Looking for contagion: Evidence from the 1992 ERM crisis

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1. Introduction

In a precursor to the paper written for this conference Forbes and Rigobon ([5]) show that standard measures of cross-market correlations are conditional on market movements over the estimation period: thus, during a period of turmoil , when the volatility of asset prices increases, such measures are upward biased [1]. When one recognizes this point, there remains little evidence of "contagion", that is of a change in the way shocks are transmitted across countries, during crisis periods. In fact in the paper written for this conference Forbes and Rigobon ([6]) conclude that "strong cross-market linkages do not change during crisis periods, so that high levels of co-movements across markets indicate 'interdependence', rather than 'contagion'.

This paper studies the ERM crisis that lead to the devaluations of September 1992. We show that when one recognizes the point made above, and appropriately distinguishes between interdendence and contagion, there remains evidence of

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[1] This observation is reminiscent of the early work on the effects of dollar fluctuations on the correlation between the Deutschemark and other ERM currencies. Such work failed to realise that the simple correlation between the dollar/DM exchange rate and the exchange rate between the DM and, say, the lira, is positive by construction. For a discussion see Giavazzi and Giovannini,([7]) .

contagion in the spreads between short-term interest rates in Germany and in a some of the European countries involved in the crisis.

We define contagion as a change in the way shocks are transmitted across countries that is not caused by a change in fundamentals, but rather by some specific "disease", that is a shock of unusual magnitude. In the episode we study the shock of unusual magnitude is the result of the June 1992 referendum in which Danish voters rejected the Maastricht Treaty. This was a country-specific shock–a clear change in the commitment of Denmark to join the monetary union, and thus, implicitely, in its committment to the fixed exchange rate parity –with global implications for the ERM. However it did not imply, at least for a few months, until the ERM broke up, a change in the monetary policy regime. We can thus model the interdependence among European interest rates using data prior to the June referendum, and then study the effects of the unusually large shock assuming that this took place in the same regime. (Note that we would not be able do this after the September devaluations: in that case the shock is accompanied by a change in policy regime, and thus, presumably, in 'interdependence, that is in the way shocks are transmitted across countries.)

Our analysis of contagion and interdependence proceeds in three stages. We start by estimating a model that describes the interdependence among short term interest rates among European countries. As shown below, this first step expands on the intuition in Rigobon([12]),who correctly points out that an endogeneity problem must be solved before assessing the importance of contagion in the international propagation of shocks. We use data on the 3-month interest rates spreads between Germany and six European countries: France, Italy, Spain, Denmark, Holland and Sweden. We add Sweden to our sample because, although not an ERM member, Sweden was shadowing the DM, until it eventually devalued at the time of the ERM break-up. We exclude instead the UK. The pound joined ERM only at the end of 1991: thus there was a change in regime right in the middle of the sample we use to estimate interdependence–and data following the UK entry into the ERM are too few to allow us to estimate the model of interdependence. Given the short-term nature of the phenomenon we investigate, we use weekly data. In our specification, the simultaneous model that describes the interdependence among short term European spreads includes, in the information set, only contemporaneous and lagged values of such spreads (we evaluate the potential effect of omitted variables running diagnostic tests on our specification.) We estimate the model on a sample running from January1988 to May 1992. The sample ends the week before the Danish referendum; it starts in January1988 because this is as far back as the data on Euro-rates allow us to extend it. Since the last ERM realignment occurred in January 1987, there is no realignment episode in our sample.

To estimate the model of interdependence we first specify a VAR as the statistical model for the joint process generating short-term interest rates spreads in our sample. The estimation of the reduced form allows a direct evaluation of the congruency (see Hendry ([8])) of the adopted statitistical model and of the goodness of fit of the exogenous variables to be used as instruments in the estimation of simulataneous feedback in the structural model. Next we estimate a simultaneous structural model for European interest rates. We construct our estimates of interdependence by analysing the simultaneous feedbacks among spreads, and the structure of the variance-covariance matrix of the residuals. The model is identified allowing for simultaneous feedbacks among all rates, but constraining the dynamics of each spread to depend only on its own lags. The validity of these just-identifying restrictions is supported by the statistical analysis of our reduced form. We then derive our final specification by restricting to zero those coefficients that are not statistically different form zero.

Next we test for the presence of contagion in the period from June to September 1992. We analyse contagion by simulating (statically) our structural model starting the week immediately following the Danish referendum. We then compare the residuals thus generated with those estimated in the sample prior to June 1992. We conclude that there is evidence of contagion whenever we observe that the variance of the simulated residuals is significantly larger than that of the estimated residuals.

