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SOURCES OF CURRENCY CRISES: AN EMPIRICAL ANALYSIS

by

Axel A. Weber
Universität Bonn and CEPR

RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITÄT BONN

D 53113 Bonn, Adenauerallee 24-42

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ABSTRACT

Two types of currency crisis models coexist in the literature: first generation models view speculative attacks as being caused by economic fundamentals which are inconsistent with a given parity. Second generation models claim self-fulfilling speculation as the main source of a currency crisis. Recent empirical research in international macroeconomics has attempted to distinguish between the sources of currency crises. This paper adds to this literature by proposing a new empirical approach to identifying the speculative and fundamental components of currency crises in the context of a structural vector autoregression model. Our results suggest that only for the French franc can a substantial speculative component be identified as a potential source of the 1992-93 ERM crisis.

JEL classification: F0, F3

Keywords: exchange rates, speculation, fundamentals, currency crisis, purchasing power parity, structural vector autoregression, impulse response

Axel A. Weber
Universität Bonn
Rechts- und Staatswissenschaftliche Fakultät
Institut für Wirtschaftstheorie II
Lennéstraße 43, 53113 Bonn
GERMANY

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1. Introduction

In their survey of the literature Agenor, Bhandari and Flood (1992), Obstfeld (1995, 1996) and Eichengreen, Rose and Wyplosz (1995a, 1995b) point out that the two generations of speculative attack models co-exist in the literature: the first generation of such models is based on theoretical work by Krugman (1979), Flood and Garber (1984a) and Obstfeld (1984), and these models have been generalized in various directions by Willman (1988), Wyplosz (1989), Gros (1992), and Goldberg (1994), amongst others. Second generation models of currency crisis originate in the work of Flood and Garber (1984b) and Obstfeld (1986), with more recent extensions in Claessens (1991), Dellas and Stockman (1992), Ozkan and Sutherland (1994), Obstfeld (1994, 1996), Bensaid and Jeanne (1994), and Flood and Marion (1996), amongst others. First generation models of currency crisis predict co-movements between speculative attacks and adverse developments in the fundamental determinants of exchange rates, such as differential movements of money growth rates, price or wage inflation rates, real output growth rates, budget or trade deficits, to mention but a few possible fundamentals. Diverging fundamentals are viewed as being inconsistent with a given parity; fundamental economic imbalances indicate a lack of central bank commitment to the parity; they are interpreted by market participants as a signal that a realignment will occur sooner or later. The ability of a central bank to postpone realignments typically depends on the volume of their foreign exchange reserves. In most models expectations of a change in the exchange rate emerge as soon as these reserves have fallen below a critical threshold. Such realignment expectations are reflected by increasing risk premia and rising interest rate differentials during the attack. Note that in these first generation speculative attack models only tight international policy co-ordination aimed at keeping fundamentals closely in line can ultimately avoid a currency crisis. In second generation models this remedy is useless, because these models predict that self-propagating and potentially self-fulfilling speculative attacks may occur out of the blue, even if fundamentals are consistent with the indefinite maintenance of a given fixed parity. Recent theoretical research has stressed that self-fulfilling speculative attacks may have contagious effects on other currencies. For the precise modelling of these international spillovers see Gerlach and Smeets (1994), Buiter, Corsetti and Pesenti (1995, 1996) or Eichengreen, Rose and Wyplosz (1995c).

Given these alternative views, which is the empirically more relevant model? The answer to this question solely depends on whether or not empirically a currency crisis must be viewed as being justified by fundamental imbalances or as being purely speculative. Systematic empirical research on these issues is only just emerging, and the evidence is mixed. By using event studies Eichengreen, Rose and Wyplosz (1995a, 1995b) and Kaminsky (1996) show that currency crises are frequently preceded by fundamental macroeconomic imbalances and early warning signs. Jeanne (1995) and Jeanne and Masson (1996), on the other hand, demonstrate empirically that the French franc crisis of 1992-93 had strong self-fulfilling characteristics. Flood and Marion (1996) also try to distinguish between fundamental and speculative components of a currency crisis by analysing data from the Mexican peso crisis of 1992-94.

The present paper extends the empirical literature by proposing a new empirical approach to identifying the speculative and fundamental components of a currency crisis in the context of a structural vector autoregression model. To get to grips with this issue, we develop a theoretical model in which the exchange rate is driven by various fundamental factors, but also has a speculative component. We will focus on both monetary and real fundamentals: on the real side of the economy we allow for differential behaviour of real wages, real interest rates, employment and output between the two countries under study. On the monetary side we focus on differential movements of nominal interest rates, money, prices and wages. We view these variables as being jointly driven by five distinctive fundamental disturbances: labour supply and productivity shocks, aggregate demand shocks, and financial shocks, such as money supply and money demand (velocity) shocks. We also include a speculative shock in our model by allowing for time-varying risk premia. We will derive the reduced form rational expectations solution of the model under both fully flexible prices (long-run solution) and under sluggish price adjustment (short-run solution). Based on these alternative solutions we will try to pin down theoretically the effects of the various shocks on the nominal exchange rate and the other variables in our model, and we will attempt to empirically estimate the relative contribution of each of these shocks to nominal exchange rate movements.

The remainder of the paper is organized as follows: section 2 outlines our theoretical model and derives the rational expectations reduced forms for the short-run under sluggish price adjustment and for the long-run under flexible prices. Our approach to identification is described in section 3, and section 4 presents our empirical results for the United States and some European economies. Section 5 concludes.

2. A model of exchange rates, fundamentals and speculation

Our basic model is an extended version of the stochastic two-country rational expectations open economy macro model developed by Obstfeld (1985) and Clarida and Galí (1994), as presented in Weber (1997). In the analysis below we focus primarily on the long-run properties of the model, which displays many of the long-run neutrality properties that typically characterize macroeconomic equilibrium in a neoclassical framework. Following the usual tradition all variables except interest rates are in logarithms and represent home relative to foreign levels. For example, $y_t \equiv y_t^h - y_t^f$ represents the logarithm of the output ratio home (y_t^h) and abroad (y_t^f).

The goods market is characterized by a standard output demand function which displays the real exchange rate ($q_t = s_t - p_t$), the real interest rate differential $\left(i_t - E_t\left(p_{t+1} - p_t\right)\right)$ and the relative real wage rate $(w_t - p_t)$ as its main arguments:

$$y_t^d = h\left(s_t - p_t\right) - s\left(i_t - E_t\left(p_{t+1} - p_t\right)\right) + f\left(w_t - p_t\right) + d_t \ , \tag{1}$$

where d_t is a relative demand shock. Contrary to Clarida and Galí (1994), we only allow for a permanent component (e_t^d) of the relative demand shock. In particular, we suppose that the shock to relative demand in period t is given by:

$$d_t = d_{t-1} + e_t^d \tag{2}$$

where e_t^d is normally independently distributed (n.i.d.) with zero mean and constant finite variance.

The basic structure of the supply side of the simple open economy macro model follows Shapiro and Watson (1988) in assuming that firms in the long-run produce consumer goods with a Cobb-Douglas technology:

$$y_t^s = A_t + a l_t + (1 - a) k_t, \tag{3}$$

where k_t is the log level of the capital stock, l_t is the log level of the labour input, and A_t is the log level of technology. In order to avoid having to incorporate the capital stock into our model we adopt the assumption that the long-run steady state capital-output ratio is constant:

$$k_t = y_t + k, \tag{4}$$

and given by a value of κ. Substituting (4) into (3) and rearranging yields the long-run log level of output:

$$y_t^s = \frac{(1-a)k}{a} + \frac{1}{a} A_t + l_t, \tag{5}$$

whereby the constant ((1-α)κ/α) will be suppressed below. To capture the dynamics of technology we introduce a stochastic forcing process, which reflects the impact of permanent stochastic production technology innovations (ε_t^z):

$$A_t = A_{t-1} + \varepsilon_t^z, \tag{6}$$

whereby the technology shocks (ε_t^z) are assumed to be normally independently distributed with zero mean and constant finite variance.

The demand for labour in each country depends on relative factor costs for labour and is a negative function of the real wage rate. As a result, home relative to foreign labour demand is given by:

$$l_t^d = -\beta(w_t - p_t), \tag{7}$$

and is decreasing in the real wage differential. Labour supply, on the other hand is a positive function of the real interest rate differential and the real wage differential:

$$l_t^s = \varphi\left(i_t - E_t\left(p_{t+1} - p_t\right)\right) + \gamma\left(w_t - p_t\right) + \omega_t, \tag{8}$$

where ω_t represents the stochastic component of the evolution of the labour supply resulting from permanent labour supply shocks (ε_t^ω):

$$\omega_t = \omega_{t-1} + \varepsilon_t^\omega, \tag{9}$$

with the labour supply shocks (ε_t^ω) being assumed to be normally independently distributed with zero mean and constant finite variance.

To introduce some nominal rigidities into the model we adopt a version of the price setting equation that has been studied in open economy macro models by Flood (1981), Mussa (1982), Clarida and Gali (1994), and others:

$$p_t = (1-\theta)E_{t-1}p_t^e + \theta p_t^e. \tag{10}$$

According to this price setting rule the price level in period t is a weighted average of the market clearing price expected in period t-1 to prevail in period t, $E_{t-1}p_t^e$, and the price that would actually clear the output market in period t, p_t^e. When $q = 1$, prices are fully flexible and output is supply determined. When $q = 0$ prices are fixed and predetermined one period in advance.

