Exchange rates and prices: sources of sterling real exchange rate fluctuations 1973-94

Mark S Astley[*]

and

Anthony Garratt[**]

* Monetary Analysis, Bank of England, London, EC2R 8AH.
E-mail: mark.astley@bankofengland.co.uk

** Department of Applied Economics, University of Cambridge, Sidgwick Avenue, Cambridge CB3 9DE. E-mail: a.garratt@econ.cam.ac.uk.

The views expressed are those of the authors and not necessarily those of the Bank of England. We would like to thank Clive Briault, Andrew Haldane, Danny Quah, Chris Salmon, Frank Smets and Peter Westaway for their useful comments. Remaining errors are, of course, entirely our responsibility. Our thanks go to Siobhan Phillips for excellent research assistance.

Issued by the Bank of England, London EC2R 8AH to which requests for individual copies should be addressed; envelopes should be marked for the attention of the Publications Group (telephone: 0171 601 4030). Working papers are also available from the Bank's Internet site at http:\\www.bankofengland.co.uk.

ISSN 1368-5562

Contents

Abstract

This paper attempts to identify the *sources* of UK exchange rate and relative consumer price fluctuations between 1973 and 1994. We follow Clarida and Gali (1994) in using the Blanchard and Quah (1989) structural VAR (SVAR) method to identify the effects of three structural shocks within a Dornbusch (1976)/Obstfeld (1985) model. We find that IS shocks underlay the majority of the variance of sterling real and nominal exchange rates. Aggregate supply (AS) shocks were the second most important source of such variations, while LM shocks played an extremely limited role. In contrast, the variance of UK relative consumer prices was primarily attributed to LM shocks. Combining those results with the estimated impulse response functions indicates that the sterling exchange rate depreciations over the floating rate period were largely associated with *falls* in UK relative consumer prices. But it would be inappropriate for policy-makers to base any future policy response to sterling fluctuations on that finding because: (a) the Lucas critique applies to it; and (b) it represents the average dynamic interaction over the sample period. We also find that: (i) the estimated impulse responses following each of the shocks are highly theory-consistent; and (ii) the periods in which the SVARs suggest that particular shocks were especially important can be linked to observed macroeconomic developments. Both those findings indicate that the SVAR representations of the data have a high economic content.

Key words: Real exchange rates, relative prices, real and nominal shocks, structural VAR.
JEL classifications: C32, F41

1. Introduction

What are the price (inflation) implications of an exchange rate movement?

Several factors have to be borne in mind in answering this question. First, exchange rates and prices are both *endogenous* variables, whose values are determined by *exogenous* shocks. As such, exchange rate changes constitute one (potentially important) *channel* through which such exogenous developments affect prices. But they do not constitute an independent *source* of price fluctuations *unless* the authorities allow wage-bargaining and price-setting behaviour to be affected by such changes.[1] Second, economic theory shows that both the direction and magnitude of the price movements associated with an exchange rate change depend on the *type* of shock underlying that currency movement. So it is crucially important to identify the (unobservable) *source* of any exchange rate change to answer the question posed above.

The sources of real exchange rate movements is a long-debated issue. The ‘disequilibrium’ approach of, *inter alia,* Dornbusch (1976) and Mussa (1982) posits that sluggish price adjustment means that *nominal* shocks will play a large role.[2] Another prominent theory[3] is the ‘equilibrium’ approach of Stockman (1987, 1988), which argues that *real* shocks (with large permanent components) are likely to be the main source of real exchange rate fluctuations.[4]

Theory also, of course, provides information on the likely sources of movements in other (endogenous) macroeconomic variables ¾ such as consumer prices and GDP. And there are advantages of taking account of this information when examining the sources of currency movements. In particular, such a *systems* approach aims, by taking account of the fact that such variables are jointly determined, to avoid simultaneous equation biases. And it allows a wider range of exogenous shocks to be considered ¾ reducing potential omitted variables biases. Finally, it provides us with a richer information set ¾ allowing us to determine the sources of movements in each of the macroeconomic variables considered, and their responses to each of the shocks. The latter are, of course, crucial to answering the question posed above.

---

(1) Even here it can be argued that it is the (lack of) policy response, rather than the currency movement *per se*, that is the true source of the price movements.

(2) The well-documented strong positive correlation between real and nominal exchange rate movements supports the disequilibrium view. But the Meese and Rogoff (1988) empirical rejection of the predicted strong correlation between real interest differentials and real exchange rate changes called the approach into question.

(3) Other popular theories include the monetary approach (which is the long-run solution to Dornbusch (*op cit*)), the portfolio balance approach and the currency substitution approach.

(4) The Huizinga (1987) finding that a high proportion of real exchange rate variation is due to permanent shocks (real exchange rates contain unit roots) supports the equilibrium view.

Because of these advantages, we adopt a systems-based empirical method. The endogenous variables in our systems are sterling bilateral exchange rates, UK relative consumer prices (UK consumer prices minus their foreign equivalents) and UK relative output (UK real GDP minus its foreign equivalent). Our approach is to apply the Clarida and Gali (1994) US-based analysis to UK data ¾ estimating UK-centred two-country open-economy macro models in the spirit of Dornbusch (*op cit*). The exogenous structural shocks driving endogenous variable movements are identified by applying the Blanchard and Quah (1989) structural VAR (SVAR hereafter) method. This involves imposing three theory-derived restrictions (detailed in Section 2.2) on the *long-run* response of endogenous variables to exogenous shocks.[5] The strength of these restrictions is their generality and uncontentious nature. And the remaining responses ¾ long-run and short-run ¾ are entirely data-determined, rather than being *imposed.* The three structural shocks identified by this approach are: (i) *real* aggregate supply (AS) shocks; (ii) *real* goods market (IS) shocks; and (iii) *nominal* money market (LM) shocks. Because the models are relative ones, our approach only uncovers *asymmetric* shocks. We consider, in turn, the United States, Japan, Germany and France as the foreign countries in our empirics.

Our results can also help us address several ancillary questions discussed in the exchange rate literature. First, our results can be used to discriminate between the exchange rate theories discussed above. This is because our empirics, by taking account of both *real* (AS and IS) and *nominal* (LM) shocks, encompass both theories. Second, our results can help determine whether the observed real exchange rate movements represented *permanent* shifts to new equilibrium levels, or *temporary* deviations from an unchanged equilibrium. This issue has previously been investigated by, *inter alia*, Lastrapes (1992), Evans and Lothian (1993) and Rogers (1995).

Our main findings are:

(a) Goods market (IS) shocks were the main source of sterling real and nominal exchange rates movements between 1973 and 1994. AS shocks were the secondary source of these fluctuations, while LM shocks played extremely limited ¾ and usually statistically insignificant ¾ roles, even at short horizons.

(b) This dominance of real shocks is more *consistent* with the Stockman (*op cit*) equilibrium view than the Dornbusch (*op cit*) disequilibrium approach. It also, when combined with other results, suggests that the observed sterling real exchange rate movements mainly constituted permanent shifts to new equilibrium levels.

---

(5) These restrictions *exactly* identify the model. They cannot therefore be directly tested. We determine the economic content of the SVARs by implementing several *informal* 'over-identifying' tests commonly used in the literature.

(c) LM shocks were the main source of UK relative consumer price movements between 1973 and 1994. Of the real shocks, the influence of AS shocks was most apparent.

(d) Combining (a) with the estimated impulse response functions suggests that sterling exchange rate depreciations over the floating rate period were largely associated with *falls* in UK relative consumer prices. In particular, we find that a 10% nominal sterling depreciation (appreciation) was most likely to have been associated with a small (around 1%) fall (rise) in UK relative consumer prices over our sample. This reflects the shocks that produce currency movements affecting UK relative consumer prices through a number of channels. But it is inappropriate for policy-makers to base any policy response to sterling fluctuations on this finding.

(e) The estimated dynamic responses of the variables to each of the three shocks are highly theory-consistent.

(f) The periods in which the SVARs indicate that particular shocks were most important can be linked to observed (off-model) relative productivity, domestic demand and monetary aggregate developments.

(g) Both (e) and (f) indicate that the SVAR representations of the data have a high economic content.

The remainder of the paper is organised as follows. Section 2 provides further details of our method ¾ outlining the structural VAR approach and describing the open-economy stochastic exchange rate model that underlies the empirics. Section 3 presents the results, the implications of which are discussed in Section 4. Section 5 concludes.

2. Method

2.1 Structural VAR (SVAR) overview

SVARs are dynamic simultaneous equation systems that allow the dynamic impact of exogenous shocks on endogenous variables to be quantified.[(6)] They are based upon the reduced-form Vector Autoregression (VAR) representation ¾ where movements in each endogenous variable are represented as a response to past movements in all the endogenous variables. In particular, we can *identify* the dynamic effects of the *unobservable* exogenous shocks ¾ obtain the structural moving-average representation ¾ by imposing restrictions on the VAR representation.

What are the possible identifying restrictions?

The Sims (1980) approach imposes a Wold causal chain on the *contemporaneous* relationships between shocks and endogenous variables to achieve identification. But Cooley and LeRoy (1985) observed that such restrictions frequently imply economic structures that are difficult to reconcile with economic theory.[(7)] Moreover, the results obtained with that method are frequently sensitive to the ordering of variables in the VAR ¾ which is often difficult to determine *a priori*.

SVARs side-step such problems by using restrictions derived explicitly from economic theory. Here we apply the Blanchard and Quah (1989) SVAR method[(8)] ¾ basing our identification restrictions on the *long-run* effect of exogenous shocks on endogenous variables. Appendix A provides a full description of the mechanics of identification. Using long-run restrictions to achieve identification has several benefits. First, because there is a degree of consensus on the long-run effects of shocks, such restrictions are likely to hold in a range of models. So the empirics are not tied to a particular model. Second, the *short-run* dynamics, about which there is considerably less agreement in the literature, are left completely unconstrained (data-determined). Third, the fact that the identification restrictions (described in Section 2.2) are derived from theory means that the forecast error variance decompositions, impulse responses, historical decompositions and shock series generated by the method can be given structural interpretations.

---

(6) Keating (1992) is a good introduction to the SVAR literature. SVARs, however, are not without their detractors ¾ see, for example, Faust and Leeper (1994).

(7) These types of identifying restrictions are known as the Choleski decomposition. Early researchers often incorrectly asserted that such a method was 'atheoretical'.

(8) Other SVAR approaches use theoretically motivated contemporaneous restrictions (Bernanke (1986)) and a combination of contemporaneous and long-run restrictions (Gali (1992)).

2.2 A structural exchange rate model

The Obstfeld (1985) stochastic two-country version of the Dornbusch (*op cit*) model underlies our empirics. This serves the two usual purposes in the SVAR literature. First, it provides the economic underpinnings of the long-run identifying restrictions imposed. Second, it supplies the theoretical priors to compare the estimated dynamic responses against ¾ one of the important informal 'over-identifying' tests of SVARs. But, importantly, the empirical strategy is not tied to this particular model; a number of mainstream models display the same long-run conditions and predicted short-run responses.

The Obstfeld (*op cit*) model is a relative one, defined in terms of home-country (UK) variables minus foreign-country ones. In particular, the endogenous variables determined by the model are: UK relative output; sterling bilateral real exchange rates; UK relative consumer prices; and sterling bilateral nominal exchange rates (the nominal exchange expression is derived from the real exchange rate and relative price ones). Since we take natural logarithms of all the individual country variables in the empirics, the relative output and relative price measures represent ratios. The model determines the effects of three exogenous structural shocks: (i) *real* aggregate supply (AS) shocks, which include all labour market factors, such as differential productivity developments, that shift the aggregate supply curve; (ii) *real* goods market (IS) shocks, encompassing exogenous changes to *real* relative domestic absorption due to shifts in consumption, investment, government expenditure and home/foreign goods tastes; and (iii) *nominal* money market (LM) shocks, reflecting shifts in both relative money supplies and relative money demands. The model's two-country formulation means that we only model the effects of *asymmetric* shocks. Table A summarises the long-run and short-run model solutions, which are derived in Appendix B.

Take the long run, which coincides with flexible prices and rational expectations holding, first. Table A[(9)] reports that relative output is then determined entirely by AS shocks. This is because the long-run aggregate supply curve is vertical in our model (and many others). The zero long-run effects of IS and LM shocks on the long-run *level* of relative output constitute two of the three *theory-based* restrictions required to achieve identification. In particular, those restrictions allow us to distinguish AS shocks from IS and LM shocks. The final theory-based identifying restriction is that LM shocks have no long-run effect on the real exchange rate. That restriction allows us to distinguish between IS and LM shocks.

---

(9) All subsequent tables are presented in Appendix D.

Table A: Expected long-run (LR) and short-run (SR) responses of variables to (positive) shocks

Shock		Relative output	Real exchange rate	Relative prices	Nominal exchange rate
AS	LR	↑	↑	↓	? (↑)
	SR	↑ (< LR)	↑ (< LR)	↓ (< LR)	? (↑)(< LR)
IS (Temp)	LR	Zero	Zero	↑	? (↓)
	SR	↑	↓	↑(< LR)	? (↓) (< LR)
IS (Perm)	LR	Zero	↓	Zero	? (↓)
	SR	Zero	↓ (< LR)	Zero	? (↓) (< LR)
LM	LR	Zero	Zero	↑	↑
	SR	↑	↑	↑ (< LR)	↑ (>LR?)

Key: ↑(↓) = increase (decrease); ? = ambiguous response; > = greater than; < = less than.
Note: Exchange rate increases represent depreciations.

Our model distinguishes between *temporary* IS shocks (eg cyclical fiscal policy changes) and *permanent* IS shocks (eg lasting shifts in foreign consumers' preferences). And Table A shows that temporary and permanent IS shocks have different effects on the endogenous variables. In particular:

- While temporary IS shocks affect long-run relative prices, permanent ones do not. This is because permanent IS shocks affect real/nominal interest rates equally in each country, leaving *relative* interest rates unchanged. And long-run relative output ¾ the other argument in the LM relationship ¾ is, as discussed above, unaffected by IS shocks in the long run. Given this, the long-run LM relationship can only hold if relative prices, and hence real money balances, are also unaffected by permanent IS shocks in the long run. This is achieved by permanent IS shocks having, in the long run, equal effect on all countries' price levels. For example, *positive* permanent IS shocks increase all countries' price levels.

- Only permanent IS shocks have any long-run effect on real exchange rates. This is because the foreign exchange market discounts the reversal of temporary IS shocks (Appendix B shows this algebraically).

Most of the expected *directions* of responses presented in Table A are intuitive. The real exchange rate responses, however, require further explanation. Table A shows that positive AS shocks produce long-run real exchange rate *depreciations.* Why? Because an improvement in competitiveness is required to stimulate demand for the extra output that positive AS shocks generate.[10] Conversely, positive permanent IS shocks produce long-run real depreciations.