We conclude by observing that our results are relevant for the ongoing debate between theories in which the propagation of shocks is "crisis contingent"–that is determined by endogenous liquidity shortages, multiple equilibria, or political contagion–and theories which relate the propagation of shocks to trade, learning, or aggregate shocks, leaving no special role to crisis.

2. Contagion and interdependence in the ERM

Our definition of contagion hinges crucially on the identification of shocks: a structural model of interdependence is thus the necessary pre-requisite to identify contagion. In modelling interdependence we must recognize the implication, for the behaviour of short-term interest rates, of the constraints imposed on the countries in our sample by membership in the ERM. We deal with these problems in three steps. Consider, for simplicity, an ERM consisting of only three countries: country 1 represents Germany, the core of the ERM; countries 2 and 3 two other members of the system. Their short-tem interest rates are $R_1, R_2$and R_3. If the exchange rate arrangement is credible we should observe a single (common) stochastic trend driving all three rates. The interest rate spreads of countries 2 and 3 on country 1 should thus be stationary and fastly mean reverting–since short-term fluctuations around the mean are possible only within the limits imposed by the upper and lower bands on exchange rates. We model interdependence by considering the following specification for interest rates spreads $s_1 = R_2 - R_1$ and $s_2 = R_3 - R_1$:

$$\begin{aligned} s_{1,t} &= b_{12}s_{2,t} + a_{11}s_{1,t-1} + u_{1t} \\ s_{2,t} &= a_{22}s_{1,t-1} + u_{2t} \\ \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \mid I_{t-1} &\sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{pmatrix}\right] \end{aligned}$$

where short-term interdependence is measured by the b_{12} parameter. For the sake of simplicity we allow only simulataneous feedback from $s_{2,t}$ to $s_{1,t}$, and we assume that u_{1t} and u_{2t} are orthogonal, but the results that follow can be extended to the more general case.

In order to test for contagion, we first need to define the shock that is supposed to induce it. Consistently with our definition above, we assume that the crisis is a particularly large shock to one of the equations[2]. Let us assume that u_{2t} is replaced by $u_{2t} + \varepsilon_{2t}$, where ε_{2t} is an additional shock, orthogonal to both u_{1t} and u_{2t}

$$\begin{aligned} s_{1,t} &= b_{12}s_{2,t} + a_{11}s_{1,t-1} + u_{1t} + c_1\left(u_{2t} + \varepsilon_{2t}\right) \\ s_{2,t} &= a_{22}s_{1,t-1} + u_{2t} + \varepsilon_{2t} \end{aligned}$$

We describe contagion, *i.e.* the transmission of the shock $(u_{2t} + \varepsilon_{2t})$ to country 1, allowing for the possibility that it affects the interest rate spread in the other

[2]This definition is consistent with the one proposed by Rigobon([12]) whose analysis isbased on the assumption that during crises the variance of disturbances is likely to increase.

country beyond the simultaneity that exists in normal times. This is the role of the coefficients c_1.

Within our specification it is easy to check that a change in the correlation between asset prices–or short term spreads in our example) is not sufficient to indicate the presence of contagion. As shown by Rigobon([12]) and by Forbes and Rigobon([5]), the correlation (conditional and unconditional) between variables is the wrong approach to assess the relevance of contagion. To see this, define

$$\rho = \frac{Cov\left(s_{1,t}, s_{2,t} \mid I_{t-1}\right)}{\sqrt[2]{Var\left(s_{1,t} \mid I_{t-1}\right) Var\left(s_{2,t} \mid I_{t-1}\right)}}$$

the correlation between interest rates spreads in countries 1 and 2. Next compute ρ^d, and ρ^{nd}, the correlations in the presence and in the absence of the special shock ε_{2t}, respectively. Note that following the large shock the correlations are always greater than in the absence of such a shock, *independently* of the existence of contagion. Computing $\rho^d$and ρ^{nd} it is easy to check that $\rho^d > \rho^{nd}$independently of c_1 :

$$\begin{aligned}
\rho^d &= \frac{\left(b_{12}+c_1\right)\left(\sigma_2^2+\sigma_\varepsilon^2\right)}{\sqrt[2]{\left(\sigma_2^2+\sigma_\varepsilon^2\right)\left[\left(b_{12}+c_1\right)^2\left(\sigma_2^2+\sigma_\varepsilon^2\right)+\sigma_1^2\right]}} \\
&= \frac{1}{\sqrt[2]{1+\frac{\sigma_1^2}{\left(b_{12}+c_1\right)^2\left(\sigma_2^2+\sigma_\varepsilon^2\right)}}}
\end{aligned}$$

$$\begin{aligned}
\rho_i^{nd} &= \frac{\left(b_{12}+c_1\right)\sigma_2^2}{\sqrt[2]{\sigma_2^2\left[\left(b_{12}+c_1\right)^2\sigma_2^2+\sigma_1^2\right]}} \\
&= \frac{1}{\sqrt[2]{1+\frac{\sigma_1^2}{\left(b_{12}+c_1\right)^2\sigma_2^2}}}
\end{aligned}$$

On the basis of this result, we proceed to test for contagionon after having explicitly modelled interdependence.