The money market of the simple open economy rational expectations model is described by a standard demand for money function which features relative incomes (y_t) and the nominal interest rate differential (i_t) as its main arguments. We relate the inverse of the relative income velocity of money to movements in the interest rate differential and asymmetric velocity shocks:

$$m_t^d - p_t - y_t = -l i_t + \left(e_t^m - d_t\right), \tag{11}$$

where $e_t^m - d_t$ is the inverse of the relative velocity shock which has a relative demand shock component d_t and a relative money demand shock component e_t^m, which both are normally independently distributed with zero mean and constant finite variance. Nominal interest rates are assumed to be determined by the uncovered interest rate parity condition:

$$i_t = E_t\left(s_{t+1} - s_t\right) + y_t, \tag{12}$$

where y_t represents a time-varying risk premium. Such risk premia reflect the fact that domestic and foreign bonds may not be perfect substitutes: in order to induce domestic agents to hold the more risky foreign bonds they have to be granted such risk premia. As pointed by Engel (1996), there is substantial empirical evidence that risk premia have a unit-root. Taking this into account, we model the risk premium as a non-stationary stochastic process which is driven by speculative shocks e_t^y:

$$y_t = y_{t-1} + e_t^y, \tag{13}$$

where ε_t^{ψ} is normally independently distributed with zero mean and constant finite variance. We view this speculative component of the risk premium as the major source of a potential non-stationarity in nominal interest rate differentials.[1] [2]

Note that inserting (12) into (11), using the definition of the real exchange rate, and solving for the nominal exchange rate yields:

$$s_t = \underbrace{m_t + q_t - y_t + \left(\varepsilon_t^m - \delta_t\right)}_{\text{fundamental component}} + \lambda \underbrace{\left[E_t\left(s_{t+1} - s_t\right) + \psi_t\right]}_{\text{forward-looking component}}.$$

This equation is at the heart of most models of currency crisis, and it is the forward looking component through which devaluation expectations or speculative bubbles influence the current exchange rate. To model these forward looking rational exchange rate expectations we need to specify the monetary policy reaction function.

We close the model by specifying the relative money supplies, which we take as being determined by two important aspects of central banking. On the one hand, central banks are assumed to target a constant money growth rate, which for simplicity is set to be equal in both countries. Whilst the deterministic component of money growth differentials is assumed to be zero, the evolution of the relative money supplies may be captured by a simple stochastic trend. However, European central banks also operate under an exchange rate constraint. In our model this implies that within certain limits they have to stabilize exchange rate movements caused by both fundamental and speculative shocks. To capture both aspects of central banking we employ the money supply equation:

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[1] Near unit roots in nominal interest rate differentals are frequently found in the data. See Rose and Svensson (1994) for references to this stylized fact for ERM countries. These authors furthermore show that under pegged exchange rates expected realignment rates account for a substantial component of nominal interest rate differentials. We identify expected realignments with the non-stationary component of interest rate differentials, whilst their stationary stochastic component is due to transitory exchange rate fluctuations as a result of money demand shocks, as will be shown below.

[2] Note that our identification strategy would still go through if we were to model speculative shocks as being a stationary stochastic process or a mean-reverting process. However, the resulting analytical solutions would look slightly more complicated.

$$\begin{aligned} m_t^s &= m_{t-1} + e_t^m - g^s(s_t - E_{t-1}s_t) \\ &= m_{t-1} + e_t^m - g_w^s e_t^w - g_z^s e_t^z - g_d^s e_t^d - g_m^s e_t^m - g_m^s e_t^m - g_y^s e_t^y \end{aligned} \tag{14}$$

with e_t^m as a relative money supply shock, which again is assumed to be normally independently distributed with zero mean and constant finite variance. This general specification allows the central bank to conduct its monetary policy under an exchange rate constraint by "leaning-against-the-wind" and using sterilized or non-sterilized intervention. Note that the above feedback-rule, in which the central bank responds to contemporaneous shocks in order to stabilize nominal exchange rates (or prices), will only qualitatively alter the behaviour of prices and exchange rates. For example, central banks may choose the feedback coefficients (g) such as to eliminate the effects of a particular shock, say the speculative shock, on the nominal exchange rate. This would imply certain symmetry restrictions for the effects of this shock on real exchange rates and relative prices.[3] But since we want to estimate the contribution of the various shocks to exchange rate movements we prefer not to impose any identifying restrictions on nominal exchange rates or relative prices. To economize on notation we will therefore use equation (14) with all g-coefficients set equal to zero, but we will return to the sensitivity of our identification strategy with respect to the choice of the g-coefficients when discussing the empirical results.

2.1 Solving the model

To solve the model, we begin with deriving an expression for the real interest rate differential that would prevail in the flexible-price rational expectations equilibrium, r_t^e. This can be shown to be the sum of the risk premium ψ_t and the transitory component of real exchange rate movements, which is zero:

$$r_t^e = y_{t-1} + e_t^y . \tag{15}$$

[3] The objective of our approach is to achieve just-identification of all shocks with our theoretical model. However, such symmetry restrictions may be tested for in our model in the form of overidentifying restriction tests. See Galí (1992) for details.

The flexible price solution for the relative employment levels may be derived by substituting the equilibrium real wage rate and real interest rate together with the laws of motion for w_t and ψ_t into (7) to obtain:

$$\mathrm{l}_t^e = \frac{bj}{b+g}\left(y_{t-1} + e_t^y\right) + \frac{b}{b+g}\left(w_{t-1} + e_t^w\right), \tag{16}$$

and the solution for the output ratio is obtained by inserting (6) and (16) into (5):

$$\mathrm{y}_t^e = \frac{\left(\mathrm{A}_{t-1} + e_t^z\right)}{a} + \frac{bj}{b+g}\left(y_{t-1} + e_t^y\right) + \frac{b}{b+g}\left(w_{t-1} + e_t^w\right). \tag{17}$$

Note that in the long-run both employment and output are independent of aggregate demand shocks and nominal shocks such as money supply or money demand shocks.

Substituting the equilibrium real wage and real interest rate ratios together with the laws of motion for A_t, d_t, ψ_t and w_t into (1), solving for q_t^e, and carrying out the conditional expectation projections results in:

$$\mathrm{q}_t^e = \frac{1}{h}\left(\frac{\left(\mathrm{A}_{t-1} + e_t^z\right)}{a} - \left(\mathrm{d}_{t-1} + e_t^d\right)\right) + \frac{(b+g)s + j(b+f)}{(b+g)h}\left(y_{t-1} + e_t^y\right) + \frac{s+f}{h(b+g)}\left(w_{t-1} + e_t^w\right). \tag{18}$$

The flexible-price real exchange rate depreciates in response to relative technology shocks, relative labour supply shocks and changes in the risk premium, and it appreciates in response to a relative demand disturbance.

To derive an expression for the relative price level p_t^e in the flexible-price rational expectations equilibrium we solve (11) for p_t^e, and using (12) to (14) we obtain:

$$\begin{aligned}\mathrm{p}_t^e = &\left(\left(\mathrm{m}_{t-1} + e_t^m\right) - \frac{\left(\mathrm{A}_{t-1} + e_t^z\right)}{a} + \left(\mathrm{d}_{t-1} + e_t^d\right)\right) \\ &+ \frac{(b+g)l - jb}{b+g}\left(y_{t-1} + e_t^y\right) + \frac{b}{b+g}\left(w_{t-1} + e_t^w\right) - \frac{1}{(1+l)}e_t^m.\end{aligned} \tag{19}$$

All six shocks influence the relative price level in the flexible-price solution: the relative price level rises equiproportionally to the relative money supply shocks and falls in response to relative money demand shocks. Relative prices also decline as a result of a relative supply shock (technology shocks or labour supply shocks), and they rise in response to relative demand shock. Without an order condition (i.e. $l > jb/(b+g)$) the effect of an increases in the risk premium on the price level ratio is uncertain.

Comparing (16) and (17) yields an equation for the nominal exchange rate:

$$\mathrm{s}_{\mathrm{t}}^{\mathrm{e}} = (\mathrm{m}_{\mathrm{t}-1} + e_{\mathrm{t}}^{m}) - \frac{(1-h)}{h}\left[\frac{(\mathrm{A}_{\mathrm{t}-1} + e_{\mathrm{t}}^{z})}{a} - (\mathrm{d}_{\mathrm{t}-1} + e_{\mathrm{t}}^{d})\right] - \left(\frac{1}{(1+l)}\right) e_{\mathrm{t}}^{\mathrm{m}}$$
$$+ \frac{(b+g)(s+hl)+jf+(1-h)jb}{(b+g)h}(y_{\mathrm{t}-1} + e_{\mathrm{t}}^{y}) + \left(\frac{f+(1-h)b}{h(b+g)}\right)(w_{\mathrm{t}-1} + e_{\mathrm{t}}^{w})_{\mathrm{t}}.$$

In the flexible-price solution both money supply shocks and money demand shocks have an identical impact on the price ratio and the nominal exchange rate. Also notice that without order conditions (i.e. $1-\eta > 0$) the effect of productivity shocks, labour supply shocks, aggregate demand shocks and changes in the risk premium on the nominal exchange rate is uncertain.[4]

Let us briefly return to the money supply equation (14) and assume that we are in a managed float with "leaning-against-the-wind". Using the feedback-rule rather than the free float specification then implies that central banks can completely insulate both nominal exchange rates and prices from relative money supply shocks e_{t}^{m} and money demand shocks $e_{\mathrm{t}}^{\mathrm{m}}$ by choosing $\mathrm{g}_{\mathrm{m}}^{\mathrm{s}} = -1/(1-l)$ and $\mathrm{g}_{m}^{\mathrm{s}} = 1$. However, in the face of asymmetric labour supply shocks e_{t}^{w}, productivity shocks e_{t}^{z}, demand shocks e_{t}^{d} or speculative shocks e_{t}^{y} the optimal policy response can either insulate the nominal exchange rate or the price level ratio from these shocks,

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4 The same feature arises in the model of Clarida and Galí (1994).

but never both. This is due to the fact that the real exchange rate component and the relative price component of nominal exchange rates both depend on real shocks, whereas the real exchange rate component is independent of the financial shocks e_t^m and e_t^m. The trade-off between relative price stability and nominal exchange rate stability has important implications for the long-run viability of a nominal exchange rate peg: pegging to a country with a strongly asymmetric real economy may ultimately erode competitiveness and depress output, and this in turn may spark expectations of a future realignment aimed at reversing these real effects. In our model, such expectations may be reflected by time-varying risk premia.

The flexible-price solution for the ex ante nominal interest rate differential i_t can be obtained from (12) by carrying out the rational expectation projections of the expected rate of exchange rate change based on the exchange rate equation above:

$$i_t^e = \left(\frac{1}{(1+l)}\right) e_t^m + \left(y_{t-1} + e_t^y\right).$$

Inserting this expression into the money demand equation yields the long-run flexible-price solution for level of real money balances as:

$$\begin{aligned} m_t^e - p_t^e = & \frac{\left(A_{t-1} + e_t^z\right)}{a} - \left(d_{t-1} + e_t^d\right) + \left(\frac{1}{(1+l)}\right) e_t^m \\ & - \frac{(b+g)l - jb}{b+g}\left(y_{t-1} + e_t^y\right) + \frac{b}{(b+g)}\left(w_{t-1} + e_t^w\right)_t. \end{aligned} \tag{20}$$

Real money balances rise in response to relative money demand shocks, whilst money supply shocks have no long-run effect on real money balances. Furthermore, real money balances increase in response to relative technology shocks and relative labour supply shocks, whilst relative aggregate demand shocks reduce the demand for real money balances. Also notice that without order conditions (i.e. $1-\eta > 0$) the effect of an increase in the risk premium on relative real money balances is uncertain.