The long-run *nominal* exchange rate responses also require explanation. Table A shows that only LM shocks have unambiguous effects.[11] In particular, positive LM shocks produce nominal depreciations. The indeterminate effects of IS and AS shocks arise because they have opposite effects on real exchange rates and relative prices. However, intuition suggests that nominal exchange rate movements should help facilitate the required *real* exchange rate response to IS or AS shocks. If this were not the case, then unrealistically large relative price movements would be needed to achieve the required real exchange rate response.[12] Moreover, that scenario contradicts the high positive correlation between nominal and real exchange rate movements observed over the sample period. So, as the table shows in parentheses, positive AS shocks should produce nominal depreciations. And positive IS shocks should produce nominal appreciations.[13]

Now consider the short-run ('sticky price') responses. Table A shows that in the short run all shocks potentially affect all endogenous variables (with two exceptions discussed below). This underlies our identification restrictions being purely long-run ones. Table A also show the intuitive result (derived in Appendix B) that the short-run relative price effect of each of the shocks is less than their long-run equivalents. We also confirm the usual result that positive LM shocks depreciate the real exchange rate when prices are sticky. And price stickiness means that real exchange rates undershoot their long-run responses following AS and IS shocks. The nominal exchange rate may either undershoot or overshoot in the short run, depending upon parameters such as the responsiveness of relative output to the real exchange rate and interest rate differentials. Relative output is demand-determined in the short run, with positive LM shocks and the temporary component of positive IS shocks raising relative output. And price stickiness reduces the output effect of AS shocks.

The two exceptions are that permanent IS shocks are predicted to have a zero short-run effect on both relative prices and relative output (matching the equivalent long-run effects). However, those results rely on the assumption that permanent IS shocks affect real and nominal interest rates equally in each country in the short run

---

(10) That prediction is based upon two assumptions about AS shocks: (i) they affect all sectors of the economy equally; and (ii) their direct supply effects outweigh any derived wealth (demand) effects (Neary (1988) showed that real exchange rate depreciations follow any shock whose supply effects exceed its demand effects). Assumption (i) rules out Balassa-Samuelson effects, which are well known to potentially produce predictions that conflict with the above.

(11) The expected nominal exchange rate responses are obtained by combining the relative price and real exchange rate expressions.

(12) In particular, relative price movements would have to equal the required real exchange rate movement *plus* the nominal exchange rate movement.

(13) Intuitively, this is due to the rise in domestic interest rates induced by an outward shift in the IS curve stimulating capital inflows.

(as well as in the long run), which may be interpreted as overly restrictive. So we view the model-generated distinction between permanent and temporary IS shocks as being less well-defined in the short run than in the long run. More importantly, however, that assumption has no effect on our empirical results. This is because our identifying restrictions are purely long-run ones and are not specific to the Obstfeld (*op cit*) model.

3. Results

3.1 Estimation

The first stage in method is to estimate, for each country pair, a VAR of the *first differences* of relative real GDP (Δy_t), the real exchange rate (Δq_t) and relative consumer prices (Δp_t). Appendix A shows that this allows us, in the second stage of the method, to impose our theory-derived identifying restrictions on the *levels* of those variables. The VARs were estimated on quarterly data between 1973 Q1 and 1994 Q4. The real exchange rate (q_t) is constructed by subtracting relative prices from the nominal exchange rate (s_t). We reverse that procedure when analysing the estimation output to obtain the nominal exchange rate impulse responses, from which we derive the nominal exchange rate forecast error variance decompositions (FEVDs).(14) Exchange rates are defined as the number of units of domestic currency required to purchase a unit of foreign currency; so rises in q_t (s_t) constitute real (nominal) depreciations. Appendix C provides full details of the data employed.

It is important to establish the time-series properties of the data. The ADF tests reported in Tables B and C indicate that all the variables are I(1). Turning to possible cointegration, the Johansen test results reported in Table D indicate that the null hypothesis of no cointegrating relationships among the three variables cannot be rejected.(15) This means that it is appropriate to estimate the first-stage VARs in first differences.(16)

The lag lengths of the first-stage VARs were selected using sequential likelihood ratio tests. We preferred these to Akaike and Schwartz information criteria because of the DeSerres and Guay (1995) findings that such criteria tend to select an insufficient number of lags and, consequently, produce biased structural parameter

---

(14) Equation A9 shows that FEVDs are based upon transformations of impulse responses (in levels or differences). So the nominal exchange rate FEVDs are based upon the nominal exchange rate impulse responses. They are not the summation of the real exchange rate and relative price FEVDs.
(15) The results were most marginal in the UK-Japanese system. But we proceeded on the assumption of no cointegration because: (i) the rejection of the null of no cointegration only occurred at the 90% confidence level; (ii) ADF tests revealed that the resulting residuals were I(1); and (iii) the coefficients of the cointegrating vector uncovered had no economic content.
(16) If cointegration had been detected, then the first differences VARs would suffer from omitted (levels) variable biases. And more efficient estimates of the short-run dynamic relationships among the variables could have been obtained by taking account of such long-run relationships. The approach of King, Plosser, Stock and Watson (1989) would need to be applied if cointegration were found.

estimates. Our selection procedure indicated that three lags were appropriate in the UK-US system, one lag in the UK-Japanese and UK-German systems, and four lags in the UK-French system. And re-running the systems with higher number of lags (up to eight) produced only minor changes in results and reduced the length of the sample period that could be examined.

We investigated possible VAR instability by undertaking several variants of recursive Chow tests. Policy regime changes in both the United Kingdom and abroad constitute one potential source of instability. The one step ahead tests indicate that *outliers* are present, especially in the exchange rate equations; Figure 1[(17)] plots the UK-US system results.[(18)] But the n-step tests indicate that these outliers did not translate into *regime shifts* ¾ see Figure 2 for the UK-US system results ¾ which we are more concerned about. Moreover, those findings ¾ which are not unusual in the literature[(19)] ¾ were not a function of poorly specified VARs.[(20)]

3.2 Forecast error variance decompositions (FEVDs)

FEVDs tell us which shocks were the primary *sources* of movement in the endogenous variables over the sample period. In particular, FEVDs determine the proportion of the forecast error variance of each endogenous variable at different forecast horizons attributable to each of the shocks. In each case we calculate the FEVDs on the levels of the endogenous variables,[(21)] as these correspond most closely to the questions we wish to address. The results are presented in Tables E-H. The point estimates appear, for every horizon, in the top row. The two standard errors[(22)] associated with these point estimates appear on the lower row, in smaller font. The implied error bands allow us to determine whether the contribution of a particular shock is significantly different from zero at a 95% confidence level.

---

(17) All the figures are presented in Appendix D.

(18) Interestingly, the major £/$ outlier occurs around 1985, tying in with the Evans (1986) finding that the £/$ was subject to a speculative bubble between 1981-84 and the general perception of dollar misalignment around this period.

(19) For example, Evans and Lothian (*op cit*) and Sarantis (1994) uncovered no evidence of instability in their dollar and sterling-based analyses over similar periods to our own.

(20) Importantly, serial correlation was never a problem. But there was some evidence of outliers producing non-normal errors; however, this is relatively benign in our set-up, as it is such outliers that allow us to examine (interesting) sub-sample variation.

(21) The FEVDs of the first differences of variables produced broadly similar results to the levels ones. This need not necessarily be the case. This is because, as equation A9 shows, the levels (first difference) FEVD of a variable are based upon non-linear transformations of the levels (first differences) impulse responses of that variable to each of the shocks.

(22) Calculated using 100 draws of Monte Carlo simulations. These error bands are portrayed, for computational simplicity, as symmetric. Runkle (1987) and Blanchard and Quah (op cit) illustrate that this is not necessarily the case when bootstrapping methods are used.

(i) Real exchange rates

Table E presents the strong result that IS shocks were the main source of movements in each of the four sterling real exchange rates considered. IS shocks were most important in determining real £/$ movements, where they accounted for more than 90% of variation at all horizons. But they also accounted for at least 75% of the fluctuations in the three other rates, with their importance often rising at longer horizons. AS shocks were usually the second most important source of real sterling movements. Their effect was most pronounced, and statistically significant, in the £/¥ and £/FFr cases, where they accounted for around 20% of movements at most horizons.

LM shocks were usually unimportant sources of real sterling fluctuations at all horizons. The only exception is the £/DM rate. But the effect is limited even here ¾ a maximum of 19% ¾ and is only apparent at short horizons. Though an identifying restriction underlies the unimportance of LM shocks at long horizons, their extremely limited role at short horizons is entirely data-generated.

Clarida and Gali (*op cit*) similarly concluded that LM shocks were unimportant determinants of real $/£ fluctuations. But they found that LM shocks played larger roles in real $/DM and $/ù movements.[23] This might initially suggest that different factors underlie sterling and dollar movements. But there are several reasons for not overplaying these differences. First, movements in both currencies primarily reflect IS shocks. Second, considering a broader range of bilateral rates might blur the above distinction. Indeed it is noticeable that, on our dataset, LM shocks accounted for a maximum of 0.6% of real $/FFr fluctuations. And other sterling exchange rates might replicate the higher, though still small, importance of LM shocks in real £/DM fluctuations.

Rogers (1995), in his application of the Lastrapes (1992) bivariate SVAR model to the $/£ exchange rate, also produced results consistent with those of Table E. In particular, he found real (permanent) shocks to be the main source of real and nominal $/£ movements. Similarly, Evans and Lothian (*op cit*) concluded that temporary (nominal) disturbances played only a small, but significant, role in *sub-sample* real £/$ movements.[24] But Rogers (*op cit*) uncovered, in a trivariate SVAR, results at odds with those of Table E. In particular, he found that nominal shocks accounted for around 50% of *short-horizon* real $/£ fluctuations. The weakness of these cross-checks of the robustness of our results is that they refer to only one of the four bilateral sterling exchange rates we consider. So a useful subject

---

(23) Clarida and Gali found that LM shocks accounted for up to 36% (53%) of real $/ù ($/DM) movements. The point estimates we obtain for those rates using our (longer) dataset are lower, but not significantly different.

(24) Accounting for a maximum of 14% of the one-month variation in 1977/78, but more usually around 5%.

for future research would be to apply these alternative frameworks to the full range of sterling exchange rates analysed in this paper.

(ii) Relative consumer prices

UK relative consumer price movements were, as Table F shows, mainly due to *LM* shocks. The role of LM shocks was most pronounced in UK-US prices, where they accounted for 80% of movements at the shortest horizon and 97% inside a year. But they also accounted for approximately 70% of the variation of UK-Japanese and UK-German prices, with comparatively little variation across horizons. Finally, LM shocks were the second most important determinants of UK-French price movements at every horizon, accounting for up to 44% of the fluctuations.

AS shocks also played large, and statistically significant, roles. In particular, they were the main source of UK-French price movements (up to 66% at short horizons) and the second most important source of fluctuations in the remaining series. IS shocks were uniformly the least important source of relative price fluctuations. Their role was most pronounced at long horizons, where they accounted for at least 10% of the observed movements (except in the UK-US case).

(iii) Nominal exchange rates

LM shocks played a larger role in sterling *nominal* exchange rate movements (see Table G) than in the real exchange rate equivalents. But this role was still small. They accounted for a maximum of 35% of movements (£/DM rate), but more frequently less than 15%. This larger role obviously reflects the dominant role that LM shocks played in relative price movements. But their effect remains extremely limited because the nominal exchange rate paths largely mirrored their real rate equivalents. This close tracking means that IS shocks again constituted the main source of nominal rates movements. This dominance was most pronounced in the £/$ and £/FFr rates. *AS* shocks also often underlay some of the nominal rate movements, especially of £/DM and £/ù rates.

(iv) Relative output

UK relative output fluctuations were primarily attributable to AS shocks (see Table H). This ties in with similar results derived in Holland and Scott (1997). The first and second identifying restrictions (see Section 2.2) obviously underlie this finding at long horizons. But it is again entirely data-generated at shorter horizons. AS shocks accounted for more than 80% of movements in most of the relative output series after two quarters. The only exception was the large (60%) role that LM shocks played in *short-horizon* UK-French output movements.

3.3 Impulse responses

Figures 3-6 present the estimated dynamic responses of the variables to each of the structural shocks. The dark line in the figures represent the *point estimates* of the response of the *levels* of each of the variables to a one percentage point perturbation to each of the three shocks. The lighter lines on either side of these point estimates represent the two standard deviation error bands. Like Clarida and Gali (*op cit*), we find that the signs of these responses are typically consistent with our theoretical priors. Moreover, the relative magnitudes of the responses are also sensible: exchange rates respond by more than relative prices, which in turn respond by more than relative output. Our results therefore pass the first informal 'over-identifying' test of SVARs. This means that we can be confident of the economic content of the FEVDs.

(i) Responses to AS shocks

AS shocks produce dynamic responses that are highly theory-consistent. Positive AS shocks usually generate falls in relative prices, real exchange rate depreciations and rises in relative output. The only counterintuitive response is the real £/$ *appreciation.* But Clarida and Gali (*op cit*) also uncovered exactly this 'perverse' real $/£ response; this suggests that neither set of results are outliers.

Relative prices respond sluggishly to AS shocks, uniformly taking at least eight quarters to approach their new long-run equilibria. This price stickiness is most apparent in UK-French prices, which take twelve quarters to 'level off'. Positive AS shocks usually cause relative prices to fall by between 1.1%-1.6% in the long run. The exception is the much smaller UK-US response. The long-run real exchange rate responses are, at between 1.9% and 3.5%, considerably larger and more dispersed. Though real exchange rates adjust more quickly than relative prices, this adjustment is again comparatively slow; full adjustment takes up to seven quarters. Those relative price and real exchange rate responses mean that nominal exchange rates *depreciate* (slowly) following positive AS shocks. That accords with the intuition of Section 2.2. The long-run relative output responses are, at between 1.0% and 1.5%, fairly uniform.

(ii) Responses to IS shocks

The IS shocks responses require a little more explanation. IS shocks usually produce, across countries and variables, responses that initially look counterintuitive ¾ *falls* in relative prices/output and real exchange rate *depreciations.* But that initial impression is misplaced. This is because, as Faust and Leeper (1994) note, the SVAR method does not tie down the *sign* of each of the elements on the principal diagonal of the structural impulse response matrices. This indeterminacy arises because the method involves solving a quadratic expression ¾ whose solution can be either positive or negative.[25] This means that we can only conduct the first informal 'over-identifying' test in terms of the *relative* consistency of the impulse responses. In the present case, the uniformly 'incorrectly' signed responses ¾ based upon the assumption of positive shocks ¾ indicate that *negative* IS shocks have been identified. The easier to interpret *positive* IS shock results can be obtained by multiplying the negative IS shock results uncovered by minus one.[26]

This is an important point to understand. It shows that the FEVD result that IS shocks underlie the majority of sterling exchange rate movements has some economic content. But there is also a corollary. Because the 'incorrectly' signed £/FFr response to IS shocks is not matched by counterintuitive output and price responses, we have less grounds for arguing that negative UK-French IS shocks have been identified. So our finding that IS shocks underlay a high proportion of £/FFr movements may be shaky.

Relative prices again rise sluggishly following positive IS shocks, taking up to nine quarters to approach their long-run responses. Interestingly, European (UK-German and UK-French) prices appear stickiest. The UK-US responses again constitute the main outlier, their long-run movements lying considerably below the 0.8% to 1.3% range of the remaining relative prices.

The real exchange rate appreciations following positive IS shocks are again large and quite dispersed ¾ the long-run responses lying between 3.3% (£/FFr) and 7.8% (£/ù). The adjustment to the new long run is usually smooth and comparatively protracted; it takes up to six quarters for steady state to be reattained. Interestingly, there is some evidence of real £/FFr overshooting. But this probably reflects the comparative volatility of that response. Combining the real exchange rate and relative price responses shows that positive IS shocks produce nominal appreciations. This again accords with the intuition of Section 2.2. The increases in relative output following positive IS shocks are uniformly small, peaking at 0.4%.