2.1. The statistical model: a reduced form for ERM spreads

We start our investigation by specifying a reduced form VAR which describes the joint distribution of European interest rates spreads. The source for the data (weekly observations on 3-months Euro rates) is Datastream. We consider the six spreads on German rates respectively for Holland, France, Italy, Spain, Denmark and Sweden. The observations for the levels of euro-interest rates and their spreads on the German rates are shownin Figure 1 and Figure 2, respectively.

Insert Figures 1 and 2

A first glance at the data suggests the existence of a common stochastich trend only between the German and Dutch short-term interest rates; all the other spreads show a remarkable degree of persistence. This visual impression is confirmed by the results of the estimation of our baseline model, a first-order VAR for interest rates spreads, whose results are reported in Table 1.

Table 1: A reduced form model of European interest rate spreads

Sample: July 1988-May 1992. Estimation by OLS.

Dep. Var.	Constant	s_{t-1}^{NL}	s_{t-1}^{FR}	s_{t-1}^{IT}	s_{t-1}^{ES}	s_{t-1}^{DK}	s_{t-1}^{SW}
s_t^{NL}	-0.04 (0.043)	0.64 (0.059)	0.024 (0.029)	0.021 (0.014)	-0.0014 (0.01)	0.013 (0.016)	-0.01 (0.01)
s_t^{FR}	-0.19 (0.082)	-0.197 (0.08)	0.94 (0.04)	0.033 (0.019)	0.0027 (0.015)	0.038 (0.022)	-0.014 (0.014)
s_t^{IT}	0.13 (0.11)	0.001 (0.15)	0.13 (0.074)	0.91 (0.035)	0.003 (0.028)	-0.064 (0.04)	0.017 (0.026)
s_t^{ES}	0.056 (0.083)	-0.19 (0.11)	0.09 (0.05)	0.03 (0.02)	0.94 (0.02)	-0.005 (0.03)	0.006 (0.019)
s_t^{DK}	-0.04 (0.007)	-0.14 (0.10)	0.042 (0.05)	-0.005 (0.02)	0.027 (0.02)	0.95 (0.028)	-0.02 (0.018)
s_t^{SW}	0.20 (0.10)	-0.10 (0.14)	0.20 (0.07)	-0.06 (0.03)	0.025 (0.026)	-0.013 (0.038)	0.89 (0.024)

Testing for vector autocorrelation (lags 1 to 7) $\chi^2(252) = 273.32$ [0.1701]

Testing for vector heteroscedasticity $\chi^2(441) = 455.27$ [0.31]

Standard deviations and correlation matrix of residuals:

	σ	s_t^{DL}	s_t^{FR}	s_t^{IT}	s_t^{ES}	s_t^{DK}	s_t^{SW}
s_t^{NL}	0.12	1.00	0.36	0.28	0.35	0.51	0.16
s_t^{FR}	0.16	0.36	1.00	0.28	0.42	0.46	0.16
s_t^{IT}	0.29	0.28	0.28	1.00	0.23	0.19	0.14
s_t^{ES}	0.21	0.35	0.42	0.23	1.00	0.40	0.26
s_t^{DK}	0.20	0.51	0.46	0.19	0.40	1.00	0.17
s_t^{SW}	0.28	0.16	0.16	0.14	0.26	0.17	1.00

We have included in the VAR eight dummies to eliminate a corresponding number of outliers–have defined as residuals with an absolute value three times larger than the estimated standard deviation.) After the inclusion of these dummies[3], the VAR features rather well behaved residuals, reported in Figure 3, with no apparent evidence of correlation and very little evidence of heteroscedasticy despite some evidence of a (moderate) non-normality of the residuals. It is interesting to note that, with the exception of Holland, all spreads show a very high degree of persistence. Moreover, with no exception, the coefficient on the lagged dependent variable is the only significant coefficient in the lag structure.