The dynamic response of our six key variables to the various shocks in the "long-run" flexible-price solution can be summarized as:

$$\begin{bmatrix} r_t \\ l_t \\ y_t \\ s_t - p_t \\ m_t - p_t \\ p_t \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & 0 & 0 & 0 & 0 \\ l_{21} & l_{22} & 0 & 0 & 0 & 0 \\ l_{31} & l_{32} & l_{33} & 0 & 0 & 0 \\ l_{41} & l_{42} & l_{43} & l_{44} & 0 & 0 \\ l_{51} & l_{52} & l_{53} & l_{54} & l_{55} & 0 \\ l_{61} & l_{62} & l_{63} & l_{64} & l_{65} & l_{66} \end{bmatrix} \begin{bmatrix} e_t^{y} \\ e_t^{w} \\ e_t^{z} \\ e_t^{d} \\ e_t^{\mathrm{m}} \\ e_t^{m} \end{bmatrix}. \tag{21}$$

This matrix of "long-run" multipliers is lower triangular: only the price level and hence also the exchange rate are driven by all six shocks, whilst relative employment and output levels in the long run only respond to changes in risk premia and supply shocks (labour supply and technology shocks), but not to aggregate demand shocks or nominal shocks (money supply and money demand shocks). These nominal shocks only drive nominal variables, such as the nominal money, nominal interest rate differentials, the nominal exchange rate and the relative price of output. Monetary shocks thereby have identical long-run effects on the nominal exchange rate and relative prices (or wages), which in turn renders the real exchange rate independent of such monetary shocks in the long run. This is not true for shifts in favour of demand for domestic goods, which for a given relative supply of goods and labour will result in a real depreciation if markets are to clear. Finally, speculative changes in the risk premium have potential effects on all variables in the system. Increases in risk premia work just like a bond market imperfection: they reduce the availability of credit on domestic bond markets, which impairs the ability of individuals to substitute between current and future consumption and/or labour. As a result, individuals work and produce more when compared to a situation in which home and foreign bonds are perfect substitutes.

Under sluggish-price-adjustment, real quantities are demand rather than supply determined. In this case the solution of our model can be summarized as:[5]

$$\begin{bmatrix} r_t \\ l_t \\ y_t \\ s_t - p_t \\ m_t - p_t \\ p_t \end{bmatrix} = \begin{bmatrix} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} & f_{16} \\ f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & f_{26} \\ f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} \\ f_{41} & f_{42} & f_{43} & f_{44} & f_{45} & f_{46} \\ f_{51} & f_{52} & f_{53} & f_{54} & f_{55} & f_{56} \\ f_{61} & f_{62} & f_{63} & f_{64} & f_{65} & f_{66} \end{bmatrix} \begin{bmatrix} e_t^{y} \\ e_t^{w} \\ e_t^{z} \\ e_t^{d} \\ e_t^{\mathrm{m}} \\ e_t^{m} \end{bmatrix}, \tag{22}$$

This matrix of "short-run" multipliers displays no neutrality characteristics, and all six variables are jointly driven by linear combinations of all six structural shocks.

2.2 Identifying fundamental and speculative shocks

To outline our approach to identification, we re-write the solution of our model as:

$$\begin{bmatrix} r_t \\ l_t \\ y_t \\ s_t - p_t \\ m_t - p_t \\ p_t \end{bmatrix} = C(L) \begin{bmatrix} e_t^{y} \\ e_t^{w} \\ e_t^{z} \\ e_t^{d} \\ e_t^{\mathrm{m}} \\ e_t^{m} \end{bmatrix}, \tag{23}$$

where in order to allow for some dynamics we have replaced the matrix of short-run multipliers by a matrix polynomial C(L), which is a function of the lag polynomials in the various structural shocks. Our long-run identifying restrictions can now be written in terms of the long-run multipliers, that is the sum C(1) of the elements of C(L):

[5] Since we do not employ short-run restrictions we do not derive this solution here. However, these results are available from the author on request. See also Clarida and Gali for this feature of the model.

$$
C(1) = \begin{bmatrix} l_{11} & 0 & 0 & 0 & 0 & 0 \\ l_{21} & l_{22} & 0 & 0 & 0 & 0 \\ l_{31} & l_{32} & l_{33} & 0 & 0 & 0 \\ l_{41} & l_{42} & l_{43} & l_{44} & 0 & 0 \\ l_{51} & l_{52} & l_{53} & l_{54} & l_{55} & 0 \\ l_{61} & l_{62} & l_{63} & l_{64} & l_{65} & l_{66} \end{bmatrix}. \tag{24}
$$

In the analysis below we will exclusively rely on these long-run identifying restrictions implied by the flexible price solution of our model, and we restrict C(1) to be lower block triangular.

3. Empirical implementation and the structural VAR methodology

Following Galí (1992), the SVAR approach assumes that $x=[x_1,x_2,x_3,...,x_k]$ is a covariance stationary vector process. Each element in x has zero mean, or rather, has been demeaned or detrended prior to estimation. Each element in x can be expressed as a linear combination of current and past structural shocks $\boldsymbol{\varepsilon}=[\varepsilon_1,\varepsilon_2,\varepsilon_3,...,\varepsilon_k]$. Formally, x has a moving average representation, as described in equation (23), and is given by:

$$
x=C(L)\boldsymbol{\varepsilon}. \tag{25}
$$

The reduced form Wold moving average representation is given by:

$$
x=E(L)\boldsymbol{\eta}, \tag{26}
$$

where $E(L)=[E_{ij}(L)]$, $E(0)=I$, and $E(L)$ is required to be invertible. The vector of reduced form shocks $\boldsymbol{\eta}=[\eta_1,\eta_2,\eta_3,...,\eta_k]$ is assumed to have a zero mean vector and a variance covariance matrix $\boldsymbol{\Omega}$. The corresponding reduced form autoregressive representation in terms of the shocks $\boldsymbol{\eta}$ is given by:

$$
B(L)x=\boldsymbol{\eta}, \tag{27}
$$

with $B(L)=[B_{ij}(L)]$, $B(L)=E(L)^{-1}$, and $B(0)=I$, whilst the autoregressive representation in terms of the structural shocks $\boldsymbol{\varepsilon}$ follows as:

$$A(L)x=\varepsilon, \tag{28}$$

with $A(L)=[A_{ij}(L)]$, $A(L)=C(L)^{-1}$ and $A(0)=S^{-1}$. The reduced form innovations η are now assumed to be a linear combination of the structural disturbances ε:

$$\eta=S\varepsilon. \tag{29}$$

Given equations (25) and (26) this implies

$$C(L)=E(L)S. \tag{30}$$

Since OLS estimation of equation (27) yields estimates of B(L) and hence estimates of its inverse, $E(L)=B(L)^{-1}$, the matrix C(L) can be uniquely identified to the extent that we introduce enough restrictions to just-identify the matrix S.

How may such restrictions be derived? First, it is straightforward to assume that the structural shocks ε are mutually orthogonal, which together with a convenient normalization condition[6] implies that $E(\varepsilon\varepsilon')=I$. Using this normalizing condition together with equation (29) implies:

$$SS'=\Omega, \tag{31}$$

and this factorization provides k(k+1)/2 non-linear restrictions on the elements in S, given the OLS estimate of the variance-covariance matrix Ω of the reduced form errors η. This leaves us with the problem of determining the remaining k(k-1)/2 restrictions on the elements of S. Blanchard and Quah (1989) were the first to propose identification of S in terms of long-run restrictions on the sum of the polynomial lags in C(1). From equation (30) it follows that C(1)=E(1)S, and hence, placing zero restrictions on the long-run impact C(1) of the structural shocks on x is useful in identifying elements in S, given the estimate of E(1). Open economy applications of such long-run restrictions to identify the real exchange rate effects of

6 This normalization ensures that the vector of shocks is measured in terms of one standard deviation of the corresponding variable in the vector x

various disturbances include Galí and Clarida (1994), Canzoneri, Vallés and Vinals (1996) and Weber (1977).

4. Empirical results for the European economies

In this section we represent our empirical results, with which we seek to answer a number of questions: first, what are the sources of nominal exchange rate movements since the collapse of the Bretton Woods system, and, in particular, do currency crises appear to be driven by fundamental shocks or by speculative shocks? If fundamentals matter, is it nominal or real shocks that play a major role? Before presenting our results, we take a brief look at the time series properties of the data.

4.1 Unit-root and cointegration properties of the data

In the econometric work we limit ourselves to seasonally-adjusted monthly data beginning in 1971.VIII and ending in 1994.XII. Our starting date stems from the beginning of the more freely floating exchange rate period, which can be dated back to the closing of the gold window by the U.S. Federal Reserve in August 1971. We make use of four-month lags in estimating the VARs, and our estimates cover the years 1972.I through 1994.XII, or 276 observations. The data sources are described in Appendix A of the paper.