(iii) Responses to LM shocks

LM shocks generate responses that uniformly accord with our theoretical priors. A positive LM shock produces a temporary rise in relative output, a temporary real exchange rate depreciation,[27] a permanent increase in relative prices and a permanent nominal exchange rate depreciation.

---

(25) In particular, the signs of each of the principal diagonals of C_0 solved in equation (A4) are indeterminate. If C_0^a satisfies (A4), then so will $C_0^b = C_0^a F$, where F is a diagonal matrix with either 1 or -1 on the diagonal.
(26) The transformed IS shock series also have considerably more intuition. This adds further weight to the argument that negative IS shocks have been uncovered.
(27)The temporary relative output and real exchange rate responses reflect the second and third identifying restrictions (see Section 2.2).

Relative prices adjust slowly to LM shocks, typically taking around ten quarters to adjust more or less fully.[28] The long-run responses are, at between 1.7% and 2.9%, reasonably consistent across the country pairs. The temporary real exchange rate depreciations are, except for the £/DM rate, relatively short-lived ¾ reaching their zero long-run effects within six quarters.[29] And these short-lived real exchange rate responses mean that the nominal exchange rate responses largely mirror the relative price responses at all but short horizons.

Our estimates of the speed of adjustment of nominal sterling exchange rates to LM shocks differ from the existing dollar-based findings. Clarida and Gali (*op cit*) and Eichenbaum and Evans (1993) found that dollar exchange rates take around two years to respond fully to LM shocks and monetary *policy* shocks respectively. While we uncover a similar lag in the £/$ responses, this is not a general feature of our results. In particular, the £/ù rate adjusts quickly and the £/DM and £/FFr rates overshoot slightly in the short run. This suggests that the existing dollar-based results may not hold for other currencies. But further work is required to clarify this issue.

3.4. Sub-period analysis

This section addresses two questions. First, how do the SVARs explain sterling real exchange rate and UK relative consumer price movements throughout the sample period (presented in figure 7)? This is the sub-sample analogue to the full-sample FEVD results presented above. Second, can those SVAR explanations be linked to *observed* economic developments? This is the second informal 'over-identifying' test of SVARs, which allows us to check their economic content.

We employ several tools to address the first question. First, historical decompositions (HDs). These allow us to plot separately the historic paths that the endogenous variables would have followed in response to each of the structural shocks. This allows us to determine the relative importance of each of the shocks over *historic episodes*. We simply examine how closely the endogenous variable movements due to each of the shocks (the light lines in Figures 8 to 15) correspond to the total endogenous variable movements (the dark lines).[30] The main limitation of HDs is that they contain a propagation mechanism component that

---

(28)UK-US prices appear stickiest, taking more than three years to reach any kind of plateau.

(29)Again, these short-run responses are entirely data-generated. They do not, for example, reflect the horizon at which the long-run restrictions are imposed or the VAR lag lengths employed. For example, the long-lived £/DM response arises from a VAR with only one lag.

(30) The 'total' paths (dark lines) are not the actual endogenous variable movements. Rather they are the actual movements minus the SVAR's unconditional forecast ¾ or 'base projection' ¾ formed on the basis of a few initial periods of shocks (which is essentially a drift term). HDs decompose this forecast error (or 'news') into the proportions attributable to realisations of each of the structural shocks after the initial periods (whose contributions must, by definition, sum to the forecast error).

does not vary over sub-samples. To fill this gap, we also examine FEVDs estimated recursively and over a rolling window (Figures 16 to 19). We look for sub-periods when the role of the shocks lie outside the error bands associated with the full sample FEVD.[31] Finally, we examine the sub-sample patterns of the three (constructed) structural shocks hitting the economy.[32] (Figures 20 to 23.)

We address the second question by comparing those SVAR predictions with observable (off-model) proxies for the three classes of shocks identified by our empirics. In particular, we proxy AS shocks by relative productivity developments[33] (Figure 24), IS shocks by relative domestic demand movements (Figure 25) and LM shocks by relative broad[34] money growth rates (Figure 26). We uncover a high correspondence between these observable developments and the SVARs' predictions. This again suggests that the SVAR results have a high economic content. And our results reveal interesting sub-period differences to the full-sample FEVD results: AS shocks occasionally contribute to real exchange rate movements, and AS and IS shocks both underlie some sub-sample relative consumer price developments. But there are no episodes where LM shocks underlay a high proportion of real exchange rate movements.

The 1973/74 and 1979 oil price shocks were both largely associated with real sterling appreciations. The HDs attribute a high proportion of both appreciations to (positive) IS shocks. The intuition is that such positive IS shocks reflect the combined effect of the oil price rises and the discovery/exploitation of UK North Sea oil reserves. This is because, as Eastwood and Venables (1982) and Bean (1987) show, a resource discovery increases permanent income ¾ a positive (permanent) IS shock. And this permanent income rise will be larger the higher is the market price of that resource. This interpretation is obviously most contentious around the first oil shock, when the United Kingdom remained a net oil importer. But the Bank of England (1980, 1982) observed that a large proportion of the United Kingdom's oil reserves had been *discovered* at that time. So the positive IS shocks uncovered can be rationalised by (forward-looking) foreign exchange market participants taking account of this discovery. Moreover, this interpretation is supported by a shift in domestic demand towards the United Kingdom (Figure 25) and positive constructed IS shocks being apparent around *both* periods.[35]

---

(31) The major limitation of this procedure is that, for presentational clarity, only one FEVD horizon can be examined at a time. In the main, we examine the FEVDs six quarters out.

(32) We only examine broad patterns because: (i) these are point estimates; and (ii) each of the shocks is *constructed* to have unit variance and zero covariance with the other two shocks in the system.

(33) As measured by manufacturing output/industrial production per head of employment in manufacturing.

(34) Using narrow money aggregates produced similar results.

(35) Forsyth and Kay (1980), Bond and Knobl (1982) and Bean (1987), *inter alia*, also attribute the early 1980s real sterling appreciation to the United Kingdom becoming a net oil exporter. The fact that no role is attributed to IS shocks in the early 1970s relative consumer price movements may reflect product markets being less likely to have discounted the impact of discovered, but not exploited, oil reserves.

But we would also have expected the 1973/74 rise in oil prices to have negative supply implications, while discovered North Sea oil reserves remained unexploited. This should, *a priori*, constitute negative (positive) asymmetric supply shocks relative to countries which were *less* (more) oil-dependent than the United Kingdom in the early 1970s. And the recursive FEVDs do indeed indicate that AS shocks contributed to the relative price and sterling exchange rate movements in the early 1970s. Their contribution to relative prices is most intuitive. In particular, AS shocks' role in the rises (falls) in UK-US (UK-Japanese) prices implies negative (positive) supply shocks. This is consistent with the US (Japan) then being less (more) oil-dependent than the United Kingdom. And AS shocks' smaller role in the UK-German and UK-French price rises reflects the United Kingdom, Germany and France then being similar in their oil dependence. Moreover, the AS shock series uncovered by the SVARs also largely accord with these patterns. But supply shocks' role in the early 1970s sterling exchange rate movements are less well founded. This is because the uniform real *appreciations* suggest negative AS shocks ¾ implying that the United Kingdom was, in the early 1970s, *more* oil dependent than all four foreign countries considered. While this appears sensible relative to the United States, it is considerably less so for the remaining countries, especially Japan.

Negative supply shocks also occurred at the end 1970s. The cause this time was the general fall in UK relative productivity (Figure 24) associated with the 'winter of discontent'. The HDs/rolling FEVDs confirm that this shock again contributed to the early 1980s real appreciations and relative price rises. And the fact that negative supply shocks are apparent in the SVAR series (especially UK-Japanese ones) further corroborates that conclusion.

The HDs indicate that (positive) LM shocks were the main source of the general rise in UK relative prices in the 1970s and 1980s. This reflects UK monetary aggregate growth rates generally exceeding their foreign equivalents over that period (Figure 26). And we can stretch this link further. In particular, our results attribute the 1973/4 fall in UK-Japanese prices to the negative LM shocks that we uncover around that period. And this is consistent with (observed) UK money growing slower than its Japanese equivalent around that period.[36]

The HDs indicate that IS shocks underlay much of the general 1981-86 real sterling depreciations. This is largely paradoxical ¾ Figure 25 shows that relative domestic demand was fairly stable around this period. We can only rationalise this finding in the UK-US case, where the role of IS shocks looks strongest. The rationalisation is that the observed *slight* shift in UK-US domestic demand away from the United Kingdom and the negative IS shocks uncovered are consistent with suggestions by *inter* alia Feldstein (1986), Branson (1988) and Frankel (1993) that the large US

(36) This argument's weakness is the short lag between money growth and relative price movements.

fiscal deficits underlay the early 1980s dollar appreciation. But we are unable to uncover such supporting developments in the remaining country pairs.

The large role attributed to IS shocks in the general 1986-90 real sterling appreciations[37] is, however, considerably more intuitive. Relative domestic demand shifted slightly in favour of the United Kingdom in the second half of the 1980s[38] ¾ the positive IS shocks that the HDs are picking up.

UK relative productivity increased steadily from the early 1980s (Figure 24). And our results point to these positive AS shocks often playing intuitive roles in the observed endogenous variable movements. For example, the HDs indicate that they contributed to the 1981-86 real sterling depreciations. And we again uncover the required shocks in the SVAR constructed series. But counterintuitive results are also uncovered. In particular, these positive AS shocks are attributed: (i) a role in the relative price rises in the early and late 1980s;[39] and (ii) a limited role in the 1986-90 real sterling appreciations.

The HDs indicate that (positive) AS shocks played a large role in the 1990s flattening of UK relative prices (Figures 13 to 15). We think that this reflects the Figure 24 evidence that the 1980s improvement in UK relative productivity accelerated in the 1990s. The origin of these positive AS shocks varies between country pairs. For example, the negative short-term effects of German reunification and the bursting of the Japanese asset price bubble are obvious candidates in those respective systems. Moreover, AS shocks' negligible role in the real UK-US relative price movements ties in with UK-US productivity differentials being virtually unchanged (around zero) over this period.

The HDs indicate that these positive AS shocks played a large role in the sharp post-1992 real sterling depreciations. Again, this has the intuitive appeal of being least apparent in £/$ movements. In contrast, our results provide virtually no evidence of LM shocks playing a role in these depreciations. This is contrary to the Mussa (1986) argument that an exchange rate regime change ¾ such as suspending sterling's ERM membership ¾ should constitute a nominal (LM) shock. But our results are unsurprising. The observed fall in UK relative monetary aggregate growth rates (figure 26) around this period constitute *negative* (less positive) LM shocks. These, of course, produce real appreciations (slower depreciations), rather than the depreciations observed.

Our results do, however, suggest that LM shocks contributed to the observed flattening of UK relative prices. And, noticeably, relative money growth rates

---

(37) This was the period of 'DM-shadowing' in advance of sterling's 1990 ERM entry.
(38) This shift was least apparent against Japan. This probably reflects the United Kingdom and Japan both experiencing asset price driven booms around this period.
(39) The exception is the correct role that these positive AS shocks played in the early 1980s *fall* in UK-French prices.

slowed most at the start of the 1990s ¾ exactly when LM shocks appear to have had their largest price impact.

3.5 Robustness

We implemented several cross-checks of the robustness of the results reported above. First, as mentioned in Section 3.1, we varied the number of lags in the quarterly, bivariate systems. Second, we estimated a UK trade share weighted system. Here the relative GDP/price measures were defined as the UK variable relative to a (UK trade share) weighted average of each variable in the M6 countries, and a sterling (trade share weighted) M6 effective rate index was used in the place of the bilateral rates. Third, we estimated the SVARs (both bilateral and 'effective' variants) on monthly data, using industrial production as our output measure. In general, each of those variants produced similar results to those reported above ¾ suggesting that those results are not specific to the VAR specification and data underlying them.

4. Implications

We now return to the question posed at the outset: What are the price implications of an exchange rate movement?

Our results have confirmed the theoretical proposition that what matters is the *type* of shock underlying the exchange rate/price movements. In particular, they indicate that the common perception of exchange rate depreciations increasing relative consumer prices ¾ through their impact on import prices ¾ is usually misplaced. This is because an examination of the impulse responses reveals that this scenario only holds if LM shocks underlie the exchange rate/price movements. In contrast, we have shown that depreciations in response to IS or AS shocks are associated with *falls* in relative prices. And those are precisely the shocks that our results indicate have been the major sources of sterling exchange rate movements.[40] In other words, our results suggest that sterling exchange rate depreciations are most likely to have been associated with *falls* in UK relative consumer prices.

And we can quantify those arguments. To do this we use the impulse responses to examine, in turn, the relative price movements associated with a 10% *nominal* sterling depreciation caused by each of the shocks. In each case we normalise the depreciation as occurring three quarters after the shock hits the economy; this side-steps potential problems with perverse short-run dynamic effects and long-run restrictions being imposed. We also exclude incorrectly signed responses[41] and only consider the average of the four country pairs' point estimate responses. We find that a depreciation caused by a (positive) LM shock ¾ the historically rare case

(40) The short-term role of nominal shocks in £/DM movements is the minor exception.
(41) We thus omit the UK-US results from the AS shock analysis and the UK-French results from the IS shock analysis.

¾ is initially accompanied by a 7.5% *rise* in relative consumer prices, increasing to 10% after a further three quarters. In contrast, a depreciation caused by a (positive) *AS* shock ¾ the historically more common scenario ¾ is initially accompanied by a 9.2% *fall* in relative consumer prices and a 12% fall two years after the depreciation. Likewise a depreciation caused by a (negative) IS shock ¾ the historically most common case ¾ is also accompanied by a fall in relative prices. But this fall is comparatively small ¾ around 1% initially, rising to 1.2% in the long run. We then take a weighted average of those relative price responses, with weights determined by the relative importance of each of the shocks in nominal exchange rate movements (see Table G). This suggests that, on average over our sample period, a 10% sterling nominal exchange rate depreciation was initially accompanied by a 1% *fall* in UK relative consumer prices.

The intuition of that finding is that the shocks that produce exchange rate movements can affect relative consumer prices through a number of channels. The impact on import prices ¾ which often underlies predictions that depreciations raise consumer prices ¾ is one such channel. But the impact of the other channels at work ¾ such as a shock's effect on the level of excess supply or demand in the economy ¾ can, depending on the type of shock, either reinforce or offset the import price channel effects. The systems approach implemented in this paper allows for these wide range of channels. Put differently, the common perception that depreciations increase consumer prices is often based upon a *partial equilibrium* analysis. In contrast, our results are *general equilibrium* ones. Added to this, the strength of the import price channel may be weaker than is commonly perceived. This is because there is substantial evidence that exporters 'price to market' ¾ holding their foreign currency export prices steady in the face of currency movements in order to maintain market share in their export markets.[42]

What use can policy-makers make of this sections' results? Should policy-makers base any policy reactions to sterling exchange rate movements on them? Though these are natural questions to ask, there are several reasons why basing policy reactions on these results might be inappropriate:

- First, endogenous policy responses ¾ both monetary and fiscal ¾ are already included in the results. So the association of sterling depreciations with falls in UK relative consumer prices suggested by our results could be due to policy endogenously responding to exogenous shocks. If that were the case, then basing policy on our results could eliminate that relationship between exchange rates and prices. In other words, the Lucas (1976) critique applies: past econometric relationships will not necessarily hold, especially if policy-makers attempt to use these past relationships. These problems arise because our framework cannot distinguish monetary/fiscal *policy* shocks from non-policy

(42) See *inter alia* Hooper and Mann (1989), Krugman (1987,1989) and Mann (1987,1989).

shocks. This is, however, a problem that has yet to be fully resolved by the SVAR/VAR literature.[43]

- Second, this section's results represent the *average* dynamic interactions over the sample period. So, of course, they will not apply to every exchange rate movement, either inside or outside the sample period.

