dashed lines in the relevant figures. The middle column reports the minimum level reached and the right-most column the difference between the maximum and minimum levels. Indications are that the Germany real exchange rate varied as much as 38 percent, and the Japanese real exchange rate as much as 26 percent, relative to their average levels, on account of monetary shocks. For France the range was 11 percent and for Canada and the U.K., 6 and 3.5 percent respectively. A real exchange rate movement of 3.5 percent in response to a monetary shock or series of monetary shocks cannot be ignored.

6 Explaining the Evidence

The Blanchard-Quah VAR analysis clearly indicates that, while the bulk of observed real exchange rate movements were the result of real shocks, monetary shocks were clearly present and substantial in the cases of Germany and Japan with respect to the United States. And, while their statistical significance cannot be established, there also appear to have been non-trivial effects of monetary shocks on the real exchange rates of France and Canada with respect to the U.S. Over the same period, OLS regressions treating the real exchange rates in question as the dependent variables and relevant real forces along with unanticipated money supply shocks as the independent variables indicate clearly that unanticipated money supply shocks had no significant impact on real exchange rates in a direction that would be predicted by economic theory under the assumption, of course, that these observed money supply shocks resulted from exogenous actions of the authorities. All this evidence combined suggests that demand for money shocks were quite likely important though relatively minor determinants of real exchange rate levels for Germany and Japan with respect to the U.S. and quite possibly had minor effects on the real exchange rates of France, Canada and Britain with respect to the United States.

The earlier discussion of overshooting, the conclusions of which are summarised in equation (24), established that the effects of excess money supply shocks on nominal exchange rates are likely to be immediately in the neighbourhood of ten-times the relative money shock and then to abate slowly with time. Until the prices of non-traded output components are able to adjust there should be a smaller but substantial similar effect on real exchange rates. This type of variability does not seem to be present in the historically decomposed real exchange rate movements due to money shocks.

Apart from the United States, where little attention is paid to foreign exchange rate movements, it is difficult to imagine how a modern central bank could tolerate overshooting movements in the nominal exchange rate—at a minimum, it will be expected to maintain 'orderly' domestic financial markets. Accordingly, any perceived shock to the demand for money that will impact on the nominal exchange rate will almost surely be accommodated by the authorities through equivalent adjustments in the money supply. Thus, the failure to observe any significant relationship between unanticipated money supply shocks and real exchange rate probably results from the fact that observed money supply shocks reflect a response to shocks to the demand for money. In some cases, the accommodation may be inadequate in which case there will be a positive relationship between the observed domestic unanticipated money shock and the real exchange rate, while in other cases there may be over-accommodation in which case the observed relationship between the real exchange rate and observed unanticipated money supply shocks will be negative. Over reasonably long time-horizons these random effects average out to the extent that no consistent systematic relationship is observed between real exchange rates and the set of alternative measures of unanticipated shocks to the countries' monetary aggregates.

Nevertheless, one must not be too quick to rule out the possibility of overshooting on the basis of modest effects of money shocks on real exchange rates and the rather smooth time-paths of the price level ratio series plotted in the middle and top panels of Figures 16, 18, 20, 22 and 24. The results of an OLS-regression analyses of the historically-decomposed relationship between the observed effects of money shocks on the real exchange rates obtained from the Blanchard-Quah VARs and the differences between the respective domestic and U.S. inflation rates are presented in Table 27. The underlying hypothesis is that money shocks have temporary effects on the real exchange rate and permanent effects on the nominal exchange rate. If overshooting is occurring, and there is not complete pricing to market, these temporary real exchange rate adjustments should quickly produce corresponding price-level changes along with their permanent effects on the nominal exchange rate. Ultimately, the changes in the price level will be inversely proportional to the change in the nominal exchange rate as the real exchange rate returns to its equilibrium level. Because asset equilibrium cannot be maintained in the short-run through output changes, given the time it takes for exports and imports to respond to real exchange rate changes, adjustments of the real money supply via price level adjustments will be necessary. These should appear as temporary changes in the inflation rate, in the opposite direction to the real exchange rate effect of the monetary shock, that will dissipate in the long run when the nominal exchange rate and price level have fully adjusted.