We aim at estimating the system $x=[\Delta r_t,\Delta l_t,\Delta y_t,\Delta s_t-\Delta p_t,\Delta m_t-\Delta p_t,\Delta p_t]$, whereby the variables in x are defined as follows: Δr_t is the logarithm of the bilateral real interest rate differential, defined as the difference of the nominal interest rate differential Δi_t and the consumer price inflation differential Δp_t, $\Delta r_t=\Delta i_t-\Delta p_t$. The first difference in the logarithm of the employment ratio is denoted by Δl_t, Δy_t is the first difference in the logarithm of industrial production ratio, $\Delta s_t-\Delta p_t$ is the logarithm of the bilateral real exchange rate, with Δs_t as the change in the nominal bilateral exchange rate and Δp_t as consumer price inflation, Finally, $\Delta m_t-\Delta p_t$ corresponds to the change in real money balances, where Δm_t is the change in the logarithm of the ratio of the monetary base. By appropriate transformation these six variables also uniquely determine the ratio of nominal money growth rates Δm_t, the nominal exchange rate Δs_t, nominal interest rate differentials Δi_t, and average labour productivity Δy_t-Δl_t. The specification of the degree of time differencing and drift or trend adjustment of the variables in x is based on prior unit root and cointegration tests, which are briefly discussed below. [7]

To identify the speculative component of currency crises we use real interest rate differentials, calculated as the difference between nominal interest rate and inflation differentials. As shown in Table 1, the ratios of price levels are integrated of order one with a trend, I(1)+trend, and thus inflation differentials are I(0)+trend. Nominal interest rate differentials were found to be I(1) for France, Italy, the United Kingdom and the United States, whilst for the Netherlands, Belgium and Denmark I(0) processes were found. In our model both nominal and real interest rate differentials have a unit root due to non-stationary risk premia, but in the data their time series properties differ. Real interest rate differentials are found to be I(0)+trend, and are dominated by large transitory inflation fluctuations. Since we are interested in the permanent component of speculative shocks, we use the first differences[8] of real interest rate differentials in the VAR estimates. However, note that our main results are not very sensitive with respect to this choice, except that when we employ the level of real interest rate differentials we obtain a much more erratic speculative component with large transitory fluctuations.

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[7] For details see also Weber (1994, 1997). Judgement is based on a variety of unit root tests, include those of Dickey and Fuller (1981), Fuller (1976), Perron (1988), Phillips (1987), Phillips and Perron (1988), Stock and Watson (1988), and Stock (1990). The complete set of unit-root and cointegration test results is available on request.

[8] Using first differences here implies no loss of long-run information because due to the stationarity of real interest rate differentials cointegration is not an issue here.

The time series properties of the endogenous variables employed in deriving the five fundamental shocks are also analysed in Table 1. All bilateral output ratios were found to be integrated of order one, I(1). The employment ratios were also in general found to be I(1) with two exceptions: for France an I(1)+trend process seems more appropriate, whilst for the United Kingdom there are indications of a stationary employment ratio relative to Germany. The nominal exchange rates and the above mentioned ratios of consumer price levels are both integrated of order one with a trend, I(1)+trend. Real exchange rates are typically also I(1), which in turn implies that relative price ratios and nominal exchange rates are not cointegrated. This statement is supported by the formal evidence from bilateral cointegration tests based on the procedure of Johansen and Juselius (1990). A similar statement applies to the analysis of cointegration between the price ratios and nominal or real money ratios in France, Italy, Belgium and the U.K., where again nominal money ratios and price ratios are not found to be cointegrated. However, for the Netherlands, Denmark and the United States there is some indication that the ratios of nominal money balances relative to Germany are stationary, implying that real money ratios and price ratios could be cointegrated. The formal cointegration tests in Table 2 suggest that for these three countries the cointegration rank is greater than zero when a system containing all five fundamental variables is checked for cointegration by using the procedure of Johansen and Juselius (1990). But if we disregard either the price ratios or the real money balance ratios in the cointegration tests we find no cointegration between the remaining four variables. The same is true if we replace the price ratios by the nominal exchange rate and check for cointegration in a system containing these five variables. To obtain estimates compatible for all countries, we proceed by using exchange rates rather than price ratios in estimating our unrestricted VAR. As pointed out above, this choice of $x=[\Delta r_t, \Delta l_t, \Delta y_t, \Delta s_t-\Delta p_t, \Delta m_t-\Delta p_t, \Delta s_t]$ leaves our identification strategy unaltered, since we impose no long-run identifying restrictions on exchange rates or price ratios.

Because the ratios of all variables employed in identifying the fundamental disturbances in our VAR were integrated of order one, we adjusted for drifts and trends in the growth rates accordingly before estimating the unrestricted VAR using a lag window of length four.[9] In presenting the results we will first focus on the impulse response functions of exchange rates to the various shocks and compare them to the predictions of our theoretical model.

4.2 Impulse responses

Figure 1 displays the impulse responses of the bilateral nominal exchange rates to a one-standard deviation disturbance for each type of shock. These signs of the impulse responses are normalized such that a speculative shock has a significant short-run and long-run positive effect on real interest rate differentials, relative labour supply shocks significantly increase the employment ratio, productivity shocks significantly boost the output ratio, money demand shocks significantly raise relative real money balances and money supply shocks significantly increase the price level ratio. The only exception is made with respect to the relative demand shock, which we normalize such that like the supply shock it significantly increases output on impact, but unlike the productivity shocks it has no long-run output effects. How do these six shocks affect the six endogenous variables of our system for each of the seven countries relative to Germany? Without going into detail through the 252 (6*6*7) impulse response functions,[10] the following main features of the results should be pointed out: firstly, the estimates in Figure 1 suggest that both relative money supply shocks and relative demand shocks are significantly inflationary in the short-run and the long-run in all 7 countries. Productivity shocks

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[9] Our results were not very sensitive with respect to the length of the lag window. Similar results were obtained by using alternative lag windows of length six or nine, but in these cases the impulse response functions indicated a overparameterization of the VAR.

[10] A detaled documentation of all impulse responses, variance decompositions and shock components discussed in this paper are available from the author on request.

and labour supply shocks have quite persistent and significantly deflationary effects for the United Kingdom and the United States, whilst these shocks have no significant short-run price effects for the ERM countries. But in most ERM countries speculative shocks have significant short-run and, with the exception of France, also long-run relative price effects, whilst for the United Kingdom and the United States this is not the case. The reason for this asymmetry between ERM and non-ERM countries becomes obvious from Figure 2: speculative shocks have quite persistent and significant effects on ERM as opposed to non-ERM nominal exchange rates, but real exchange rates move much less in response to such speculative shocks. Notice that in Figure 2 the long-run depreciation in response to speculative shocks is largest for Italy, followed by Belgium, Denmark, France and the Netherlands. Another difference between ERM and non-ERM countries lies in the effects of money supply shocks on nominal exchange rates: ERM exchange rates display by far the largest and most significant impulse response to money supply shocks. In the non-ERM countries the effects of relative demand shocks dominate, and the impulse response to money supply shocks becomes insignificant after 4-6 months. Interestingly, ERM exchange rates typically display an overshooting-effect in response to money supply and speculative shocks. Also note that for France and Italy relative supply shocks also have significant short-run and long-run nominal exchange rate effects. This reflects the fact that between the three large ERM countries business cycle asymmetries have been correlated with periods of exchange market pressure (i.e. 1973-75, 1978-81).

To summarize, the estimated responses of the various endogenous variables to our six structural shocks is quite consistent with the predictions from theory and at first sight pass the duck test.[11] We have identified important differences in the propagation of speculative shocks and monetary policy shocks between the ERM

[11] See Clarida and Galí (1995): "If it walks like a duck and quacks like a duck, it must be .... "

and more freely floating countries (U.K.,U.S.). All in all, our results suggest that fundamentals matter more for ERM nominal exchange rates than for the floating rates. Speculation is found to only have an impact on managed exchange rates, but speculation is far from being the dominant factor. To understand European exchange rate movements it is sufficient to look at few factors: loose monetary policy relative to Germany plays the key role. For the larger European economies, in particular for France, the nominal German mark exchange rates also appear to respond significantly and consistently to relative supply shocks on goods and labour markets. Thus, for intra-European exchange rates both fundamental and speculative shock appear to matter.

4.3 Historical decompositions into shock components

Figures 3 and 4 display the components of German mark real exchange rates due to the fundamental and speculative shocks. In the analysis we focus on the shock components of the stochastic trend deviations of nominal exchange rates, which are displayed in the second row of each figure. For the two large EMS economies, France and Italy, the long-run trend in nominal exchange rates largely reflects relative money supply shocks, which are the key determinant of inflation differentials. The link between relative money supply shocks and exchange rate movements is quite close during the post-1983 ERM period in France, but relatively loose before this tightening of the EMS. Prior to the EMS-period, the French nominal DM exchange rate shows a close co-movement with relative demand shocks. The same is true for the other ERM countries, whereby the switch of exchange rates from being driven by relative demand shocks to reflecting relative monetary policy shocks occurs at various points in time. These dates appear to be consistent with the estimated policy switch points for the tightening of the ERM reported in Weber (1991). Also note that for the more freely floating economies, the U.K. and the U.S., no such switch in the shock determinants of nominal exchange rates is found in Figure 4, and they are driven virtually one-to-one by relative demand shocks. In Weber (1997) it is demonstrated that (in the absence of risk premia) these relative demand shock basically reflect the non-monetary component of real exchange rates which is not accounted for by relative supply shocks on labour or product markets. But since monetary shocks by construction do not explain long-run real exchange rates movements and supply shocks typically turn out to be insignificant, these relative demand shocks may be viewed as a measure-of- ignorance with respect to the sources of real exchange rate movements, as is suggested in Weber (1997). For the more freely floating DM exchange rates, for which both nominal and real exchange rates virtually move one-for-one, our measure-of-ignorance with respect to the sources of exchange rate movements is large. This interpretation matches the frequently reported stylized fact that nominal U.S. dollar exchange rates are unpredictable with structural models and closely resemble a random walk.[12] For Europe, our results are different: we find quite substantial labour supply shock and productivity shock components of real and nominal exchange rates throughout the sample. This points towards a greater business cycle transmission in Europe as compared to the United States, a result which is consistent with the findings of Artis and Zhang (1995). Our results also indicate the importance of the nominal exchange rate as a shock absorber with respect to relative supply shocks in Europe. This is particularly obvious for the case of the Netherlands, where nominal exchange rates relative to Germany moved little by comparison with the other countries, but those small movements of the guilder exchange rates almost exclusively reflect relative labour and product market disturbances. Real fundamental supply side factors are also an important source of nominal exchange rate movements in France, Italy and Belgium. The above analysis therefore indicates that fundamentals matter more in Europe.

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[12] See for example Mussa (1979) or Isard (1995).