But despite those problems, the finding that sterling nominal exchange rate depreciations were largely associated with falls in UK relative consumer prices remains a useful piece of information in understanding developments during our sample period. And this understanding is further assisted by the Section 3 evidence on the sources of exchange rate and relative price movements ¾ whether on average over the whole sample (Section 3.2), or during distinct historical episodes (Section 3.4).

A further potential limitation is that we cannot presume that our results would hold if different foreign countries were considered in UK-based systems. Intuitively, different results seem most likely to occur when the UK-foreign country macroeconomic performance correlations are markedly different to those of the four UK-centred systems considered above. For example, LM shocks would be expected to play a larger role in currency movements if the foreign country considered had a consistently different inflation rate. We do not consider such countries because they typically account for a small proportion of UK trade.

The introduction also posed two ancillary questions:

First, which exchange rate theory receives most support from our results? The dominance of real shocks as determinants of sterling exchange rate movements makes our results most consistent[44] with the Stockman (*op cit*) equilibrium exchange rate theory. However, we have also uncovered evidence of substantial price stickiness. Yet this has not translated into LM shocks constituting major sources of sterling real exchange rate movements ¾ the disequilibrium view. This suggests that either asymmetric LM shocks were less prevalent than real shocks over the floating exchange rate period, or that they had a lower variance.

Second, were the real exchange rate movements over the sample period permanent or temporary? The real exchange rate results are, on their own, equivocal: as Table A showed, the Obstfeld (*op cit*) model indicates that while permanent IS shocks can

---

(43) SVAR attempts to model monetary policy shocks include Gerlach and Smets (1995) and Roubini and Kim (1995). Rudebusch (1996) provides a critique of the large number of VAR attempts. There are ambiguities over where monetary policy shocks show up in our model. Clarida and Gali (*op cit*) suggested that, consistent with traditional textbook treatments, they show up in LM shocks. But several arguments suggest that they will also show up in IS shocks.

(44) Our empirical results cannot be used to formally discriminate between alternative exchange rate theories.

permanently affect real exchange rate effects, temporary IS shocks cannot. So clearly we need to determine whether the IS shocks were mainly permanent or temporary. But we might infer from our findings that IS shocks played only minor roles in generating price/output movements that the IS shocks were mainly permanent (because Table A showed that permanent IS shocks have no relative price or output effects).(45) So this suggests that the sterling real exchange rate movements associated with IS shocks were mainly permanent. Added to this, AS shocks ¾ the second most important source of sterling real exchange rate fluctuations ¾ have unambiguously permanent effects. So our results indicate that most of the sterling real exchange rate movements over our sample period represented permanent shifts to new equilibrium levels.

5. Conclusions

This paper has uncovered several strong results. First, IS shocks underlay most of the variance of sterling real and nominal exchange rates. Second, LM shocks were the main source of UK relative price fluctuations. Third, contrary to common perceptions, sterling depreciations were usually associated with *falls* in UK relative consumer prices over our sample period. These results testify to the importance of uncovering the underlying *source* of exchange rate and price movements. But we have argued that it is inappropriate for policy-makers to base any policy response to sterling exchange rate movements on the third result above. We have shown that the SVAR representations of the data appear, importantly, to have a high economic content. We believe that our results are sufficiently interesting to merit further investigation in other frameworks.

---

(45) Our conclusion that the IS shocks were mainly permanent ones is based upon IS shocks having small long-run relative price and relative output effects. This reflects the model-generated distinction between permanent and temporary IS shocks as being better defined in the long run than in the short run (see Section 2.2).

Appendix A: The Blanchard and Quah (1989) structural VAR method

The first stage is to estimate a reduced-form VAR of the *first differences* of relative output (Δy_t), the real exchange rate (Δq_t) and relative consumer price movements (Δp_t). Letting X_t denote the vector of those endogenous variables, this VAR can be written as:

$$A(L)X_t = \varepsilon_t \qquad \textbf{(A1)}$$

$$var(\varepsilon_t) = \Omega$$

where A(L) is a 3-by-3 matrix of lag polynomials. Inverting this VAR produces the following moving-average (MA) representation:

$$X_t = B(L)\varepsilon_t \qquad \textbf{(A2)}$$

where $B(L) = A(L)^{-1}$

Representation **(A2)** is still a reduced form ¾ the shocks (ε_t) have no economic interpretation. The aim is to derive an alternative moving-average representation, which formulates the endogenous variable movements as a function of past *structural* shocks (e_t). By 'structural' we mean that the shocks have certain effects on the levels of the endogenous variables and are distinct economic phenomena (are mutually uncorrelated). We represent this structural moving-average formulation as:

$$X_t = C(L)\ e_t \qquad \textbf{(A3)}$$

$$var(e_t) = I$$

The aim of the method is to move from **(A1)** to **(A3)**. We first assume that a non-singular matrix S exists that links the structural shocks (e_t) and reduced-form disturbances (ε_t)
ie $\varepsilon_t = S\ e_t$. Comparing **(A1)** and **(A3)** reveals that $C_0 = S$. It is also clear that:

$$C_0C_0' = \Omega \qquad \textbf{(A4)}$$

To identify C_0, the key to the procedure, n^2 restrictions need to be imposed (n is the number of variables in the system, three in our case). The usual assumptions of orthogonality and unit variance of the structural shocks (e_t) provide $n(n+1)/2$ (six) of these restrictions. This means that **(A4)** is a system of $n(n+1)/2$ (six) equations in n^2 (nine) unknowns. Thus $n(n-1)/2$ (three) further restrictions are required to achieve (exact) identification.

We follow the Blanchard and Quah (*op cit*) approach of using long-run *theory*-based restrictions on the effects of certain shocks on the *levels* of certain endogenous variables. Because the VARs are estimated in first differences, the effect of a shock on the level of an endogenous variable is determined by the sum of the structural MA coefficients. We denote the matrix of these long-run multipliers as C(1).[46] So the restriction that shock j has zero long-run effect on the level of endogenous variable i requires that $C_{ij}(1) = 0$ be imposed. We impose the same restrictions as Clarida and Gali (*op cit*). First, the shock that we label as 'IS' has zero long-run relative output effects: $C_{12}(1) = 0$. Second, the shock that we label as 'LM' also has zero long-run relative output effects: $C_{13}(1) = 0$. Long-run relative output is thus entirely determined by the first shock, which we label as 'AS' - a vertical long-run aggregate supply curve. Third, LM shocks have zero long-run effect on the real exchange rate: $C_{23}(1) = 0$. Because of the ordering of the variables in the reduced form VAR, these restrictions mean that, as in Blanchard and Quah's (1989) bivariate case, the C(1) matrix is *lower triangular.*

The procedure to obtain an estimate of C_0 parallels that outlined in Blanchard and Quah (*op cit*). First calculate:

$$B(1)\ \Omega\ B(1)' \quad \textbf{(A5)}$$

where B(1) and Ω are both obtained from the reduced-form VAR. It is easily shown that C(1) obeys the following equality:

$$B(1)\ \Omega\ B(1)' = C(1)C(1)' \quad \textbf{(A6)}$$

But we can also compute the lower triangular Choleski decomposition of **(A5)**, which we denote by H. As C(1) is also lower triangular, it may clearly be equated to H. Combined with the fact that C(1) can also be expressed as $C(1) = B(1)\ C_0$, we obtain a C_0 as follows:

$$C_0 = B(1)^{-1}H \quad \textbf{(A7)}$$

From **(A1)** and **(A4)** it is clear that:

$$C_j = B_jC_0 \quad \textbf{(A8)}$$

showing that identifying C_0 allows the computation of the dynamic responses of the variables to the structural shocks. In brief, the above shows that, given the estimates of B_j (j = 1,2...), a restriction on a particular element of the long-run structural multiplier matrix C(1) imposes a linear restriction on the elements of C_0.

The time series of structural shocks are also easily obtained ($e_t = C_0^{-1}\ \varepsilon_t$). And the orthogonality and unit variance of the structural shocks make it simple to compute

(46) ie $C(1) = C_0 + C_1 + C_2 + ...C_n$. In our analysis we set n at 60 quarters (15 years). But because the results converged to their long-run values fairly quickly, we only present results out to 20 quarters in Tables E to H.

the structural forecast error variance decompositions (FEVDs). In particular, the proportion of the variance of the i-th variable accounted for by the j-th shock at horizon h ($R^2_{ij,h}$) is:

$$R^2_{ij,h} = \frac{\sum_{k=0}^{h-1} c^2_{ij,k}}{\sum_{m=1}^{n} \sum_{k=0}^{h-1} c^2_{im,k}} \qquad \textbf{(A9)}$$

where $c_{ij,k}$ ($c_{im,k}$) are the individual elements in the C matrices — the response of the i-th variable following the j-th (m-th) shock after k periods (ie plotting c_{ij} gives the impulse response functions). In other words, FEVDs are based upon transformations of the impulse responses. Finally, historical decompositions may also be straightforwardly obtained.

Appendix B: Outline of Obstfeld (1985) two-country Dornbusch (1976) model

The following four structural equations make up the Obstfeld (*op cit*) model:

$$y^d = \eta q_t - \sigma(i_t - E_t(p_{t+1}-p_t)) + d_t \qquad \textbf{(B1)}$$
$$m^s_t - p_t = y_t - \lambda i_t \qquad \textbf{(B2)}$$
$$p_t = (1-\theta)E_{t-1}p^*_t + \theta p^*_t \qquad \textbf{(B3)}$$
$$i_t = E_t(s_{t+1}-s_t) \qquad \textbf{(B4)}$$

The open-economy IS relationship **(B1)** states that relative output demand (y^d) rises with: (i) real exchange rate (q_t) increases (depreciations);(47) (ii) reductions in the real interest differential in favour of the home country;(48) and (iii) rises in all other exogenous changes relative to domestic absorption (d_t), such as government expenditure and home/foreign goods taste shifts.

The money market equilibria condition (LM curve) **(B2)** specifies real relative money demand as a positive function of relative output (y_t) and a negative function of nominal interest rate differentials (i_t). The price-setting rule **(B3)** specifies prices in period t as being set as an average of the *output* market-clearing price that was expected, in period t-1, to prevail in period t ($E_{t-1}p^*_t$) and the price that would actually clear the output market in period t (p^*_t). The θ parameter represents the degree of price flexibility; full flexibility occurs when $\theta = 1$. Finally **(B4)** represents a UIP condition linking nominal interest rate differentials to expected nominal exchange rate changes, with risk premia assumed constant.

The shocks are introduced by specifying the stochastic processes for the exogenous variables in equations **(B1)** to **(B3)**. We assume that the AS (z_t) and LM shocks (v_t) follow simple random walks, being solely permanent in nature. But relative IS (δ_t) shocks have both permanent and transitory components, the latter of which are offset in the following period, that is:

$$y^s_t = y^s_{t-1} + z_t$$
$$d_t = d_{t-1} + \delta_t - \gamma\delta_{t-1}$$
$$m_t = m_{t-1} + v_t \qquad \textbf{(B5)}$$

Equations **(B6)** to **(B9)** present the long-run model solution, which coincides with perfectly flexible prices and rational expectations holding. Equation **(B6)** shows that relative output is then entirely determined by AS shocks **(B6)** ¾ a vertical long-run supply curve, which gives us two of three required theory-based identification restrictions.(49) The absence of LM shocks from **(B6)** represents money neutrality.

---

(47) Demand switches towards home goods as they become more competitive.

(48) Reflecting the effect on interest-sensitive aggregate demand components such as investment.

(49) The $C_{12}(1) = C_{13}(1) = 0$ restrictions outlined in Appendix A.

$y^*_t = y^s_t$ **(B6)**

$q^*_t = (y^s_t - d_t)/\eta + (\eta(\eta + \sigma))^{-1}\sigma\gamma\delta_t$ **(B7)**

$p^*_t = -y^s_t + \lambda(1+\lambda)^{-1}(\eta+\sigma)^{-1}\gamma\delta_t + m_t$ **(B8)**

$s^*_t = y^s_t(1-\eta)\eta^{-1} - d_t\eta^{-1} + [\eta(\eta+\sigma))^{-1}\sigma + \lambda(1+\lambda)^{-1}(\eta+\sigma)^{-1}]\gamma\delta_t + m_t$ **(B9)**

The long-run real exchange rate expression **(B7)** is obtained by substituting the stochastic processes for AS and IS shocks into the IS equation and solving for q^*_t. This shows that positive AS (IS) shocks produce long-run real exchange rate depreciations (appreciations). Importantly, only the permanent component of IS shocks have long-run real exchange rate effects. This is represented by the positive γ coefficient in **(B7)** ¾ which captures the effect of the expectation of reversion of the temporary component discussed in Section 2.2. Finally, LM shocks have no long-run real exchange rate effect ¾ the final theory-based identification restriction.(50) We show below that this occurs because LM shocks induce relative price and nominal exchange rate responses that exactly offset each other.

Inverting the LM curve produces the long-run relative price expression **(B8)**. Positive AS shocks reduce relative prices, by shifting the (vertical) AS curve to the right. Positive LM shocks and the temporary component of positive relative IS shocks ($\gamma\delta_t$) both raise relative prices, by shifting the AD curve up the vertical AS curve. The permanent component of IS shocks has no long-run effect on relative prices. Section 2.2 again outlines the intuition of this result.

The long-run nominal exchange rate expression **(B9)** is obtained by summing the real exchange rate **(B7)** and price **(B8)** expressions, and simplifying. This shows that positive LM shocks depreciate the nominal exchange rate in the long run. The responses to IS and AS shocks are, algebraically, indeterminate. But Section 2.2 explains why positive AS (IS) shocks are expected to produce long-run nominal depreciations (appreciations).

Equations **(B10)** to **(B13)** present the short-run ('sticky price') model solution. Here all shocks potentially affect all endogenous variables. The short-run relative prices expression **(B10)**, obtained by substituting **(B8)** into **(B3)**, illustrates that greater price stickiness (decreases in θ) reduces the short-run price effect of each of the shocks below their long-run effects.