As can be seen from Table 27, in every country examined but France there is a significant negative relationship between the movements of the real exchange rate that result from monetary shocks and the country's inflation rate. A monetary expansion that temporarily reduces the real exchange rate will be associated with an increase in the inflation rate in subsequent quarters, although in the cases of Japan and Germany the effects are signif-

Table 27: OLS Regression Analysis of the Relationship Between the Blanchard-Quah Decomposed Monetary Shocks to the Real Exchange Rate and Domestic Minus U.S. Inflation Rates

Independent Vaariables	Canada	U.K.	Japan	France	Germany
Constant	0.172 (0.096)* [0.171]	2.183 (0.288)*** [0.462]***	-1.456 (0.205)*** [0.426]***	0.792 (0.251)*** [0.467]*	-2.150 (0.102)*** [0.168]***
Monetary Shock to Real Exchange Rate Lagged....					
Once	-1.482 (0.220)*** [0.241]***	-3.917 (0.702)*** [0.883]***	-0.483 (0.044)*** [0.101]***	-0.260 (0.233) [0.265]	-0.267 (0.012)*** [0.021]***
Twice	0.190 (0.357) [0.301]	-2.897 (0.703)*** [0.440]***		0.066 (0.219) [0.174]	
Three Times	-0.609 (0.358)* [0.246]**			-0.099 (0.229) [0.269]	
Four Times	0.718 (0.221)*** [0.211]***				
Num. Obs.	112	112	112	112	112
R-Square	.696	.394	.519	.014	.829

Notes and Sources: The estimates for Canada, the U.K. and Japan run from 1975:Q1 through 2002:Q4 while the estimates for France and Germany run from 1974:Q1 through 1998:Q4. The figures in the brackets ( ) are the standard deviations of the coefficients as conventionally calculated and the figures in the brackets [ ] are the corresponding heteroskedastic and autocorrelation adjusted standard errors with truncation lag equal to 4. Significant serial correlation is present in the residuals of all the standard regressions. The superscripts *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively according to a standard t-test. The data are from the previous Blanchard-Quah decomposition and the International Monetary Fund *International Financial Statistics.*