But what about speculation? Figures 3 and 4 show that for the more freely floating economies, the U.K. and the U.S., the speculative component of nominal exchange rate movements is neglectable. Thus, as suggested by the currency crisis literature, speculation appears to play no role for non-managed exchange rates. Our results for the ERM economies are again drastically different: speculation against the French franc appears to matter throughout the sample, and in particular in the post-1981 period. Speculative shocks appear to be consistently one-sided, and there is a substantial risk premium attached to the French franc. Interestingly, the estimates of the speculative component of the French franc exchange rate movements rises noticeably in mid 1992, shortly before the successful speculative attacks on the lira and the pound sterling. The speculation pressure on the French franc is quite persistent throughout the period up to the ERM collapse in August 1993. This finding is consistent with the results reported in Jeanne (1995), who also finds strongly self-fulfilling speculation during France's 1992-93 exchange-market travails.[13] One-sided speculation is also found for the Italian lira, the Belgian franc and the Danish krona (not reported in the graphs), and in each case speculative pressure contributes to a devaluation of these currencies relative to the German mark. Finally, except for the French franc the time pattern of the speculative shock suggests that the European currency crises of 1992/93 could not be predicted on the basis of unusually high risk premia attached to these currencies prior to the attacks. The self-fulfilling aspects of the speculative attacks of 1992/93 were clearly second order when compared to their fundamental components: throughout the EMS higher money growth and inflationary monetary policy shocks outside Germany were the main force behind long-run nominal exchange rate movements. These results are consistent with the empirical findings of Eichengreen, Rose and Wyplosz (1995a,

[13] On this point see also Rose and Svensson (1994) and Obstfeld (1996).

1995b), who found that fundamental monetary, real or fiscal imbalances typically precede speculative attacks.

5. Summary

Two generations of currency crisis models co-exist in the literature: first generation models predict co-movements between speculative attacks and adverse movements in the fundamental determinants of exchange rates, whilst in second generation models speculative attacks may be purely self-propagating and potentially self-fulfilling. Given these opposing views, which is the empirically more relevant model? The present paper has tried to deal with this issue by developing and estimating a model in which the exchange rate is driven by various fundamental factors, but also has a speculative component.

We found that exchange rate fundamentals matter in Europe. To understand European exchange rate movements it is sufficient to look at few factors only: loose monetary policy relative to Germany plays the key role. For the larger European economies, in particular for France and Italy, the nominal German mark exchange rates also appear to respond significantly and consistently to relative supply shocks on goods and labour markets. This reflects the fact that between the three large ERM countries business cycle asymmetries have been correlated with periods of exchange market pressure. But speculation matters too during currency crises. In all ERM countries nominal exchange rates move significantly in response to speculative shocks, in particular in the short run (4-8 months horizon). The long-run response of exchange rates to speculative shocks is largest for Italy, followed by Belgium, Denmark, France and smallest for the Netherlands. The size of the speculative components of exchange rate movements also varies greatly in Europe. Speculative shocks appear to be consistently one-sided. We find a substantial risk premium attached to the French franc before the 1992 crisis, and speculation pressure on the French franc remains high thereafter, which reveals a strongly self-fulfilling aspect of France's 1992-93 exchange rate crisis. One-sided speculative components of exchange rate movements are also found for the Italian lira, the Belgian franc and the Danish krona, and in each case speculative pressure contributes to a devaluation of these currencies relative to the German mark. But our results also establish that the European currency crises of 1992/93 could not be predicted on the basis of unusually high risk premia attached to these currencies prior to the attacks. Except perhaps for the French franc, the self-fulfilling aspects of the speculative attacks of 1992/93 were clearly second order when compared to their fundamental components. These results are consistent with the empirical findings of Eichengreen, Rose and Wyplosz (1995a, 1995b), who discover that fundamental monetary, real or fiscal imbalances typically precede speculative attacks. But not all currency crises are alike. We found that both the direction and the timing of the attack on the French franc can be better understood by referring to it's substantial speculative component. This is not the case for the other ERM currencies.

Where do we go from here? Future empirical research on currency crises should focus on the timing of the speculative attacks, which has been a key issue during the 1992/93 ERM crises. The fundamental and speculative components of currency crisis identified here did not suggest any particular reason why these attacks occurred when they occurred. In theoretical models of currency crises this issue is typically pinned down by incorporating deviations of the stock of central bank foreign exchange reserves from some minimal threshold into the model. Foreign exchange reserves were disregarded here because the focus of the present paper was on discriminating between the fundamental and speculative components of currency crises, but incorporating this aspect is the obvious next step. A second important field of future research would be to establish the robustness of our results by applying the SVAR approach advocated here to other currency crises, such as the Mexican peso crisis.

Appendix: Time series and data sources

All data are monthly, seasonally adjusted data. In case the original data were not seasonally adjusted, seasonal adjustment was carried out using the GAUSSX procedure SAMA. The time series and data sources used are listed below.

Output (industrial production index): International Monetary Fund (IMF), International Financial Statistics (IFS), line 66c; employment: inverse of the number of registered unemployed, longest time series available from either the Commission of the European Economies (EC), Cronos-Database, or the Organization for Economic Cooperation and Development (OECD), Main Economic Indicators (MEI); consumer price indices: IMF, IFS; monetary base (M0), IMF, IFS; line 14, national definition for the United Kingdom; nominal exchange rates IMF, IFS, line ae; nominal interest rates (call money rates): longest time series available from either IMF, IFS, line60b, or OECD, MEI;

Appendix B: Solving the model under short-run sluggish prices

The short-run sluggish-price-adjustment solution of our model may be derived by viewing quantities as being demand rather than supply determined. By substituting (19) into the price setting rule (10) and carrying out the conditional expectations projection, we derive that the ratio of home to foreign price levels, p_t, is given by:

$$\mathrm{p}_t = \mathrm{p}_t^e - (1-q)\left\{ e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{[(b+g)l - jb]e_t^y - be_t^w}{b+g} - \frac{e_t^m}{(1+l)} \right\}. \qquad \text{(B1)}$$

As in the long-run flexible-price solution, the ratio of the price levels in the short-run sluggish-price-adjustment solution is a function of all six shocks. In response to a money supply or aggregate demand shock the price level rises in the short-run, but by less than in the long-run. The same holds under the order condition from above $l > jb/(b+g)$ for speculative increases in the risk premium. Finally, the price level falls in the sticky-price solution as a result of money demand, aggregate supply or labour supply shocks, again by less than in the flexible-price solution. The degree of "sluggishness" is thereby indexed by ($1-\theta$).

The real exchange rate solution under partial price adjustment may be obtained by substituting (1) and (12) into (11) and using (B1) to obtain:

$$\mathrm{q}_t = \mathrm{q}_t^e + \left[\frac{(1-q)(1+l)(b+g)}{(s+h+l)(b+g)+jf} \right] \left\{ e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{[(b+g)l - jb]e_t^y - be_t^w}{b+g} - \frac{e_t^m}{(1+l)} \right\}. \qquad \text{(B2)}$$

An interesting feature of this solution is that both money supply and money demand shocks influence the real exchange rate in the sticky-price solution, whilst in the flexible-price solution they do not. Furthermore, in the flexible-price solution monetary shocks had an identical impact on both the price level and the nominal exchange, but in the sluggish-price-adjustment solution for the nominal exchange rate:

$$s_t = s_t^e + \left[\frac{(1-q)\left[(1-s-h)(b+g)-jf\right]}{(s+h+l)(b+g)+jf}\right]\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{\left[(b+g)l - jb\right]e_t^y - be_t^w}{b+g} - \frac{e_t^{\mathrm{m}}}{(1+l)}\right\}$$

the famous Dornbusch (1976) "overshooting-effect" in response to money supply shocks (e_t^m) can be generated for $(1-s-h)(b+g)-jf>0$. Note that this order condition also implies a short-run overshooting-effect of the exchange rate in response to speculative increases in the risk premium (e_t^y), as well as an undershooting-effect in response to money demand shocks (e_t^{m}), aggregate demand shocks (e_t^d) and productivity shocks (e_t^z).

Using (B2) and the IS equation (1) to solve for the demand-determined level of output under sluggish price adjustment results in:

$$y_t = y_t^e + \left[\frac{(1-q)(1+l)\left[(s+h)(b+g)+jf\right]}{(s+h+l)(b+g)+jf}\right]\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{\left[(b+g)l - jb\right]e_t^y - be_t^w}{b+g} - \frac{e_t^{\mathrm{m}}}{(1+l)}\right\}, \quad \text{(B3)}$$

whilst using (A1) and the labour demand equation (8) to solve for the demand-determined relative employment level under sluggish price adjustment yields:

$$l_t = l_t^e + \left[\frac{(1-q)(1+l)bj}{(s+h+l)(b+g)+jf}\right]\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{\left[(b+g)l - jb\right]e_t^y - be_t^w}{b+g} - \frac{e_t^{\mathrm{m}}}{(1+l)}\right\}. \quad \text{(B4)}$$

Both the output ratio and the employment ratio are now functions of all five shocks, and not only of technology or labour supply shocks. Home relative to foreign output and employment only partially rises in response to technology and labour supply shocks under the short-run sticky-price solution. Furthermore, relative money supply and aggregate demand shocks boost home relative to foreign output and employment in the "short-run" under partial price adjustment, whilst relative money demand shocks depress the output and employment ratios temporarily under sluggish price adjustment.

Finally, using (20) and (21) to solve for the demand-determined level of nominal interest rate differentials results in:

$$\mathrm{i}_t = \mathrm{i}_t^e - \left[\frac{(1-q)[(1-s-h)(b+g)-jf]}{(s+h+l)(b+g)+jf}\right]\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{[(b+g)l - jb]e_t^y - be_t^w}{b+g} - \frac{e_t^m}{(1+l)}\right\},$$

which together with (12) and (B1) yields the short-run solution for the real interest rate:

$$\mathrm{r}_t = \mathrm{r}_t^e - \left[\frac{(1-q)(1+l)(b+g)}{(s+h+l)(b+g)+jf}\right]\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{[(b+g)l - jb]e_t^y - be_t^w}{b+g} - \frac{e_t^m}{(1+l)}\right\}. \quad \text{(B5)}$$

Notice that whilst under the above order condition $(1-s-h)(b+g)-jf > 0$ nominal exchange rates and nominal interest rate differentials display the famous Dornbusch (1976) "overshooting-effect" in response to money supply shocks (e_t^m) and speculative increases in the risk premium (e_t^y), real exchange rates and real interest rate differentials always adjust gradually towards long-run equilibrium. Our model therefore captures quite well the high volatility of nominal financial return during periods of speculative attacks. The model also clearly shows that financial volatility is not necessarily the result of large transitory shocks; on the contrary, it may equally well arise as a result of an overreaction of financial markets to small but permanent shocks.