$p_t = \theta p^*_t - (1-\theta)(v_t - z_t + \alpha\gamma\delta_t)$ **(B10)**

$q_t = q^*_t + \nu(1-\theta)(v_t - z_t + \alpha\gamma\delta_t)$ **(B11)**

$s_t = y^s_t(1-\eta\theta)\eta^{-1} - d_t\eta^{-1} + ((\nu(1-\theta) - (1-\theta))(v_t - z_t) + \theta m_t$
$\quad + [(\eta(\eta+\sigma))^{-1} + \theta\lambda(1+\lambda)^{-1}(\eta+\sigma)^{-1} - \nu(1-\theta)]\gamma\delta_t$ **(B12)**

$y_t = y^s_t + (\eta+\sigma)\nu(1-\theta)(v_t - z_t + \alpha\gamma\delta_t)$ **(B13)**

(50) The $C_{23}(1) = 0$ restriction outlined in Appendix A.

The short-run real exchange rate expression **(B11)** is obtained by substituting **(B1)** and **(B4)** into **(B2)** and using **(B10)** to represent the difference between actual and market-clearing price levels.[51] The positive coefficient on v_t illustrates the usual result that positive LM shocks depreciate the *real* exchange rate when prices are sticky. The negative coefficient on z_t shows that price stickiness means that the real exchange rate undershoots its long-run appreciation following positive AS shocks. Likewise, the model suggests that the short-run real exchange rate response to IS shocks is less than its long-run equivalent.

Equation **(B12)** represents the short-run nominal exchange rate expression. Clarida and Gali (*op cit*) show that the responsiveness of relative output to the real exchange rate (η) and interest rate differentials (σ) are key in determining whether short-run overshooting occurs. In particular, they show that if $(1-\sigma-\eta) > 0$ then LM (AS, IS) shocks produce overshooting (undershooting).

Finally the short-run relative output expression **(B13)** is obtained by inserting the sticky price real exchange rate expression **(B11)** into **(B1)** and solving for y_t. Relative output is demand determined in the short run, with positive LM shocks (v_t) and the temporary component of positive IS shocks ($\gamma\delta_t$) raising relative output. The negative coefficient on z_t demonstrates that price stickiness reduces the output effect of AS shocks.

(51) Where $\nu = (1+\lambda)(\lambda+\sigma+\eta)^{-1}$

Appendix C ¾ The data

The GDP and consumer price series for all five countries were taken from the IMF *International Financial Statistics* database (lines 99b.r and 64 respectively). Both sets of series are indices set at 100 in 1990. The nominal bilateral exchange rates were taken from a Bank of England database. They are quarterly average spot rates.

Appendix D ¾ Tables and Figures

Table B ¾ ADF tests on levels of variables[(a)]

Country/Variable	Relative output	Real exchange rate	Relative prices
UK-US	-2.2	-2.6	-3.0
UK-Japan	-1.9	-2.5	-1.6
UK-Germany	-2.1	-2.1	-1.6
UK-France	-1.9	-1.8	-2.4

(a) ADF(4) with trend test (95% critical values = -3.5).

Table C ¾ ADF tests on first differences of variables[(a)]

Country/Variable	Relative output	Real exchange rate	Relative prices
UK-US	-5.2	-4.8	-3.9
UK-Japan	-3.1	-4.6	-4.4
UK-Germany	-4.2	-3.2	-4.1
UK-France	-4.2	-4.8	-3.9

(a) ADF(4) without trend test (95% critical values = -2.9).

Table D ¾ Johansen cointegration tests[(a)]

Country	Eigenvalue test[(b)]	Trace test[(c)]
UK-US	7.51	14.78
UK-Japan	19.80	29.22
UK-Germany	13.20	24.54
UK-France	12.63	22.47

(a) Four lags in VAR.
(b) 95% critical value = 21.07.
(c) 95% critical value = 31.52.

Figure 1: 1-Step Ahead Recursive Chow Test (Outlier Test) - UK-US System

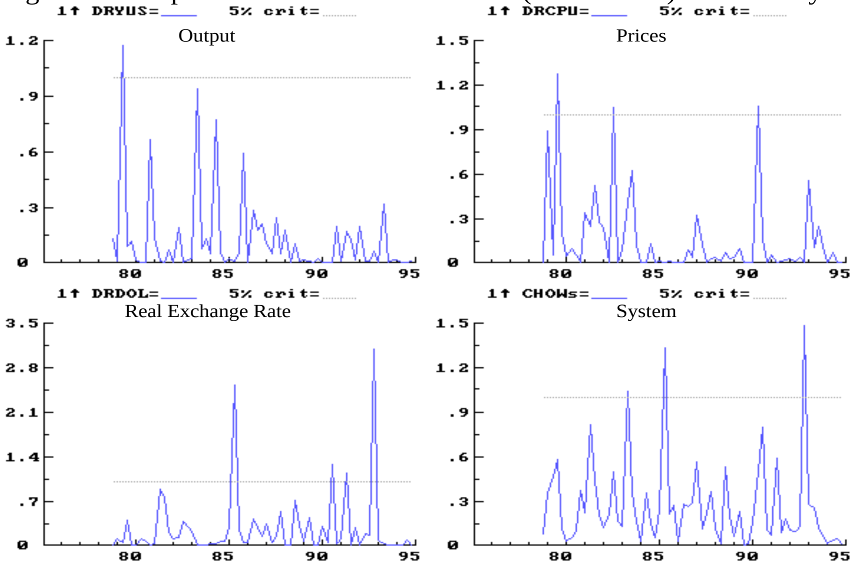


Figure 2: N-Step Recursive Chow Test (Regime Shift Test) - UK-US System

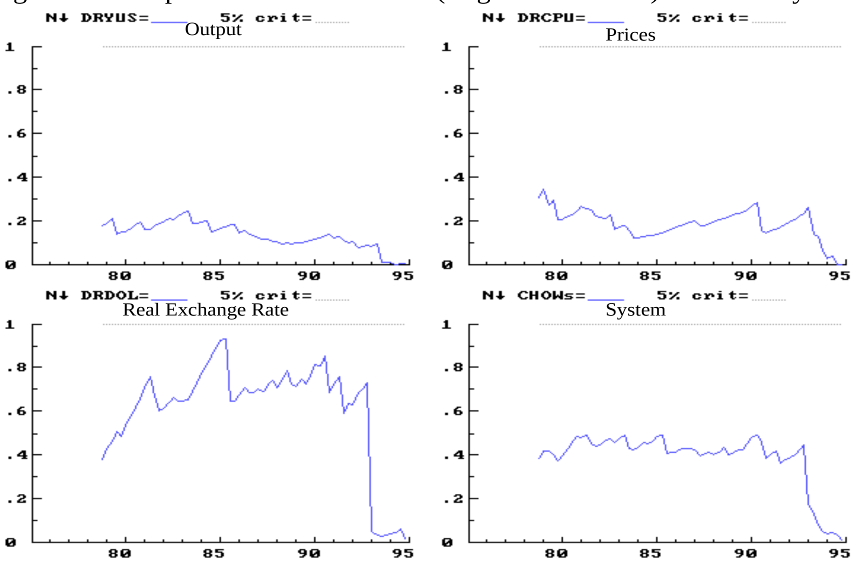


Table E: FEVDs of real exchange rates

	£/$			**£/ù**		
Horizon	AS	IS	LM	AS	IS	LM
1	0.021	0.966	0.014	0.222	0.762	0.016
	0.102	0.143	0.109	0.139	0.145	0.058
2	0.011	0.978	0.011	0.199	0.794	0.007
	0.086	0.122	0.093	0.140	0.144	0.033
4	0.035	0.959	0.005	0.181	0.816	0.003
	0.094	0.113	0.066	0.150	0.152	0.015
8	0.075	0.923	0.002	0.172	0.827	0.001
	0.122	0.129	0.039	0.160	0.161	0.006
12	0.084	0.915	0.002	0.169	0.830	0.001
	0.139	0.142	0.026	0.164	0.164	0.003
16	0.088	0.911	0.001	0.168	0.832	0.001
	0.149	0.150	0.019	0.166	0.166	0.002
20	0.091	0.908	0.001	0.167	0.833	0.000
	0.155	0.156	0.015	0.167	0.167	0.002

	£/DM			**£/FFr**		
Horizon	AS	IS	LM	AS	IS	LM
1	0.093	0.720	0.187	0.217	0.782	0.001
	0.080	0.163	0.145	0.163	0.183	0.074
2	0.112	0.749	0.139	0.200	0.799	0.001
	0.088	0.150	0.116	0.167	0.183	0.062
4	0.136	0.782	0.082	0.244	0.743	0.013
	0.107	0.140	0.073	0.186	0.189	0.050
8	0.157	0.803	0.040	0.249	0.743	0.007
	0.128	0.139	0.035	0.186	0.189	0.026
12	0.167	0.809	0.025	0.252	0.742	0.005
	0.137	0.143	0.021	0.191	0.192	0.018
16	0.171	0.811	0.018	0.252	0.744	0.004
	0.143	0.146	0.014	0.194	0.195	0.014
20	0.174	0.812	0.014	0.252	0.745	0.003
	0.146	0.148	0.011	0.198	0.199	0.011

Key: Top rows detail the fraction of variation in the variable attributable to each shock. Bottom rows give empirical two standard errors, computed by Monte Carlo simulation.

Table F: FEVDs of relative prices

	UK-US			UK-Japan		
Horizon	AS	IS	LM	AS	IS	LM
1	0.123	0.040	0.837	0.288	0.049	0.663
	0.190	0.152	0.207	0.150	0.077	0.156
2	0.053	0.035	0.913	0.276	0.082	0.642
	0.149	0.149	0.186	0.155	0.080	0.151
4	0.024	0.014	0.962	0.263	0.117	0.620
	0.135	0.132	0.172	0.166	0.089	0.154
8	0.008	0.005	0.986	0.255	0.139	0.607
	0.127	0.132	0.170	0.174	0.096	0.160
12	0.005	0.003	0.992	0.252	0.145	0.603
	0.130	0.133	0.174	0.177	0.099	0.163
16	0.003	0.002	0.995	0.251	0.148	0.601
	0.133	0.134	0.176	0.179	0.101	0.165
20	0.003	0.002	0.996	0.250	0.150	0.600
	0.135	0.135	0.178	0.179	0.101	0.166

	UK-Germany			UK-France		
Horizon	AS	IS	LM	AS	IS	LM
1	0.327	0.164	0.509	0.662	0.047	0.292
	0.210	0.171	0.197	0.230	0.126	0.184
2	0.270	0.163	0.567	0.584	0.050	0.366
	0.192	0.165	0.189	0.230	0.121	0.187
4	0.223	0.160	0.617	0.539	0.094	0.367
	0.180	0.164	0.186	0.229	0.133	0.185
8	0.196	0.156	0.648	0.485	0.093	0.422
	0.174	0.164	0.187	0.229	0.130	0.196
12	0.187	0.155	0.658	0.467	0.098	0.435
	0.173	0.164	0.188	0.231	0.134	0.201
16	0.183	0.155	0.662	0.460	0.099	0.441
	0.172	0.164	0.188	0.232	0.136	0.204
20	0.181	0.154	0.665	0.456	0.100	0.444
	0.172	0.164	0.188	0.233	0.137	0.205

Key: Top rows detail the fraction of variation in the variable attributable to each shock. Bottom rows give empirical two standard errors, computed by Monte Carlo simulation.

Table G: FEVDs of nominal exchange rates

	£/$			£/ù		
Horizon	AS	IS	LM	AS	IS	LM
1	0.006	0.911	0.083	0.136	0.756	0.108
	0.088	0.176	0.169	0.108	0.146	0.105
2	0.009	0.903	0.089	0.121	0.794	0.085
	0.097	0.176	0.167	0.112	0.134	0.073
4	0.039	0.879	0.081	0.110	0.823	0.067
	0.118	0.170	0.142	0.118	0.129	0.046
8	0.077	0.818	0.105	0.104	0.838	0.058
	0.147	0.167	0.118	0.124	0.128	0.030
12	0.083	0.791	0.126	0.102	0.842	0.056
	0.158	0.166	0.109	0.126	0.128	0.026
16	0.085	0.775	0.140	0.101	0.845	0.054
	0.164	0.167	0.104	0.127	0.128	0.025
20	0.086	0.764	0.149	0.101	0.846	0.054
	0.169	0.170	0.102	0.127	0.128	0.024

	£/DM			£/FFr		
Horizon	AS	IS	LM	AS	IS	LM
1	0.327	0.613	0.350	0.087	0.905	0.008
	0.208	0.193	0.196	0.132	0.152	0.096
2	0.270	0.618	0.341	0.061	0.911	0.028
	0.188	0.177	0.177	0.120	0.142	0.099
4	0.223	0.629	0.324	0.049	0.852	0.099
	0.170	0.166	0.154	0.124	0.157	0.118
8	0.196	0.645	0.303	0.029	0.868	0.103
	0.160	0.157	0.135	0.117	0.143	0.099
12	0.187	0.654	0.293	0.021	0.863	0.116
	0.157	0.155	0.130	0.116	0.135	0.089
16	0.183	0.658	0.287	0.016	0.861	0.123
	0.155	0.155	0.128	0.119	0.132	0.085
20	0.181	0.661	0.283	0.014	0.859	0.127
	0.155	0.155	0.128	0.122	0.132	0.083

Key: Top rows detail the fraction of variation in the variable attributable to each shock. Bottom rows give empirical two standard errors, computed by Monte Carlo simulation.

Table H: FEVDs of relative output

	UK-US			UK-Japan		
Horizon	AS	IS	LM	AS	IS	LM
1	0.877	0.066	0.057	0.799	0.139	0.062
	0.203	0.107	0.179	0.127	0.106	0.074
2	0.903	0.045	0.053	0.885	0.080	0.035
	0.190	0.097	0.168	0.082	0.067	0.043
4	0.946	0.025	0.029	0.947	0.037	0.016
	0.145	0.064	0.127	0.041	0.033	0.020
8	0.969	0.014	0.017	0.976	0.017	0.007
	0.100	0.040	0.087	0.018	0.015	0.008
12	0.978	0.010	0.012	0.985	0.011	0.005
	0.071	0.028	0.062	0.011	0.009	0.005
16	0.983	0.007	0.009	0.989	0.008	0.003
	0.052	0.021	0.045	0.008	0.007	0.004
20	0.987	0.006	0.007	0.991	0.006	0.003
	0.016	0.016	0.016	0.005	0.005	0.005

	UK-Germany			UK-France		
Horizon	AS	IS	LM	AS	IS	LM
1	0.785	0.056	0.160	0.345	0.002	0.653
	0.180	0.095	0.145	0.199	0.076	0.206
2	0.837	0.037	0.126	0.439	0.001	0.560
	0.147	0.073	0.113	0.199	0.073	0.196
4	0.900	0.021	0.079	0.631	0.002	0.367
	0.100	0.051	0.071	0.164	0.060	0.156
8	0.951	0.010	0.039	0.829	0.010	0.161
	0.052	0.028	0.035	0.089	0.043	0.074
12	0.968	0.007	0.025	0.892	0.006	0.102
	0.033	0.018	0.022	0.055	0.029	0.044
16	0.977	0.005	0.019	0.921	0.004	0.075
	0.023	0.013	0.016	0.039	0.021	0.032
20	0.982	0.004	0.015	0.938	0.003	0.059
	0.010	0.010	0.010	0.016	0.016	0.016

Key: Top rows detail the fraction of variation in the variable attributable to each shock. Bottom rows give empirical two standard errors, computed by Monte Carlo simulation.