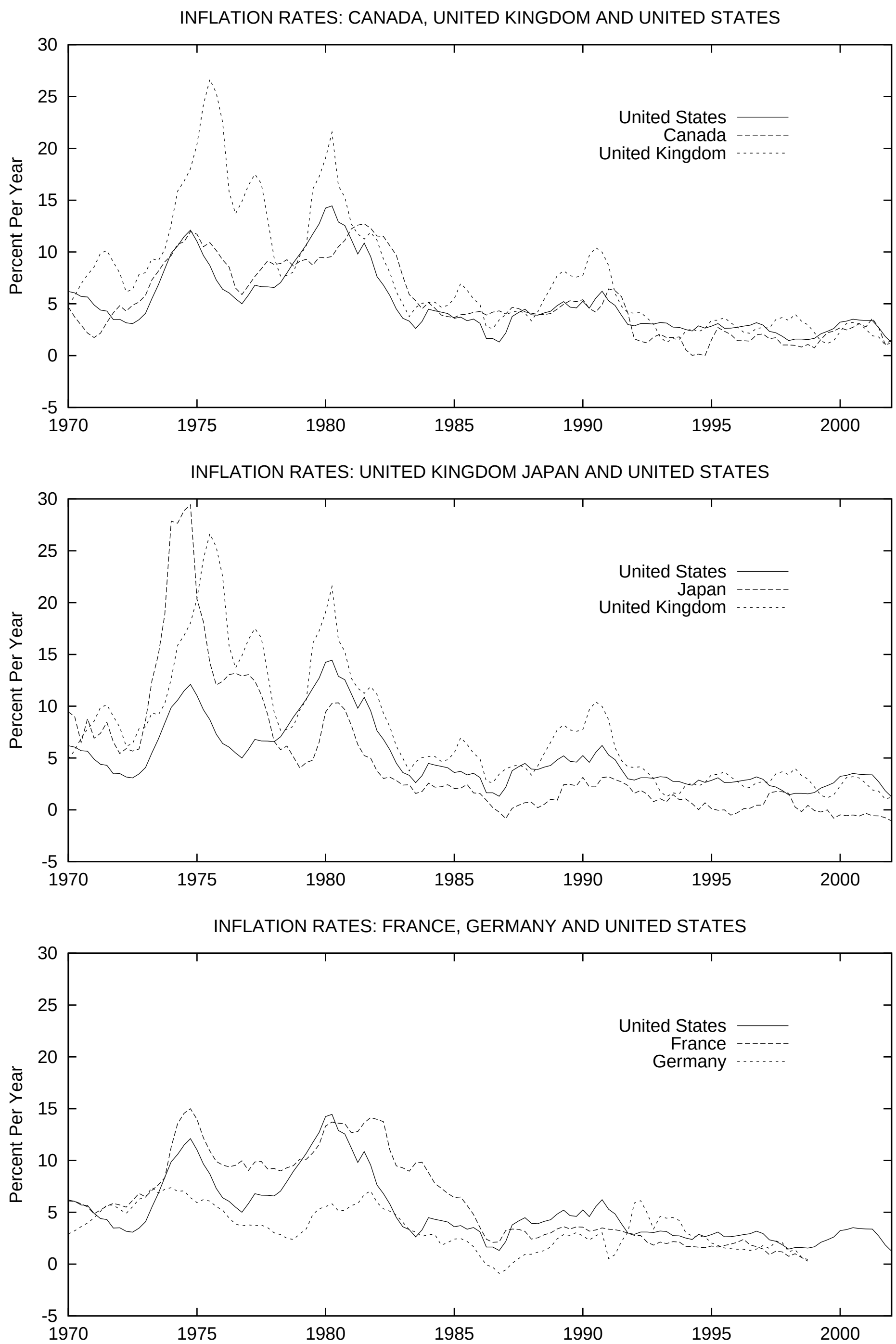

Figure 25: Comparative inflation rates of United States and Canada, United Kingdom, Japan, France and Germany. Source: International Monetary Fund *International Financial Statistics.*

icant only in the first quarter. In the Canadian case a positive relationship occurs in the fourth quarter, suggesting that the price level is achieving its new equilibrium level, thereby permitting the inflation rate to decline. Alternatively, however, since the monetary shock's effect on the real exchange rate is temporary, the inflation rate will automatically change direction as the effect of the shock on the real exchange rate changes direction.

The results for France are puzzling. Not only are the coefficients statistically insignificant, but the magnitudes of the point estimates are small. One possibility is that output changed instead of the inflation rate in response to the temporary real exchange rate effects of monetary shocks. Alternatively, the French results may have been materially affected by the distorting effect of a third shock. There may have been significant monetary shocks that were fully anticipated by the market in which case the nominal exchange rate, and price level, may have changed independently of temporary shocks to the real exchange rate. To keep this type of shock from contaminating the results, another equation would have to be added to the VAR and the additional constraint imposed to require this third shock to immediately and permanently affect the nominal exchange rate but not the real exchange rate. This is an area for future research.

On the basis of this evidence for the other four countries the possibility of overshooting cannot be ruled out although it can nevertheless be concluded that whatever overshooting movements that occurred were too small to be observable in the plots of the price-level ratio series on the same graph with the nominal and real exchange rates.

Despite the above-noted accommodation of demand for money shocks by offsetting money supply adjustments, the authorities in countries outside the United States may nevertheless systematically 'lean' in a particular direction, creating slight movements in real exchange rates in any given month or over a series of months. As an examination of equation (24) reveals, slight movements of the real (and nominal) exchange rates will involve excess money supply shocks so small as to be unobservable, given normal demand for money shocks, shifts in private sector holdings of the various types of bank deposits and changes in the ratios of the various monetary aggregates to the monetary base, the only aggregate the authorities directly control.