Finally, using the above interest rate differential equation in (11) jointly with (B3) yields the demand determined level of real money balances:

$$\mathrm{m}_t - \mathrm{p}_t = \mathrm{m}_t^e - \mathrm{p}_t^e + (1-q)\left\{e_t^m - \frac{e_t^z}{a} + e_t^d + \frac{[(b+g)l - jb]e_t^y - be_t^w}{b+g} - \frac{e_t^m}{(1+l)}\right\}, \quad \text{(B6)}$$

which again is a function of all six shocks and displays gradual adjustment towards equilibrium.

The dynamic response of our six key variables to the various shocks in the "short-run" sluggish-price-adjustment solution can be summarized in matrix notation as equation (22) in the main text.

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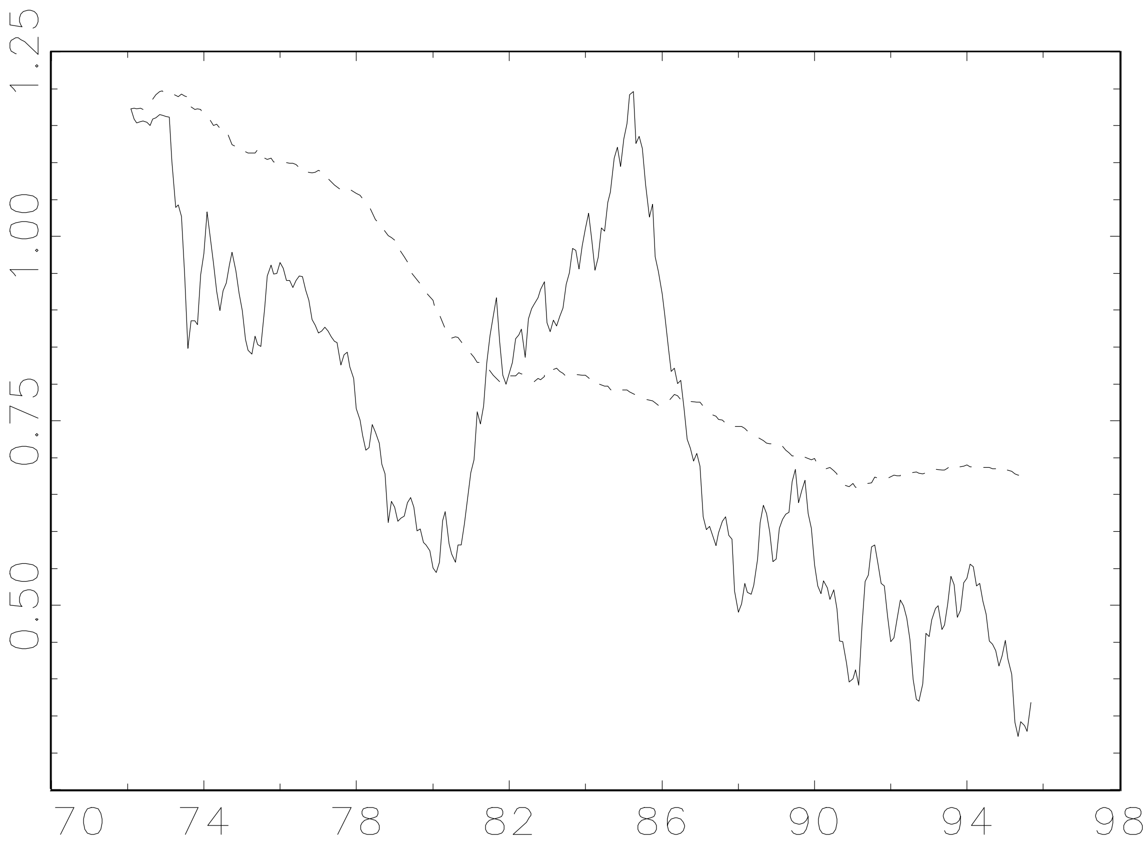
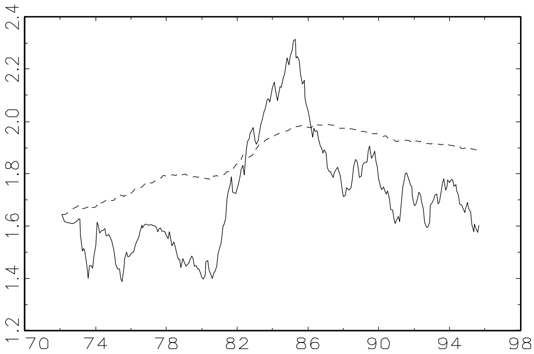
Figure 1: Nominal Exchange Rates and Price Ratios for the United States versus Germany, 1972-1996



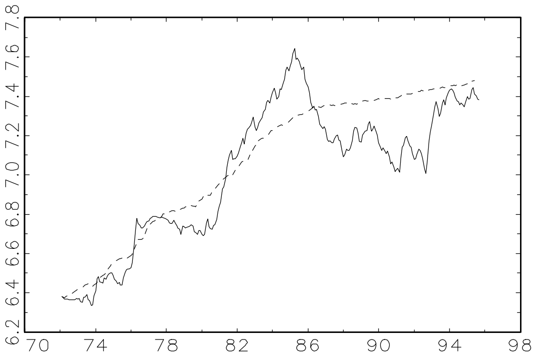
Key to Figure: ——— Log of Real Exchange Rate - - - - - Log of Price Level Ratio

Figure 2: Nominal Exchange Rates and Price Ratios of European Economies versus the United States and Germany, 1972-1996

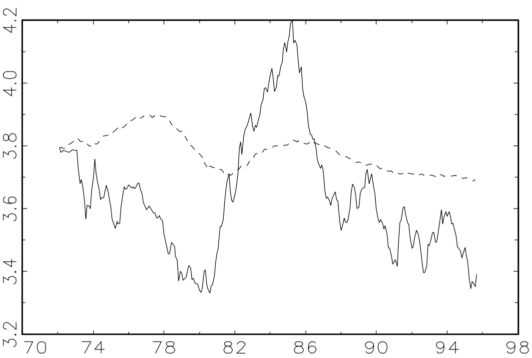
(a) France-USA



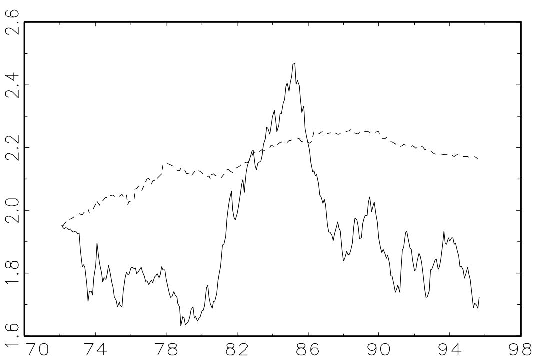
(b) Italy-USA



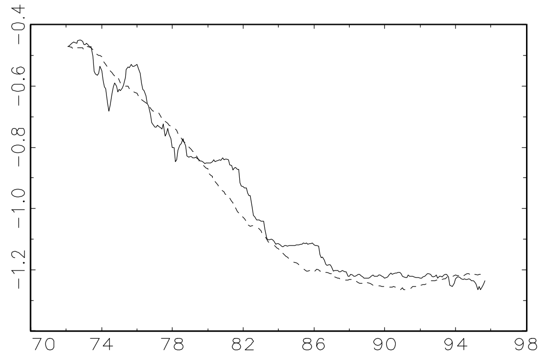
(c) Belgium-USA



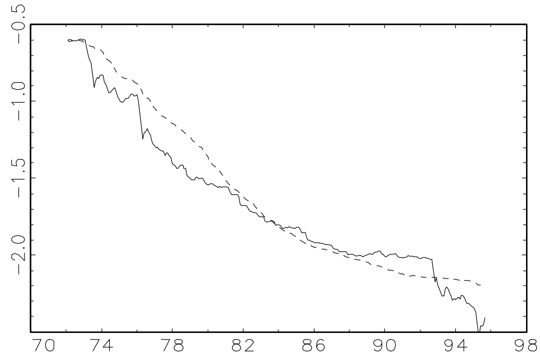
(d) United Kingdom-USA



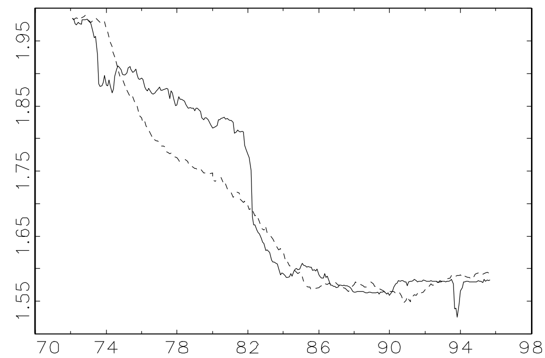
(e) France-Germany



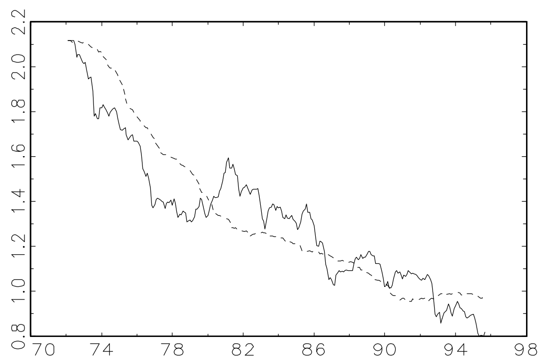
(f) Italy-Germany



(g) Belgium-Germany



(h) United Kingdom-Germany



Key to Figure: ———— Log of Nominal Exchange Rate - - - - - - Log of Price Ratio

Figure 3: Impulse Response of the Price Ratios of EC-Countries and the United States Relative to Germany to Various Types of Shocks, Monthly Data, 1972.I-1994.XII

Speculative Shock | Labour Supply Shock | Aggregate Supply Shock | Aggregate Demand Shock | Money Demand Shock | Money Supply Shock