Figure 3: UK-US responses

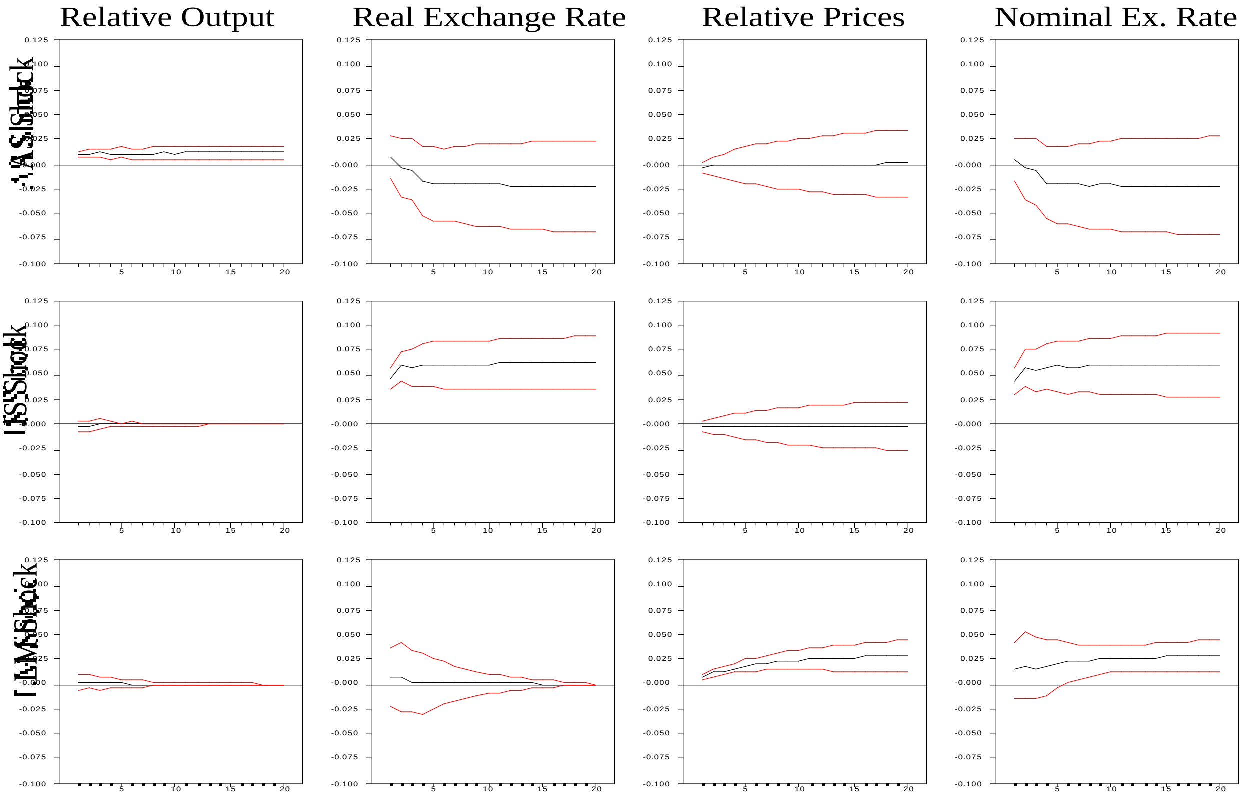


Figure 4: UK-Japanese responses

Figure 5: UK-German responses

Figure 6: UK-French responses

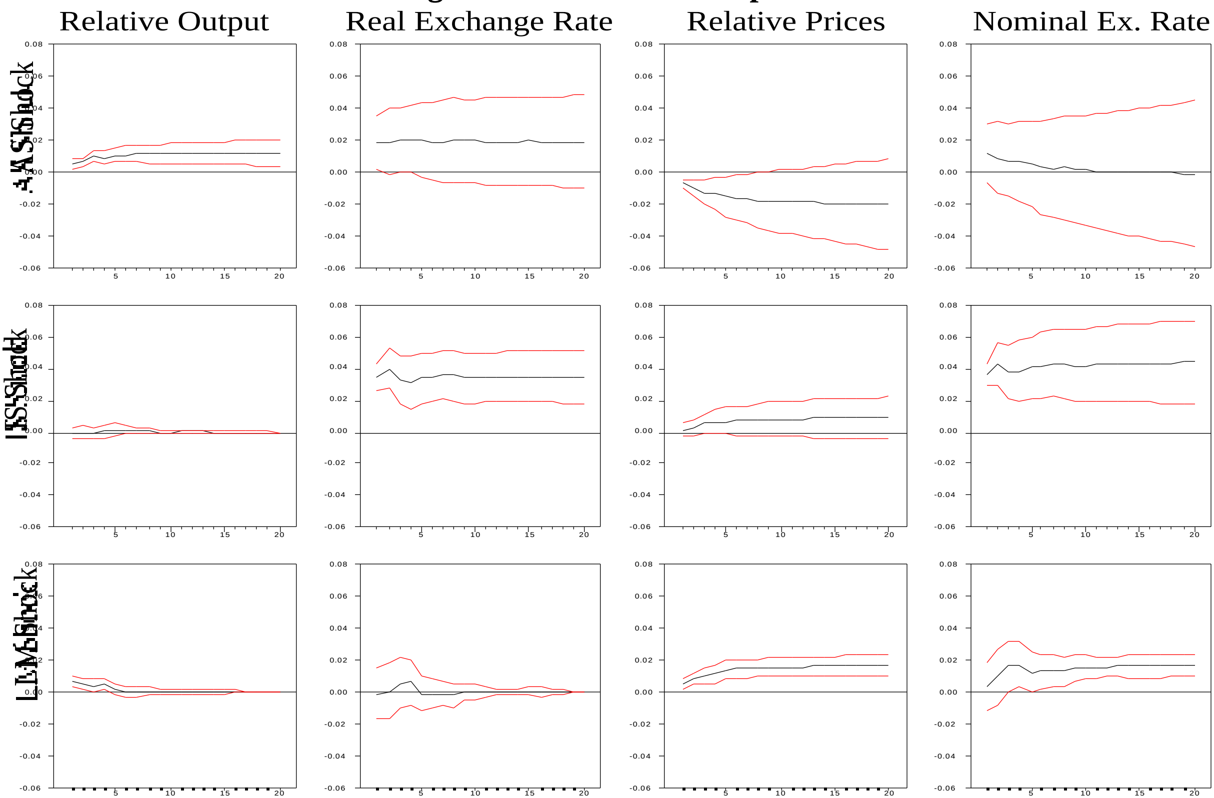


Figure 7: Real exchange rates and relative consumer prices

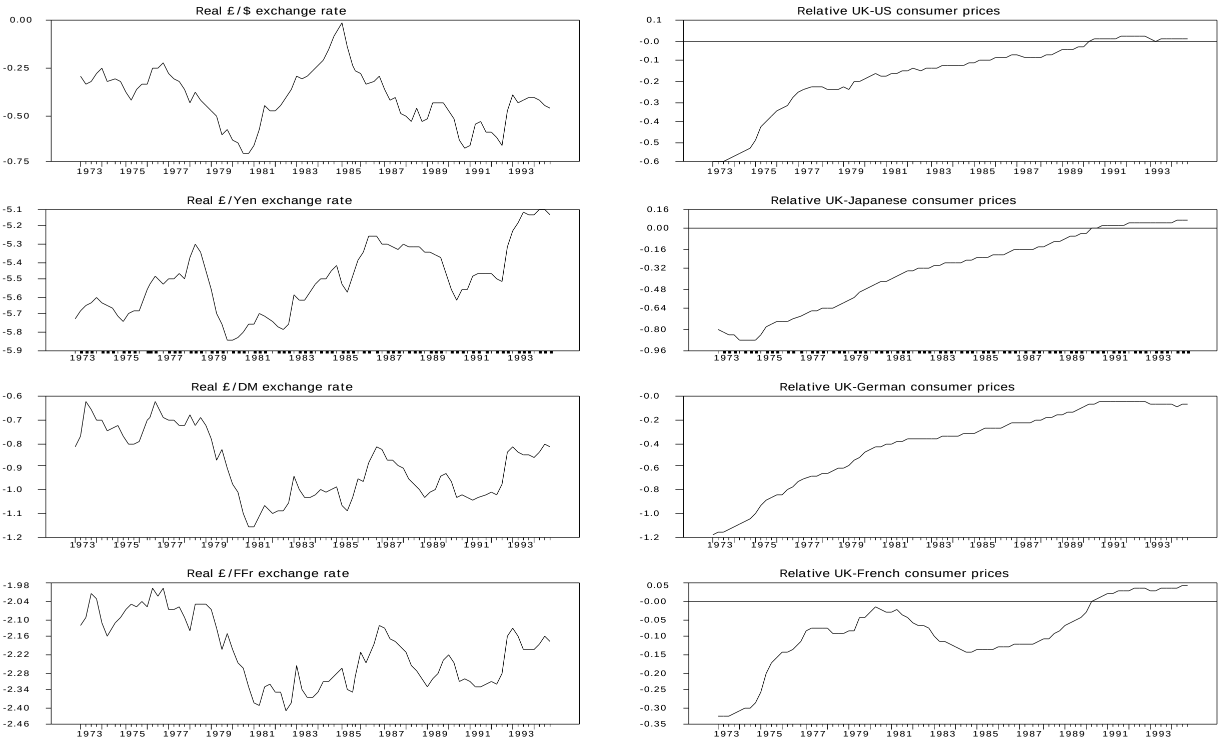


Figure 8: Historical Decomposition £/$ Real Exchange Rate

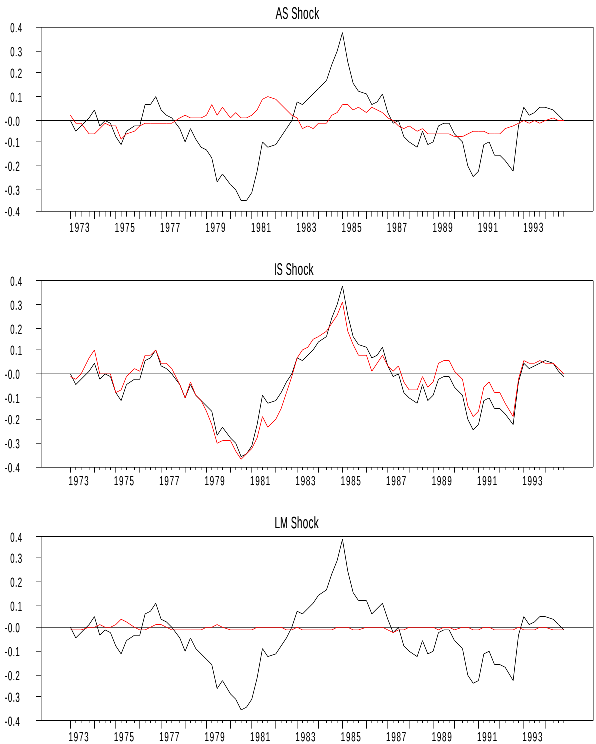


Figure 9: Historical Decomposition £/Yen Real Exchange Rate

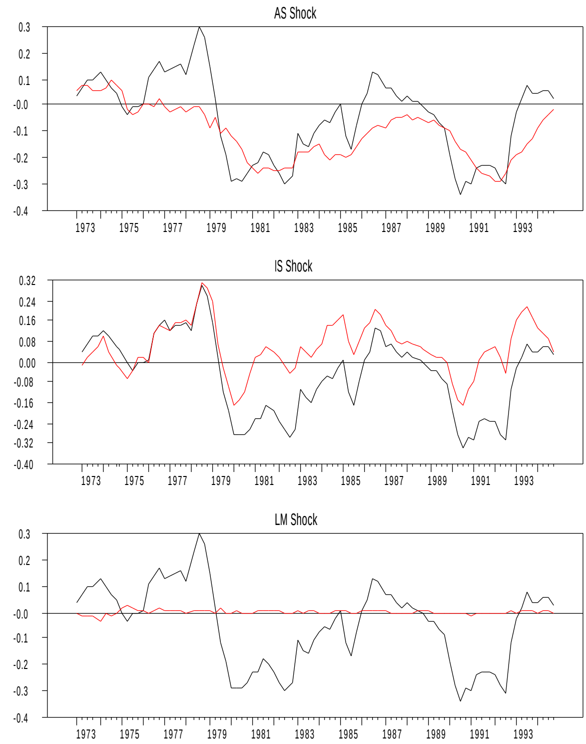


Figure 10: Historical Decomposition £/DM Real Exchange Rate

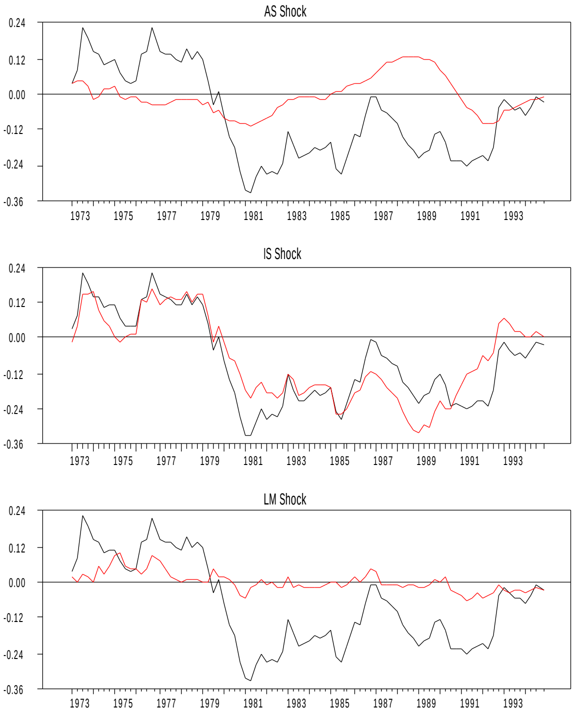


Figure 11: Historical Decomposition £/Fr Real Exchange Rate

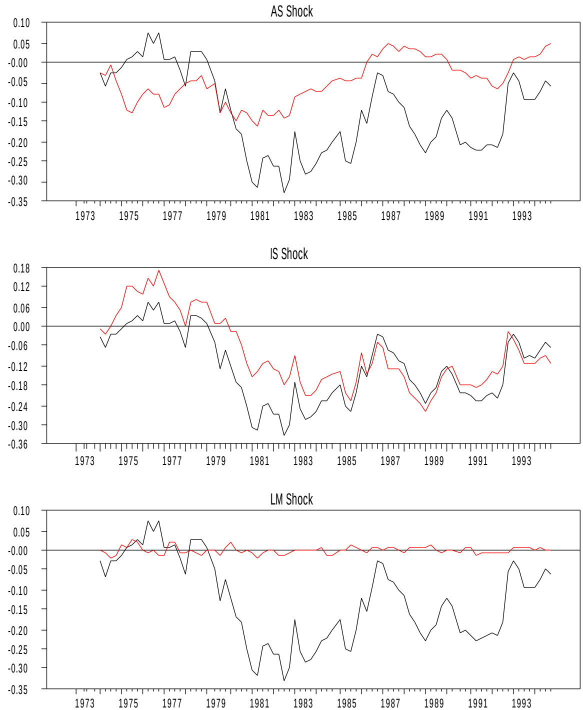


Figure 12: Historical Decomposition of UK-US Prices

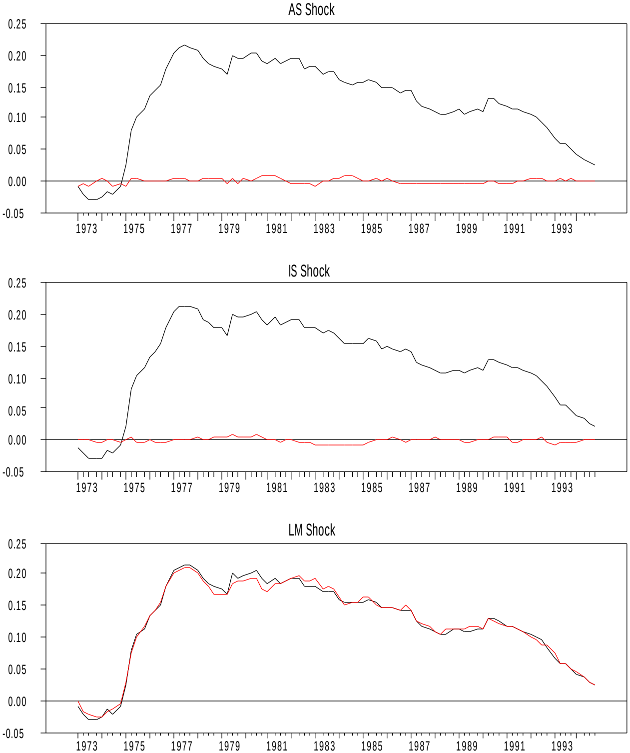


Figure 13: Historical Decomposition of UK-Japanese Prices

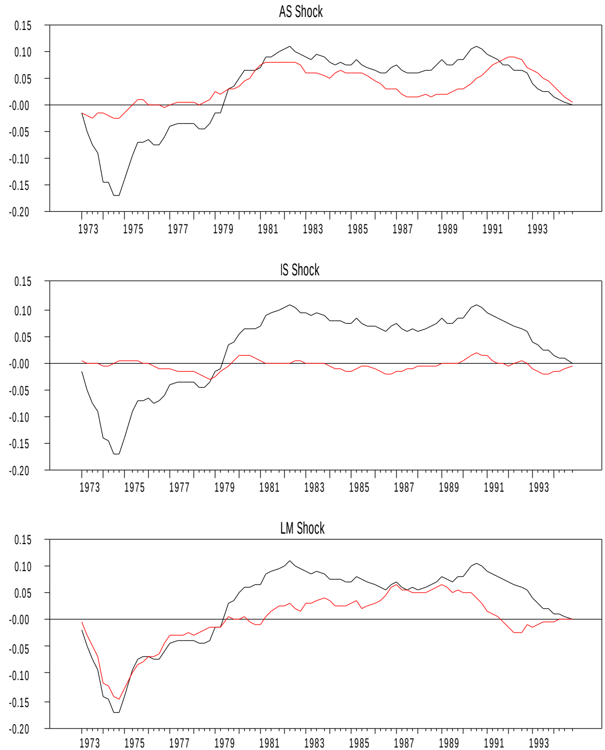


Figure 14: Historical Decomposition of UK-German Prices

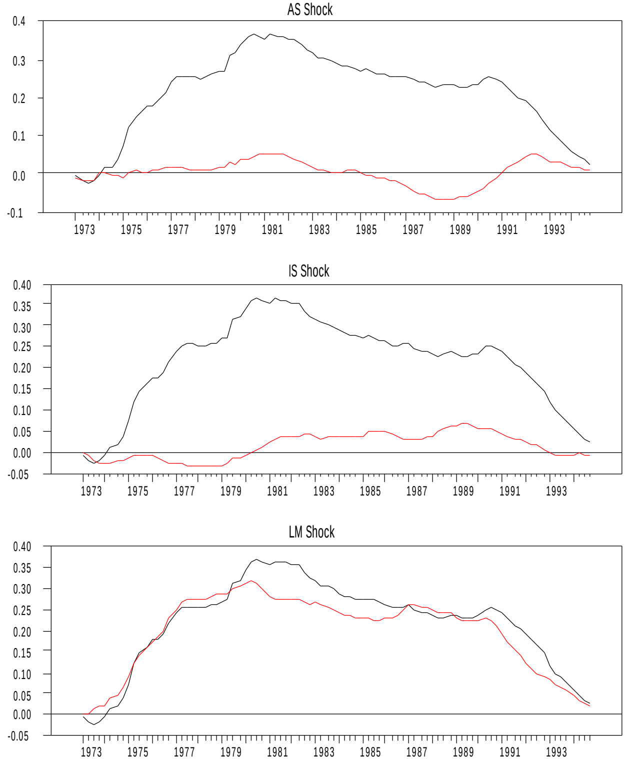


Figure 15: Historical Decomposition of UK-French Prices

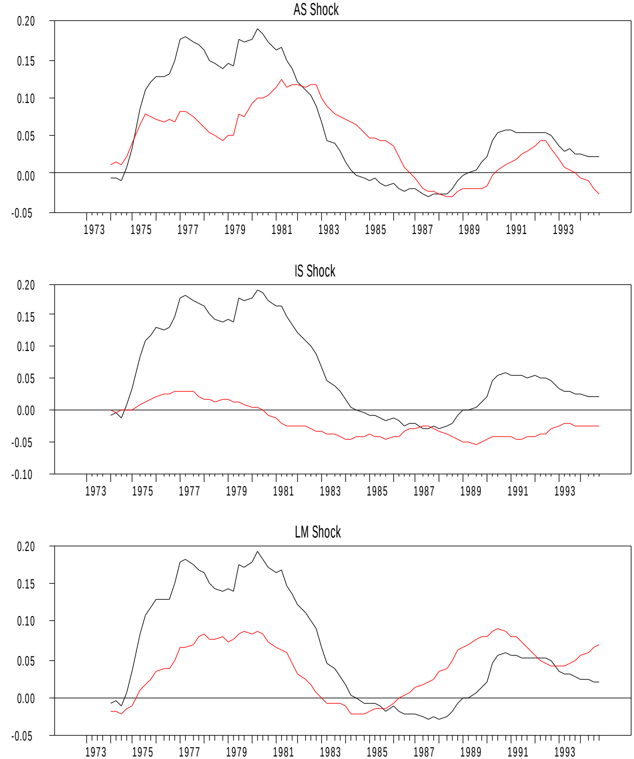


Figure 16: UK-US Rolling FEVDs

Real Exch Rate   Relative Prices

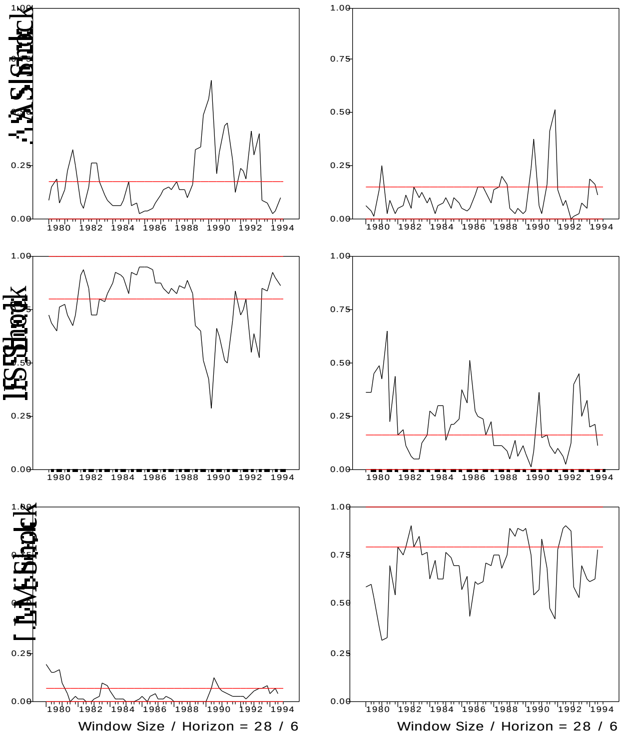


Figure 17: UK-Japanese Rolling FEVDs

Real Exch Rate   Relative Prices

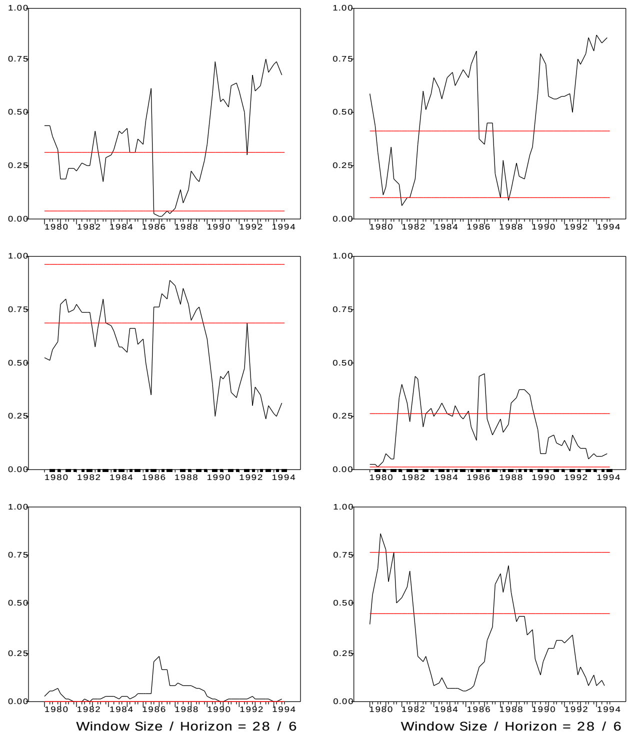


Figure 18: UK-German US Rolling FEVDs

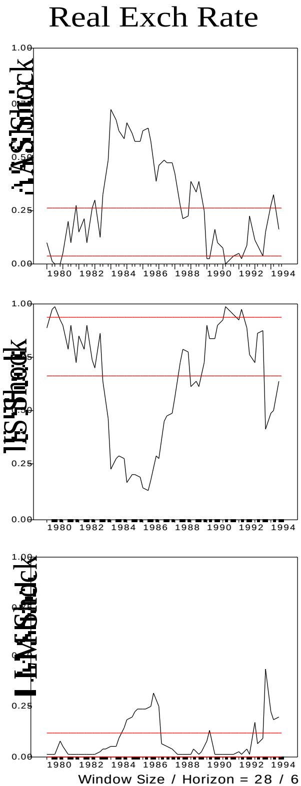


Figure 19: UK-French Rolling FEVDs

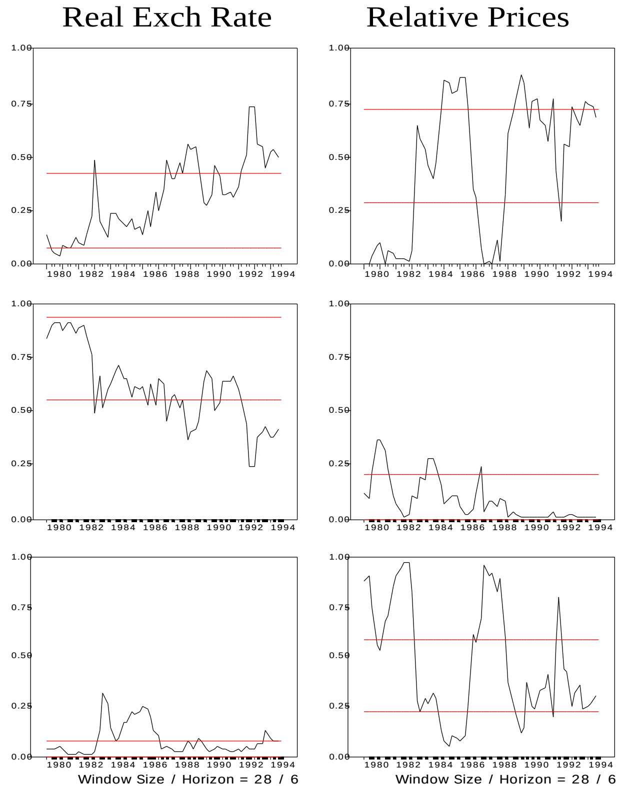


Figure 20: UK-US Structural Shocks

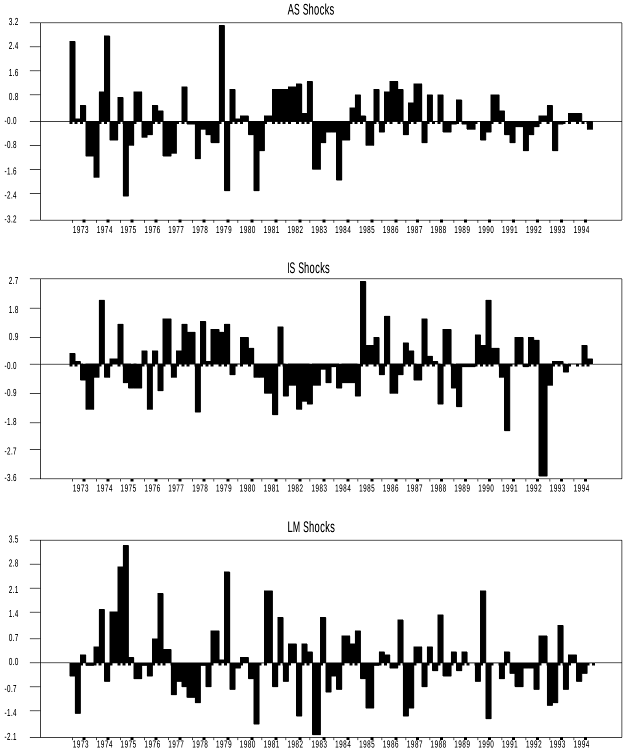


Figure 21: UK-Japanese Structural Shocks

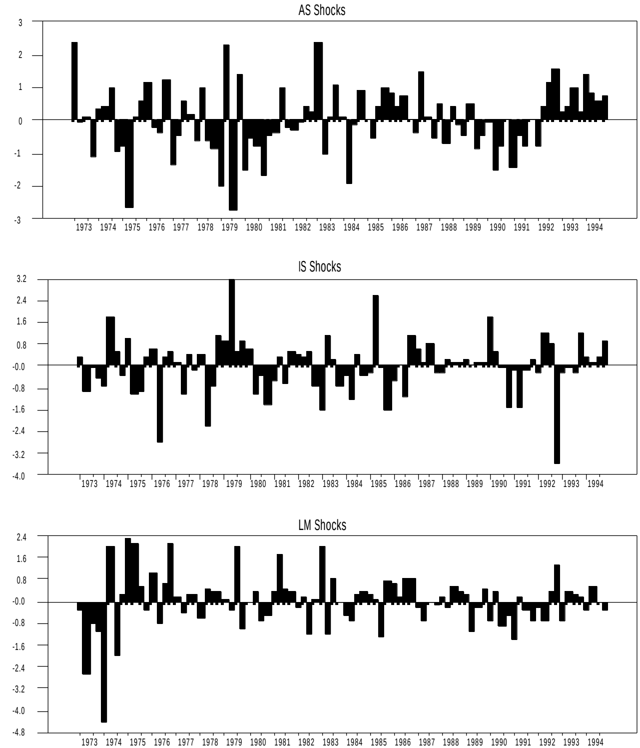


Figure 22: UK-German Structural Shocks

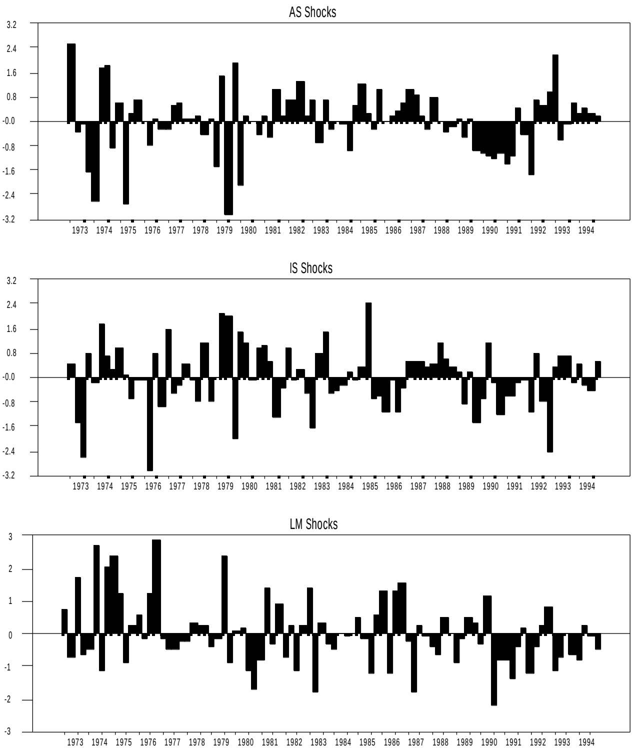


Figure 23: UK-French Structural Shocks

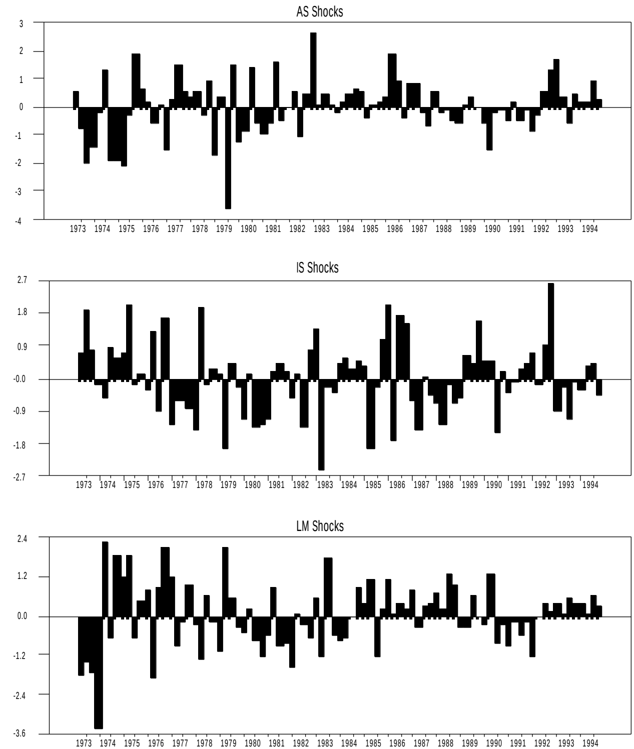
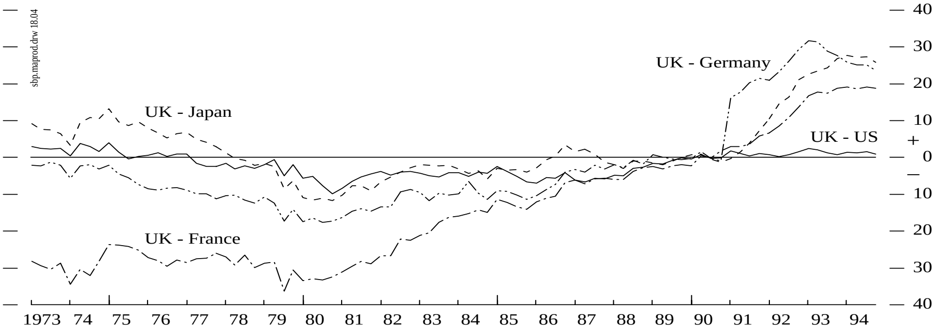
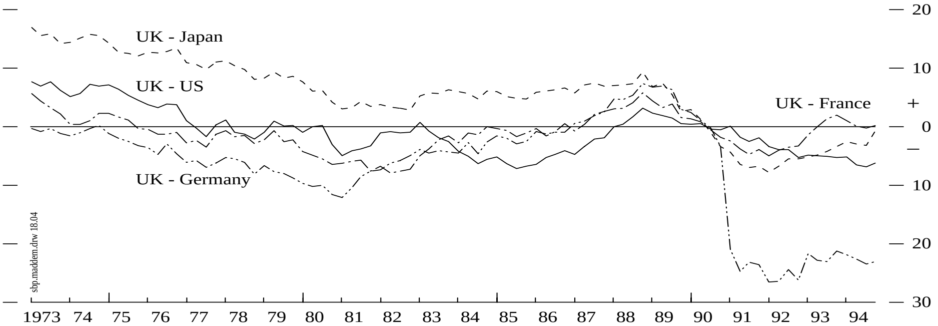


Figure 24: UK - overseas relative productivity developments (a)



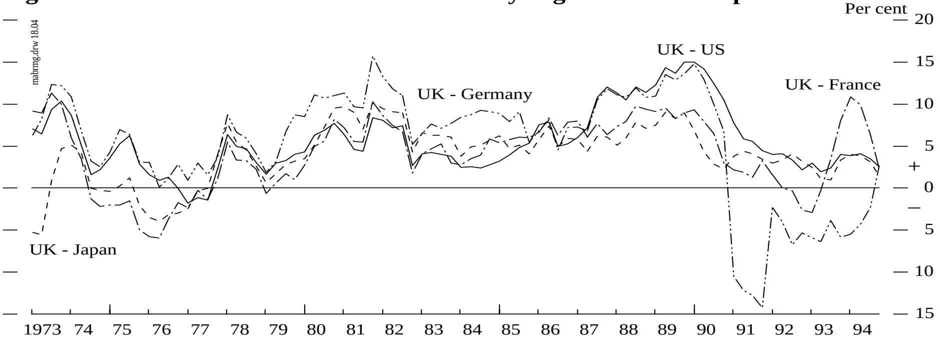
(a) UK minus overseas manufacturing output or industrial production per head of employment in manufacturing. Increases (decreases) represent positive (negative) relative supply shocks.

Figure 25: UK - overseas relative domestic demand developments (a)



(a) UK domestic demand index (1990 = 100) minus overseas equivalent. Increases (decreases) represent positive (negative) relative demand shocks.

Figure 26: UK - overseas relative broad money (a) growth (b) developments



(a) Measures used: UK M4, US M3, Japanese M2 plus CDs, German M3 and French M3.
(b) UK M4 four-quarter growth rate minus overseas equivalent. Increases (decreases) represent positive (negative) nominal shocks.

References

Baldwin, R and Krugman, P (1989), 'Persistent Trade Effects of Large Exchange Rate Shocks', *Quarterly Journal of Economics*, Vol CIV, No 4, November, pages 635-54.

Bank of England (1980), 'The North Sea and the United Kingdom economy: some longer term perspectives and implications', *Quarterly Bulletin*, December, pages 449-54

Bank of England (1982), 'North Sea Oil and Gas ¾ Costs and Benefits', *Quarterly Bulletin*, March, pages 56-73.

Bean, C (1987), 'The Impact of North Sea Oil', In R Dornbusch and R Layard, Eds, *The Performance of the British Economy*.

Bernanke, B (1986), 'Alternative Explanations of the Money-Income Correlation', *Carnegie Rochester Conference Series on Public Policy*, 25(0), Autumn, Pages 49-99.