Figure 25 plots the inflation rates of the six countries studied here. There are clear indications of both similarities and differences in their inflation experience. All countries experienced peaks in their inflation rates around the mid-1970s and 1980 and very much smaller peaks around 1990. Nevertheless, the size of the peaks differed substantially across countries and each country experienced small movements in its inflation rate that differed from the corresponding movements in other countries. This, combined with the well-known fact that the countries experienced similar business cycle variations in output, although with significant differences in the exact timing of peaks and troughs, suggests that broadly similar, yet somewhat different, monetary policies were being followed. All this occurred without obvious visual evidence in the data of exchange rate overshooting.

7 Conclusions

The main, incontrovertible, conclusion of this study is that the bulk of observed real and nominal exchange rate variations are the result of exogenous real forces related in obvious ways to technological progress and capital accumulation. In the case of Canada with respect to the U.S., the main real force explaining the variations of the real and nominal exchange rates is reallocations of world investment between the two countries. And the main factor explaining the downward trend since 1974 is probably the fall in world commodity prices. In the cases of Germany, France and, to a lesser extent the United Kingdom, with respect to the United States, the major identifiable real factor seems to be changes the those countries' terms of trade with respect to the rest of the world relative to the U.S. terms of trade with respect to the rest of the world. A whole range of real factors were important in determining the real and nominal exchange rates of Japan with respect to the United States—domestic and U.S. real GDP, Japanese less U.S. government consumption expenditure, each taken relative tot he respective country's GDP, as well as Japanese terms of trade relative to U.S. terms of trade, and Japanese minus U.S. net capital inflows as percentages of the respective GDP's, but none of these factors stand out as more important than the others. Various of these real factors along with commodity prices and oil prices were also statistically significant, though not dominant, determinants of the real exchange and nominal exchange rates of the other four countries with respect to the U.S.—the only dominant factors were the net capital inflow and commodity price variables for Canada and the terms of trade variables for France, Germany, and to a lesser extent the United Kingdom.

The evidence uncovered here extends the analysis undertaken by Baxter and Stockman and Flood and Rose who concluded that real exchange rate variability was much greater under flexible than fixed exchange rate regimes while 'market fundamentals' have been essentially the same under both, which raises the question as to why countries would ever adopt flexi-

Table 28: Variances in Periods of Fixed and Flexible Exchange Rates of Real Variables in Table 1, 5, 7, 9 and 11 OLS Regressions

	Fixed Exchange Rates			Flexible Exchange Rates		
	Raw Variance	Trend Slope	Residual Variance	Raw Variance	Trend Slope	Residual Variance
CANADA vs. U.S.	1962:Q3–1970:Q1			1974:Q1–2002:Q4		
Real Exch Rate	1.872	0.120	0.663	173.30	-0.302	70.346
Oil Prices	3.666	-0.183	0.892	522.49	-0.278	434.78
Ratio of TOT	1.171	0.075	0.699	41.908	-0.070	36.307
Diff NCI/GDP	0.686	-0.046	0.511	8.237	-0.048	5.660
Diff Govt Cons /GDP	0.750	0.083	0.175	1.660	0.025	0.940
U.K. vs. U.S.	1957:Q1–1971:Q2			1974:Q1–2002:Q4		
Real Exch Rate	32.30	0.377	2.561	275.93	0.129	257.18
Oil Prices	6.007	-0.125	1.228	522.49	-0.278	434.78
Diff NCI/GDP	1.296	0.222	0.884	4.265	-0.006	4.212
	1959:Q1–1971:Q2					
Diff Govt Cons /GDP	0.179	0.008	0.172	0.768	0.0007	0.7676
	1963:Q1–1971:Q2					
Ratio of TOT	3.112	0.270	1.176	71.192	0.083	63.450
JAPAN vs. U.S.	1957:Q1–1971:Q2			1974:Q1–2002:Q4		
Real Exch Rate	48.84	0.400	3.351	901.34	0.554	554.71
Oil Prices	6.007	-0.129	1.233	522.49	-0.278	434.78
Ratio of TOT	29.44	-0.169	21.29	229.80	0.054	226.46
Diff NCI/GDP	2.517	-0.047	1.879	4.230	-0.029	3.246
	1959:Q1–1971:Q2					
Diff Govt Cons /GDP	1.044	-0.045	0.610	5.548	0,058	1.698
FRANCE vs. U.S.	1958:Q4–1972:Q4			1974:Q1–1998:Q4		
Real Exch Rate	41.38	0.468	4.534	399.04	0.002	399.04
Oil Prices	7.058	-0.136	1.124	569.97	-0.404	432.68
Ratio of TOT	11.70	0.084	3.979	44.979	0.162	22.967
GERMANY vs. U.S.	1960:Q1–1971:Q1			1974:Q1–1989:Q4		
Real Exch Rate	15.88	0.191	7.605	663.38	-0.664	510.41
Oil Prices	4.765	-0.144	0.884	563.69	-0.036	563.25
Ratio of TOT	6.197	0.084	2.731	64.040	0.134	57.807
Diff Govt Cons /GDP	0.767	0.034	0.514	0.6199	-0.010	0.5814
				1971:Q2–1989:Q4		
Diff Govt Cons /GDP				2.392	0.031	1.942