France relative to Germany

Italy relative to Germany

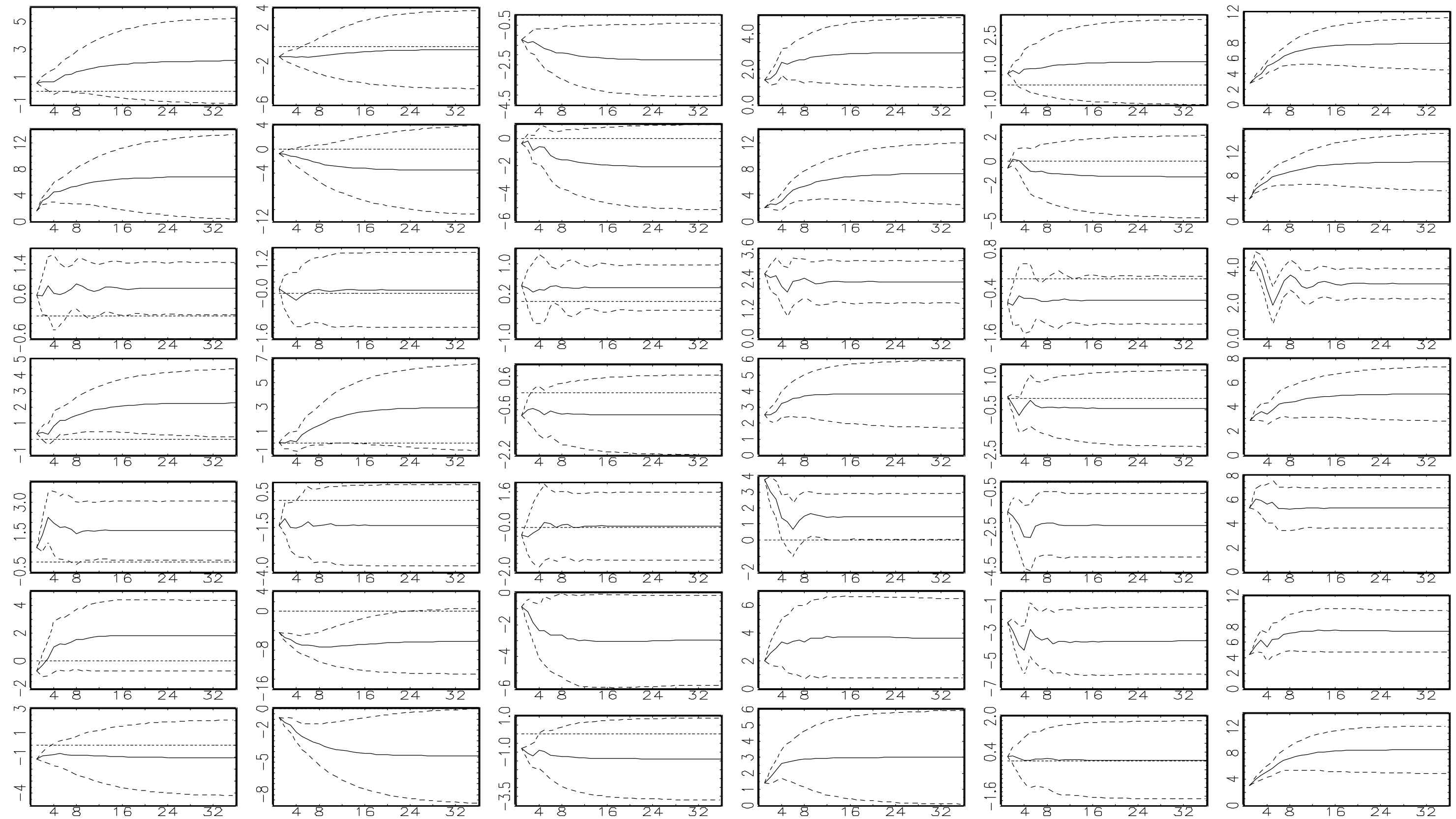
The Netherlands relative to Germany

Belgium relative to Germany

Denmark relative to Germany

United Kingdom relative to Germany

United States relative to Germany



Key: The solid lines are the mean response of the ratio of log level of the consumer price ratios to a one standard deviation shock. The dashed lines are the 2 standard error bands obtained by Monte Carlo simulation.

Figure 4: Impulse Response of the Nominal DM Exchange Rates of EC-Countries and the United States to Various Types of Shocks, Monthly Data, 1972.I-1994.XII

	Speculative Shock	Labour Supply Shock	Aggregate Supply Shock	Aggregate Demand Shock	Money Demand Shock	Money Supply Shock