Blanchard, O and Quah, D (1989), 'The Dynamic Effects of Aggregate Demand and Supply Disturbances', *American Economic Review*, Vol 79, pages 655-73.

Blanchard, O and Quah, D (1993), 'The Dynamic Effects of Aggregate Demand and Supply Disturbances: Reply', *American Economic Review*, Vol 83, pages 653-58.

Bond, M and Knobl, A (1982), 'Some Implications of North Sea Oil for the UK Economy', *IMF Staff Papers*, September, pages 363-97.

Branson, W H (1988), 'Sources of Misalignments in the 1980s', In R Marston, Ed, *Misalignments of Exchange Rates: Effects on Trade and Industry*, NBER.

Clarida, R and Gali, J (1994) 'Sources of Real Exchange Rate Fluctuations: How Important are Nominal Shocks ?', *Carnegie Rochester Conference Series on Public Policy*, 41(0), December, pages 1-56.

Cooley, T and LeRoy, S (1985), 'Atheoretical Macroeconomics: A Critique', *Journal of Monetary Economics*, November, pages 283-308.

De Arcangelis, G (1995), 'Monetary Policy and Exchange Rates in Europe. A Structural VAR Approach', *University of Michigan Research Paper in International Economics Discussion Paper No 384*.

DeSerres, A and Guay, A (1995), 'Selection of the Truncation Lag in Structural VARs (or VECMs) with Long-Run Restrictions', *Bank of Canada Working Paper 95-9*.

Dornbusch, R (1976), 'Expectations and Exchange Rate Dynamics', *Journal of Political Economy*, Vol. 84, pages 1161-176.

Eastwood, R and Venables, A (1982), 'The Macroeconomic Implications of a Natural Resource Discovery in an Open Economy', *Economic Journal*, No 92, pages 285-99.

Eichenbaum, M and Evans, C (1993), 'Some Empirical Evidence on the Effects of Monetary Policy Shocks on Exchange Rates', *NBER Working Paper No 4271*.

Evans, G (1986),'A Test for Speculative Bubbles on the Sterling-Dollar Exchange rate: 1981-84', *American Economic Review,* Vol 76, No 4, pages 621-36.

Evans, M and Lothian, J (1993), 'The Response of Exchange Rates to Permanent and Transitory Shocks under Floating Exchange Rate', *Journal of International Money and Finance*, December, pages 563-86.

Faust, J and Leeper, E (1994), 'When do Long-Run Identifying Restrictions Give Reliable Results?', *International Finance Discussion Paper No 462*, Board of Governors of the Federal reserve System.

Feldstein, M (1986), 'The Budget Deficit and the Dollar', *NBER Macroeconomics Annual*, pages 355-92.

Forsyth, P and Kay, J (1980), 'The Economic Implications of Noth Sea Oil Revenues', *The Journal of the Institute of Fiscal Studies*, Vol 1, No. 3.

Frankel, J (1993), 'Six Possible Meanings of 'Overvaluation': The 1981-85 Dollar", In 'On Exchange Rates', MIT.

Gali, J (1992), 'How Well does the IS-LM Model Fit Postwar US Data?', *Quarterly Journal of Economics*, May, pages 709-38.

Gerlach, S and Smets, F (1995), 'The Monetary Transmission Mechanism: Evidence from the G-7 Countries', *CEPR Discussion Paper No 1219.*

Holland, A and Scott, A (1997), 'The Determinants of UK Business Cycles', *Bank of England Working Paper No 58*.

Hooper, P and Mann, C (1989), 'Exchange Rate Pass-through in the 1980s: The Case of US Imports of Manufactures', *Brookings Papers on Economic Activity*, No. 1, pages 297-337.

Huizinga, J (1987), 'An Empirical Investigation of the Long Run Behaviour of Real Exchange Rates', *Carnegie-Rochester Conference Series on Public Policy,* 27, pages 149-215.