We study the equilibrium properties of the data applying the Johansen([9]) procedure. We find evidence in favour for the stationarity of the spread only for Holland [4]–a result which suggests a low credibility of the ERM over our sample period. We shall return to this point when interpreting the estimates of our structural model. On the basis of the evidence form these reduced form we proceed to the specification of a structural model for the levels of interest rate spreads. We do so by allowing for the existence of equilibrium relationships, but without imposing any specific restrictions on its parameters. In doing this we run a risk of a loss in efficiency in the estimation but we rule out any loss in consistency due to the incorrenct specification of the long-run structure of our statistical model(see Sims,Stock and Watson ([13]))

2.2. Modelling interdependence: a simultaneous model for ERM spreads

To model interdependence we move from our reduced form to a structural simultaneous model for the determination of interest rates spreads. We achieve identification by restricting the lag structure of the model. Our initial identifying assumption is that only lagged values of the dependent variable are allowed to enter each equation, while we allow for all possible simultaneous feedbacks. The validity of this set of just-identifying restrictions–which suggest to use the lagged values of each variables as instruments for the contemporaneous values– is supported by the evidence from our reduced form. We then move from a

[3] We have included the following eight dummies: dum8843, dum8852, dum8926, dum8946, dum8947, dum9043, dum9045 dum9149, dum9009. Where dummy dumyyww takes a value 1 in the week ww of the year yy and 0 otherwise.

[4] Acoording to both the trace and the maximum eigenvalue tests, the rank of the long-run matrix is one, and the restrictions that only theDutch spread belongs to the equilibrium relationship is not rejected. However, some care in interpreting these results must be exercised in the light of the presence of dummies,and of the results reported in Johansen([10]).

just-identified structure to an over-identified model by restricting to zero all the contemporaneous effects that are not significantly different from zero. Estimates of our structural model of interdependence are reported in Table 2.

Table 2: Interdependence among European interest rate spreads							
Sample: July 1988-May 1992. Estimation by FIML.							
Dep. Var	Lagged Dep.Var	Interdependence					
		s_t^{NL}	s_t^{FR}	s_t^{IT}	s_t^{ES}	s_t^{DK}	s_t^{SW}
s_t^{NL}	0.74 (0.045)			0.023 (0.007)			
s_t^{FR}	0.90 (0.003)			0.033 (0.014)		0.035 (0.016)	
s_t^{IT}	0.92 (0.029)		0.082 (0.043)				
s_t^{ES}	0.95 (0.015)		0.098 (0.029)				
s_t^{DK}	0.94 (0.022)				0.023 (0.011)		
s_t^{SW}	0.91 (0.02)		0.105 (0.029)				
Test of over-identifying restrictions: $\chi^2_{69} = 51.41$ [0.94]							

Standard deviations and correlation matrix of residuals							
	σ	s_t^{DL}	s_t^{FR}	s_t^{IT}	s_t^{ES}	s_t^{DK}	s_t^{SW}
s_t^{NL}	0.11	1.00	0.34	0.18	0.33	0.52	0.15
s_t^{FR}	0.15	0.34	1.00	0.14	0.35	0.42	0.11
s_t^{IT}	0.28	0.18	0.14	1.00	0.19	0.16	0.11
s_t^{ES}	0.20	0.33	0.35	0.19	1.00	0.36	0.23
s_t^{DK}	0.19	0.52	0.42	0.16	0.36	1.00	0.15
s_t^{SW}	0.27	0.15	0.11	0.11	0.23	0.15	1.00

Note that all estimates of the parameters that determine interdependence are positive, moreover there is positive correlation among all the structural model residuals. This reinforces the empirical relevance of modelling interdependence before looking for contagion. Having done so, we can now look for contagion.

2.3. Evidence of contagion between June and August 1992

We look for contagion by simulating our structural model starting in the first week of June, 1992, and then comparying the residuals of this simulation with those estimated in the sample prior to June 1992. Our simulation is static, that is we include on the right-hand side the realizations of the lagged variables. We shall conclude that there is evidence of contagion whenever we observe that the variance of the simulated residuals is significantly larger than that of the estimated residuals and that the increase of variance in residual is paired with a structural change in their variance-covariance matrix, attributable to some common unobserved component.

Table 3 shows the moments of structural residuals simulated over the sample June 1992-August 1992. Comparing Table 3 with Table 2 we note that the standard deviation of the Danish residuals almost doubles. In the case of Italy it increases from 0.28 to 0.90, and in case of Sweden from 0.27 to 3.13. This is in contrast with the other countries, where it uniformly declines.