France relative to Germany

Italy relative to Germany

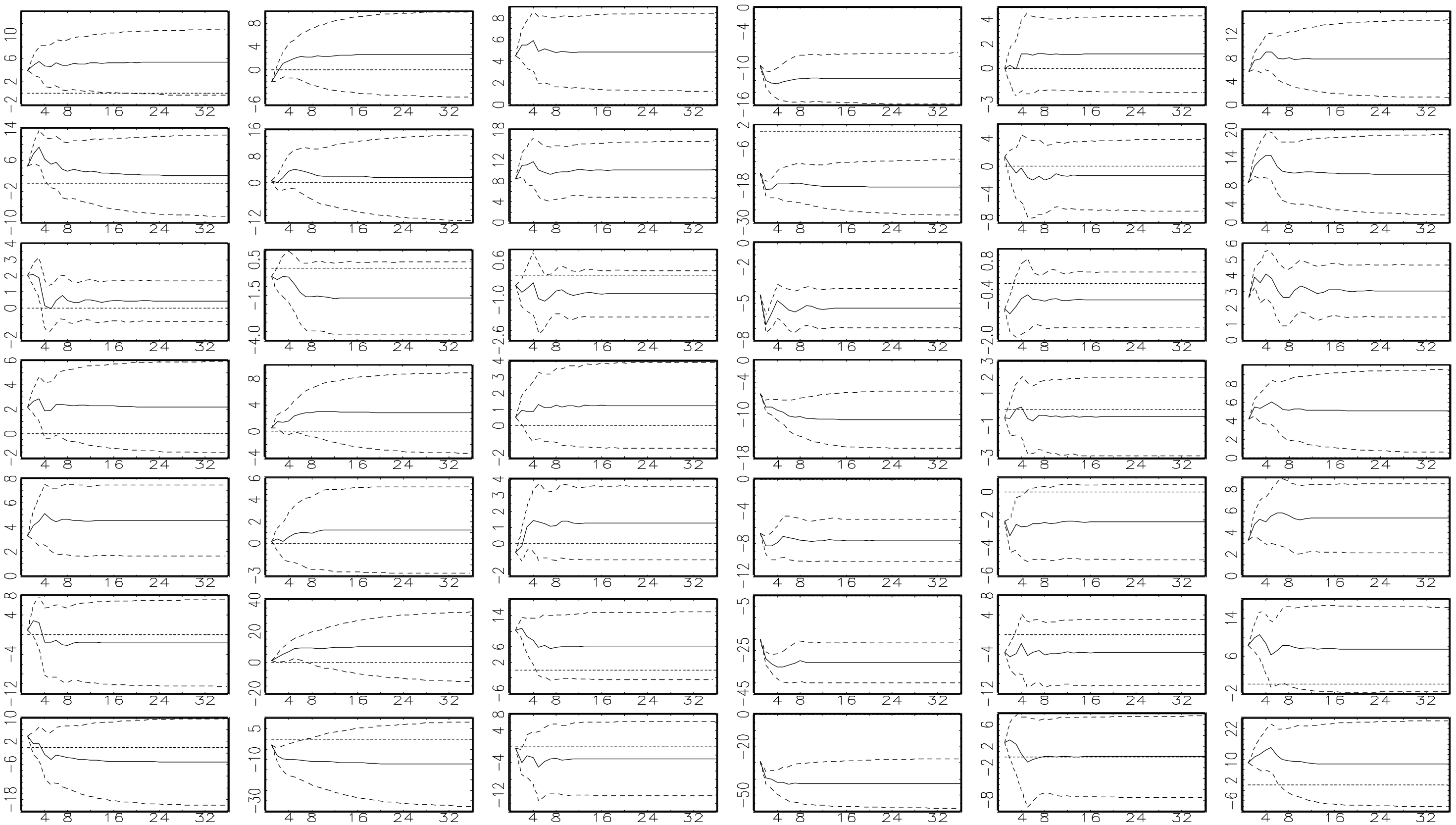
The Netherlands relative to Germany

Belgium relative to Germany

Denmark relative to Germany

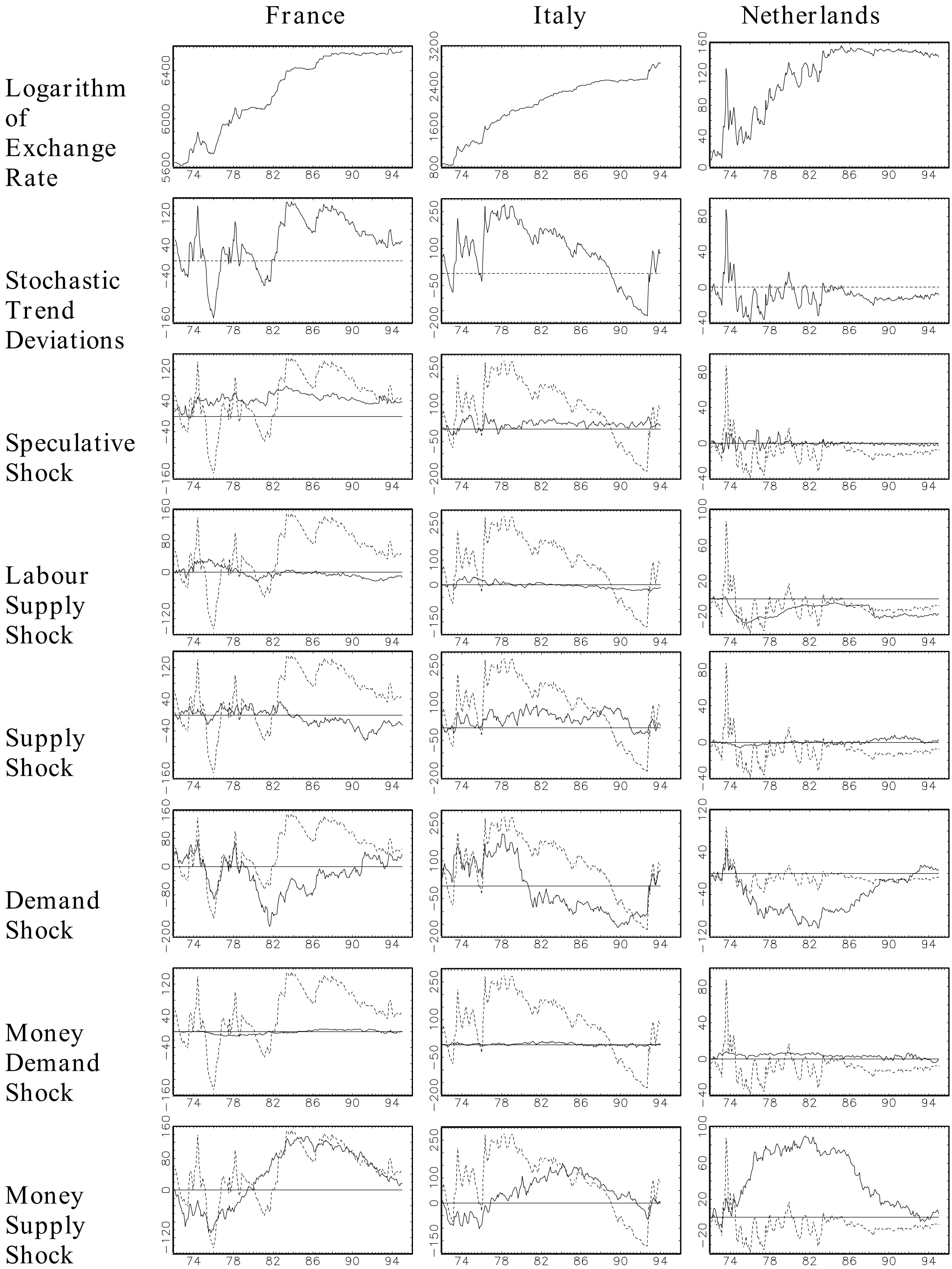
United Kingdom relative to Germany

United States relative to Germany



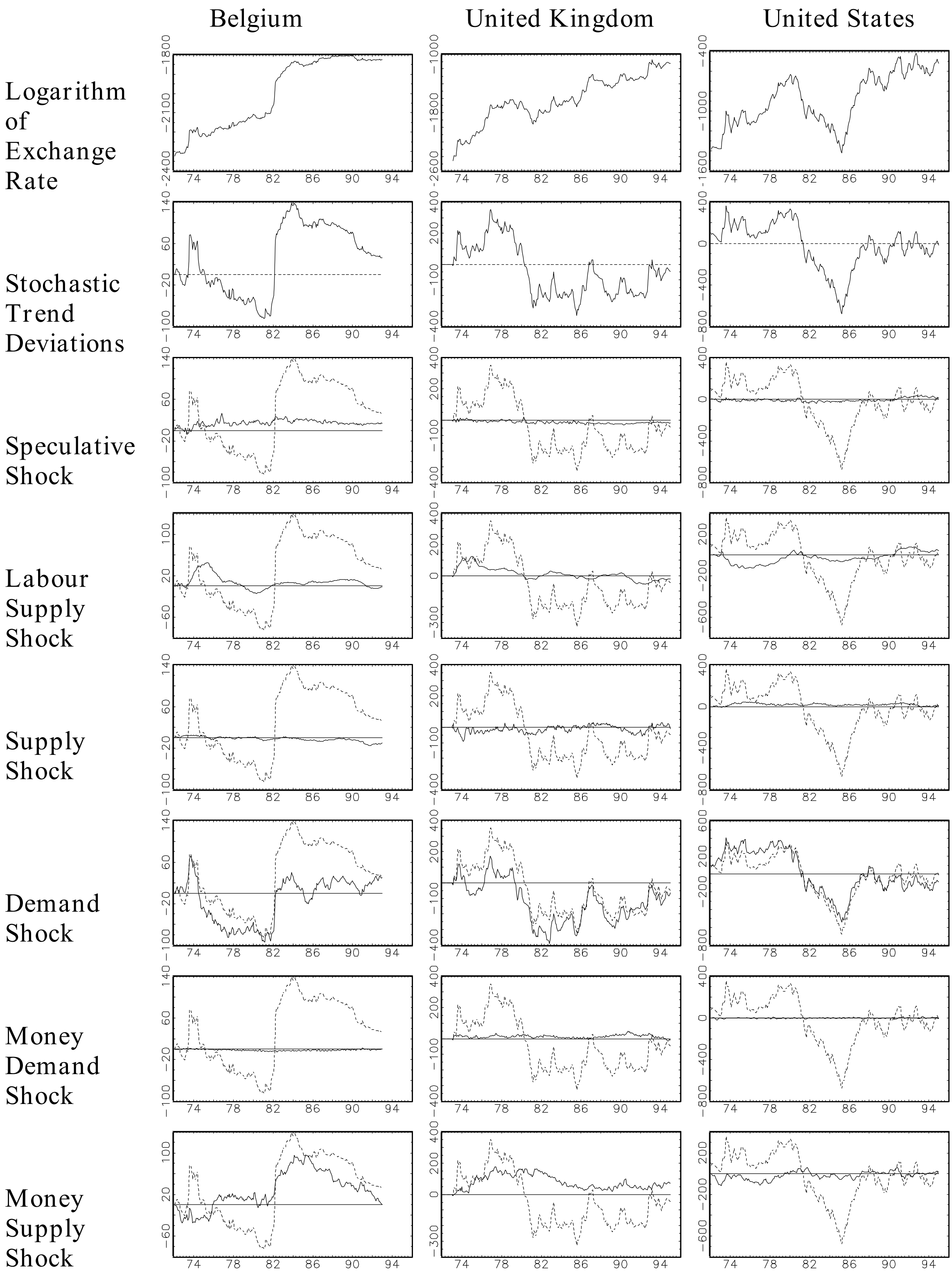
Key: The solid lines are the mean response of the ratio of log level of the exchange rate to a one standard deviation shock. The dashed lines are the 2 standard error bands obtained by Monte Carlo simulation.

Figure 5: Shock Components of the Nominal DM Exchange Rates of EC-Countries, Monthly Data, 1972.I-1994.XII



Key: To indicate the proportion of exchange rate movements due to the various shock components they are dispayed together with the stochastic trend deviations of the exchange rate (dashed lines).

Figure 6: Shock Components of the Nominal DM Exchange Rates of EC and Non-EC Countries, Monthly Data, 1972.I-1994.XII



Key: To indicate the proportion of exchange rate movements due to the various shock components they are dispayed together with the stochastic trend deviations of the exchange rate (dashed lines)

Table 1: Summary of Unit Root Test Statistics for the Key Macroeconomic Variables in all Bilateral Relationships of EC-Countries and the United States Relative to Germany

Country Variable	France	Italy	Netherlands	Belgium	Denmark	UK	United States
Employment Ratio	I(1)+trend	I(1)	I(1)	I(1)	I(1)	I(0)+trend or I(1)	I(1)+drift
Output Ratio	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Nominal Money Ratio	I(1)	I(1)+trend	I(0)+trend or I(1)	I(1)	I(0)+trend or I(1)	I(1)	I(0)+trend or I(1)
Real Money Ratio	I(1)+drift	I(1)	I(1)+drift	I(1)+drift	I(1)	I(1)+drift	I(1)
Price Level Ratio	I(1)+trend	I(1)+trend	I(1)+trend	I(1)+trend	I(1)+trend	I(1)+trend	I(1)+drift
Nominal Exchange Rate	I(1)+trend	I(1)+trend	I(1)	I(1)+trend	I(1)+trend	I(1)	I(1)
Real Exchange Rate	I(1)	I(1)	I(1)+trend	I(1)	I(1)	I(1)	I(1)
Nominal Interest Rate Differential	I(1)	I(1)	I(0)	I(0)	I(0)	I(1)	I(1)
Real Interest Rate Differential	I(0)+trend	I(0)+trend	I(0)+trend	I(0)+trend	I(0)+trend	I(0)+trend	I(0) or I(1)

Key: Own calculations using GAUSS386. The unit root properties indicated here are based on the test statistics and decision process outlined in Weber (1977) for the United States versus Germany. The full set of tables with the detailed results is available on request.

Table 2: Cointegration Test Statistics for the Key Macroeconomic Variables in the Bilateral Relationships of EC-Countries and the United States Relative to Germany

Countries	Stationary Varia- bles? Ratios of:	Specificatio n	Eigenvalue	Likelihood Ratio, (Critical Values)	No. of Cointe- gration Equations	Variables in VAR-system, Ratios of:
United States 1972.01- 1994.12	Real Interest Rates are I(0), Nominal Money are I(0)+trend <u>or</u> I(1)	linear deterministi c trend, 6 lags	0.068831	39.37 (5%: 47.21) (1%: 54.46)	None	Employment (l), Output (y), Real Exchange Rate (q), Prices (p)
France 1972.01- 1994.12	Real Interest Rates are I(0)	linear deterministi c trend, 6 lags	0.096009	67.10 (5%: 68.52) (1%: 76.07)	None	Employment (l), Output (y), Real Exchange Rate (q), Real Money (m-p), Prices (p)
Italy 1972.01- 1993.12	Real Interest Rates are I(0)	linear deterministi c trend, 6 lags	0.084656	67.17 (5%: 68.52) (1%: 76.07)	None	Employment (l), Output (y), Real Exchange Rate (q), Real Money (m-p), Prices (p)
Netherlands 1972.01- 1994.12	Real Interest Rates are I(0), Nominal Money are I(0)+trend <u>or</u> I(1)	linear deterministi c trend, 6 lags	0.067040	42.85 (5%: 47.21) (1%: 54.46)	None	Employment (l), Output (y), Real Exchange Rate (q), Real Money (m-p)
Belgium 1972.01- 1994.12	Real Interest Rates are I(0)	linear deterministi c trend, 6 lags	0.085745	60.38 (5%: 68.52) (1%: 76.07)	None	Employment (l), Output (y), Real Exchange Rate (q), Real Money (m-p), Prices (p)
Denmark 1972.01- 1994.12	Real Interest Rates are I(0), Nominal Money are I(0)+trend <u>or</u> I(1)	linear deterministi c trend, 6 lags	0.073495	37.59 (5%: 47.21) (1%: 54.46)	None	Employment (l), Output (y), Real Exchange Rate (q), Prices (p)

United Kingdom 1972.01-1994.12	Real Interest Rates are I(0), Employ-ment are I(0)+trend <u>or</u> I(1)	linear deterministic trend, 6 lags	0.056403	40.90 (5%: 47.21) (1%: 54.46)	None	Output (y), Real Exchange Rate (q), Real Money (m-p), Prices (p)

Key: Cointegration analysis was carried out using EVIEWS