Keating, J (1992), 'Structural Approaches to Vector Autoregressions', *Federal Bank of St Louis Review*, 74, September/October, pages 37-57.

King, R, Plosser, C, Stock, J and Watson, M (1991), 'Stochastic Trends and Economic Fluctuations', *American Economic Review*, Vol 81, September, pages 819-40.

Krugman, P (1987), 'Pricing to Market When The Exchange Rate Changes', In S Arndt and J Richardson (eds), *Real -Financial Linkages Among Open Economies*, Pages 49-70.

Krugman, P (1989), 'Exchange Rate Instability', *MIT Press*, Cambridge.

Lastrapes, W (1992), 'Sources of Fluctuations in Real and Nominal Exchange Rates', *Review of Economics and Statistics*, pages 530-39.

Lippi, M and Reichlin, L (1993), 'The Dynamic Effects of Aggregate Demand and Aggregate Supply Disturbances: Comment', *American Economic Review*, Vol 84, pages 644-52.

Lucas, R (1976), 'Econometric Policy Evaluation: A Critique', *Journal of Monetary Economics*, 1(2), Supplement, Pages 19-46.

Mann, C (1987), 'After the Fall: The Declining Dollar and Import Prices', *Federal Reserve Board*.

Mann, C (1989), 'The Effects of Exchange Rate Trends and Volatility on Export Prices: Industry Examples from Japan, Germany and the United States', *Weltwirtschaftliches Archiv*, 125, Pages 588-618.

Meese, R and Rogoff, K (1988), 'Was it Real? The Exchange Rate Interest Rate Differential Relation Over the Modern Floating Rate Period', *Journal of International Finance*, 43, pages 933-48

Mussa, M (1982), 'A Model of Exchange Rates Dynamics', *Journal of Political Economy*, No 90, pages 74-104.

Mussa, M (1986), 'Nominal Exchange Rate Regimes and the Behaviour of Real Exchange Rates: Evidence and Implications', *Carnegie Rochester Conference Series on Public Policy*, No 26, pages 117-213.

Neary, P (1988), 'Determinants of the Equilibrium Real Exchange Rate', *American Economic Review*, Vol 78, No 1, Pages 210-15.

Obstfeld, M (1985), 'Floating Exchange Rates: Experience and Prospects', *Brookings papers on Economic Activity*, No 2, pages 369-450.

Rogers, J (1995), 'Real Shocks and Real Exchange Rates in Really Long-term Data', *Board of the Federal reserve System, International Finance Discussion Paper No 493.*

Roll, R (1979), 'Violations of Purchasing Power Parity and their Implications for Efficient International Commodity Markets', In *International Finance and Trade*, Vol 1, ed by Sarnat, M and Szego, G.

Roubini, N and Kim, S (1995), 'Liquidity and Exchange Rates; A Structural VAR Approach', *paper presented at CEPR Workshop on Monetary Policy and Exchange Rates in Europe*, Bonn 10/11 February 1995.

Rudebusch, G (1996), 'Do Measures of Monetary Policy In a VAR Make Sense?', *Mimeo*, Federal Reserve Bank of San Francisco, January.

Runkle, D (1987), 'Vector Auto-Regressions and Reality', *Journal of Business and Economic Statistics*, No 5, pages 437-54.

Sims, C (1980), 'Macroeconomics and Reality', *Econometrica*, Vol 48, No 1, pages 1-48.

Sarantis, N (1994), 'Modelling Sterling Exchange Rates and Interest Rate Differentials', *Kingston University Economics Discussion Paper 94/2*, July.

Stockman, A (1987), 'The Equilibrium Approach to Exchange Rates', *Federal Reserve Bank of Richmond Economic Review*, March/April.

Stockman, A (1988), 'Real Exchange Rate Variability Under Pegged and Floating Exchange Rate Systems: An Equilibrium Theory', *NBER Working Paper No. 2565*.