Table 3: Standard deviations of residuals
June 1992-August 1992

	s_t^{DL}	s_t^{FR}	s_t^{IT}	s_t^{ES}	s_t^{DK}	s_t^{SW}
σ	0.089	0.066	0.90	0.11	0.29	3.13

Figures 4 and 5 give a visual impression of the crisis: a big positive residuals occuring in Denmark at the time of the referendum, clearly spreads to Italy and Sweden. The behaviour of the Spanish spread reflects those of Italy and Sweden with one lag. On the contrary, in the French and Dutch data, there is no evidence of a contemporaneous, nor of a lagged reaction. This evidence is reinforced by the correlation matrix of residuals, reported in Table 4

Table 4: Correlation matrix of residuals
June 1992-August 1992

	s_t^{NL}	s_t^{FR}	s_t^{IT}	s_t^{ES}	s_t^{DK}	s_t^{SW}
s_t^{NL}	1.00	0.61	-0.50	-0.19	0.25	-0.32
s_t^{FR}	0.61	1.00	-0.31	-0.21	0.21	-0.36
s_t^{IT}	-0.50	-0.31	1.00	0.89	0.37	0.91
s_t^{ES}	-0.19	-0.21	0.89	1.00	0.36	0.90
s_t^{DK}	0.25	0.21	0.36	0.36	1.00	0.20
s_t^{SW}	-0.32	-0.36	0.91	0.90	0.20	1.00

The evidence reported in Table 4 is interesting in two respects. First, the correlation matrix has changed[5]. Second we observe polarization: the correlations between Italy, Sweden, and Spain remain positive–and larger than in the sample period–while the correlations between each one of these countries and Holland and France become negative. On the other hand, the correlation between the Dutch and French spreads remains positive and increases. This suggest the presence of contagion following the crisis initiated by the Danish referendum, with a positive feedback parameter for Italy, Spain and Sweden and a negative one for France and the Netherlands.

3. Conclusions

The starting point of this paper is that the question whether a crisis produces 'contagion', that is a change in the way in which shocks are transmitted across financial markets, cannot be asked absent a model that describes the interdependence among those markets. This is because simple measures of cross-market correlation increase by construction during crisis periods. This paper builds such a model to analyse the behavior of interest rate spreads between six European countries and Germany during the summer of 1992, following the shock produced by the results of the Danish referendum. In order to detect contagion we estimate our model of interdependence up to the date of the referendum, and then simulate it over the summer months. We then compare the variance of the residuals derived from the estimated and the simulated model. We observe that correlations change between the two periods, thus indicating that our structural model of interdependence breaks down following the Danish shock. We interpret this as evidence of 'contagion' that is of a change in the way shocks are transmitted across financial markets.

This evidence is consistent with a large variety of models that describe alternative mechanisms through which contagion can occurr: multiple equilibria due to expectations shifts, liquidity effects, herd behaviour , foreign investors liquidity problems, macroeconomic similarities, but it is not consistent with models emphasizing trade links and the associated competitive devaluatons as the vectors of contagion. Our results are consistent with the Drazen and Masson([3])

[5] Note that our evidence reinforces the well known point that computing the Value at Risk of a given portfolio using historical correlation could be rather dangerous

model, which emphasizes the perceived change in commitment of national policy makers to fized exchange rates after the results of the Danish referendum. Note that Italy, Spain and Sweden featured the most similar behaviour in the deficit to GDP ratis and in the debt to GDP ratios among the countries in our sample. Moreover the behaviour of long-term interest rates spreads on Germany, analyzed in Favero,Giavazzi, Spaventa([4]) ,show that institutional investors put these three countries in the same category of risk and the tendency to maintain a proper proportion of such category in the portfolio could have triggered a sell-off of their holdings in all of them. On the other hand, our evidence does not support an explanation of contagion based on trade links and competive devaluation (Corsetti et al. ([2])) ,as there is no evidence of stronger links among Italy, Spain and Sweden within the set of countries in our sample.

While mute as to the question of what lied behind this episode of contagion, our findings contradict the view that evidence of contagion is only the result of the application of poor statistical techniques.

References

[1] Buiter, W.H., G. Corsetti and P. Pesenti (1998), "Interpreting the ERM Crisis: Country-Specific and Systemic Issues", Princeton Studies in International Finance, No. 84

[2] Corsetti G., Pesenti P., N.Roubini and C.Till(1998) "Competitive devaluation: a Welfare-Based Approach" available from http://www.stern.nyu.edu/~nroubini/

[3] Drazen, A. and P. Masson (1994), "Credibility of Policies versus Credibility of Policymakers", *Quarterly Journal of Economics*, 109, 735-754

[4] Favero C.A., Giavazzi F. and L. Spaventa(1997) "High yields: The Spread on German Interest Rates", *The Economic Journal ,443, 956-985*

[5] Forbes, K., and R. Rigobon (1998), "No Contagion, only Interdependence: Measuring Stock Market Co-movements", dowloadable form http://web.mit.edu/rigobon/www/

[6] Forbes, K., and R. Rigobon (1999), "Measuring Contagion: Conceptual and Empirical Issues", dowloadable form http://web.mit.edu/rigobon/www

[7] Giavazzi, F. and A. Giovannini (1989), *Limiting Exchange Rate Flexibility: The European Monetary System.* Cambridge, Mass., MIT Press.