ble exchange rates.[37] The analysis here extends what we mean by 'market fundamentals' to include the effects of domestic and world wide technological change and capital accumulation. Table 28 presents calculations of the variances, under fixed and flexible exchange rate regimes, of the real factors found in Section 3 to have influenced real exchange rates during the period from 1974 onward. It is obvious from the results that these real factors were much less variable during periods of fixed exchange rates than they were when exchange rates were allowed to float.[38] It would seem reasonable to conclude that these countries abandoned the fixed exchange rate system to protect their domestic price levels from the very substantial real exchange rate shocks that began to occur in the early 1970s. These shocks were thus accommodated by adjustments in nominal exchange rates on a par with movements in real exchange rates—otherwise they would have been transmitted to the countries' price levels.

Evidence of negative effects of exogenous unanticipated money supply shocks on the real exchange rates studied here is non-existent. But there is clear evidence of money demand shocks and also quite strong evidence of overshooting effects of monetary shocks on real and nominal exchange rates, although these effects are too small to be visible in plots of the real and nominal exchange rates and price level ratios on the same graph. The weight of this evidence suggests that, at least in countries other than the United States, monetary policy operates not through exogenous adjustments in base money or base-money financed changes in market interest rates, but through gentle pressure on nominal, and hence real, exchange rates. This is not to suggest that exchange rates were 'policy instruments', but rather, that monetary adjustments were constrained to avoid obvious exchange rate overshooting. Although differences in monetary policy existed across the countries examined, it would appear that, apart from differing underlying core inflation rates that are fully anticipated by the market, countries tend to maintain monetary conditions quite similar to those in the United States. To the extent that this is true, and U.S. authorities pay no attention to

[37] See the citations in Footnotes 1 and 2.

[38] Only in the case of the difference in government consumption expenditure as a fraction of GDP for Germany as compared to the United States was the variance roughly similar in the fixed exchange rate years and the period 1974 through 1989. When we calculate the variance for the entire flexible exchange rate period from the second quarter of 1971 through 1989, however, it is found to be much higher than in the fixed exchange rate period. Evidently, this variable changed substantially during the first two years of exchange rate flexibility. In all other cases there was no significant difference between the variance during our estimation period and the somewhat longer period in which exchange rate flexibility ruled.

the effects of that country's monetary policy on exchange rates, the United States can be said to 'run' world monetary policy. Any U.S. monetary expansion or contraction appears to induce roughly equivalent monetary expansion or contraction by other countries to prevent noticeable, and hence apparent financially destabilising, overshooting changes in their exchange rates with respect to the U.S. dollar.

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