[8] Hendry D.F.(1995) *Dynamics Econometrics,* Oxford, Oxford University Press

[9] Johansen, S. (1995) *Likelihood Based Inference on Cointegration in the Vector Autoregressive Model.* Oxford, Oxford University Press

[10] Johansen, S. (1999), "A Bartlett Correction Factor for Tests on the Cointegrating Relationships", downloadable from http://www.iue.it/Personal/Johansen/Welcome.html

[11] Baig, T. and Goldfajn I. (1998), "Financial Market Contagion in the Asian Crisis", IMF working Paper

[12] Rigobon, R. (1999), "On the Measurement of the International Propagation of Shocks", downloadable form http://web.mit.edu/rigobon/www/

[13] Sims C., Stock J. e Watson M.(1990) Inference in Linear Time Series Models with Some Unit Roots *Econometrica*, 58, 1, 113-144

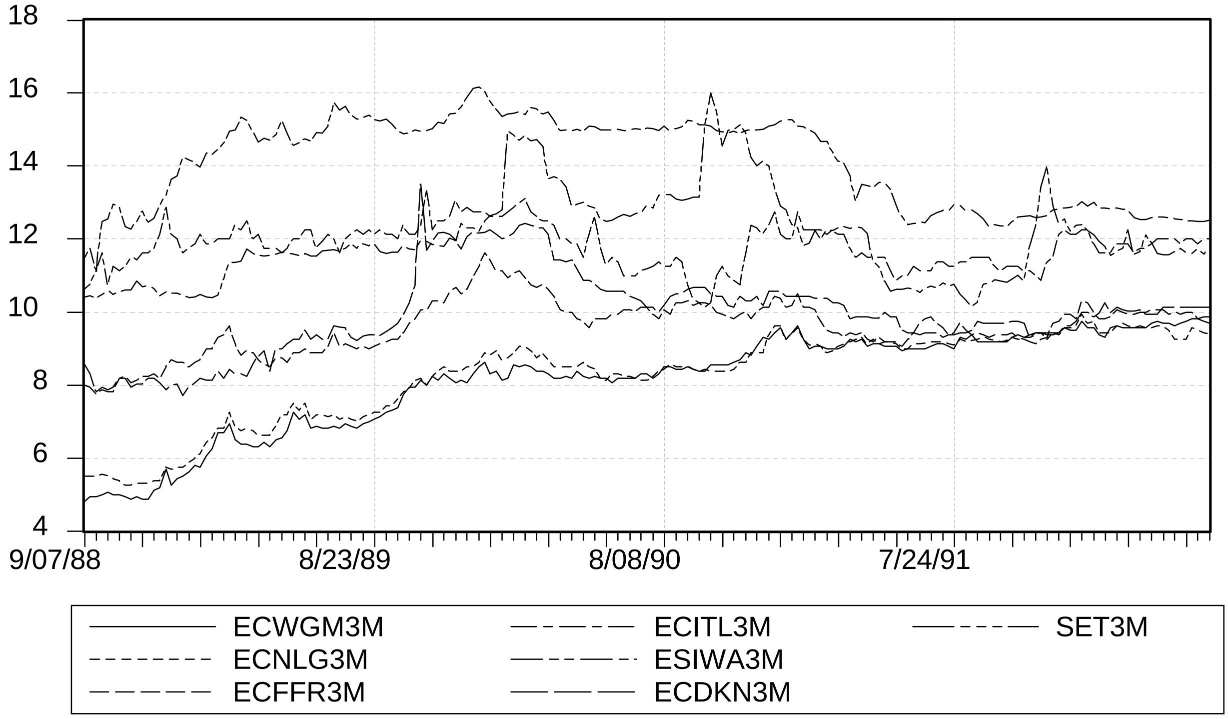

Figure 1: the level of 3 months Euro interest rates. 1988-1992

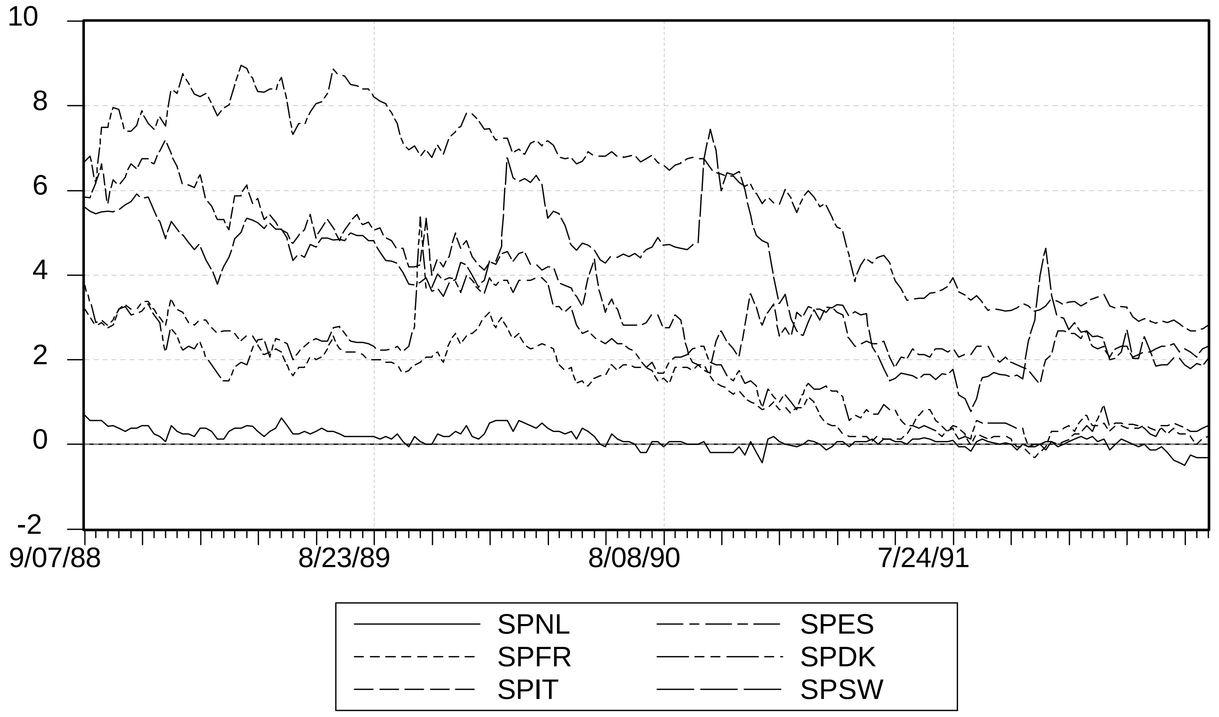

Figure 2: the spreads on 3month Euro-DM interest rates. 1988-1992

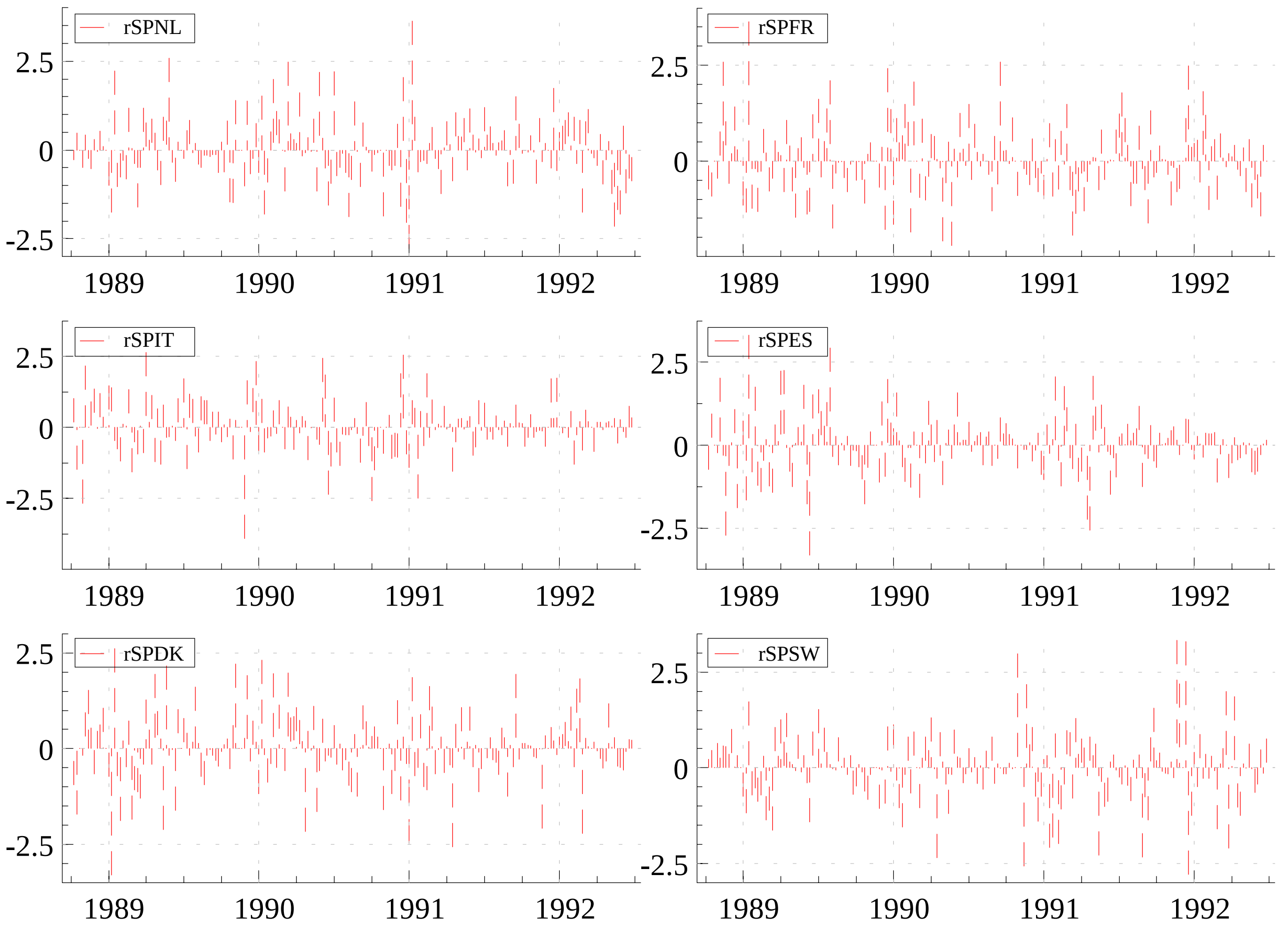

Figure 3: The residuals form the reduced form for European interest rates spreads on German rates

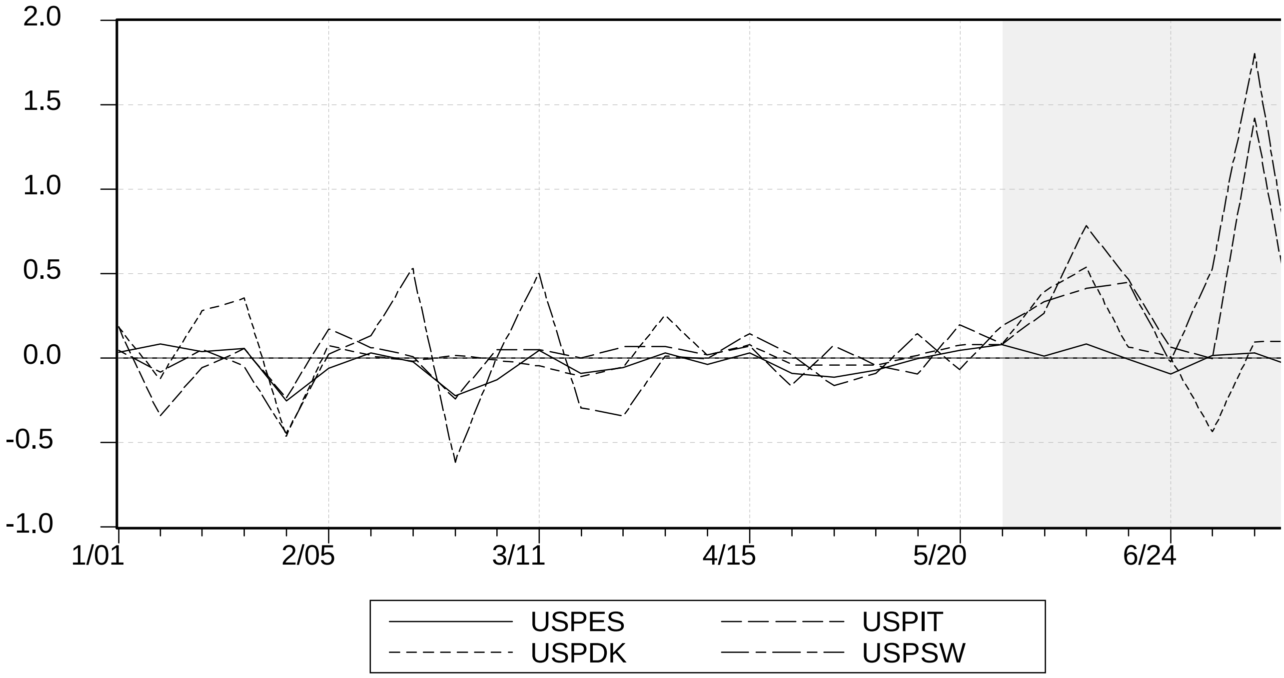

Figure 4: residuals from our structural model of interdependence of the pre-crisis and the post-crisis (shaded area) observations. Denmark(USPDN), Italy(USPIT), Spain(USPES), and Sweden(USPSW)

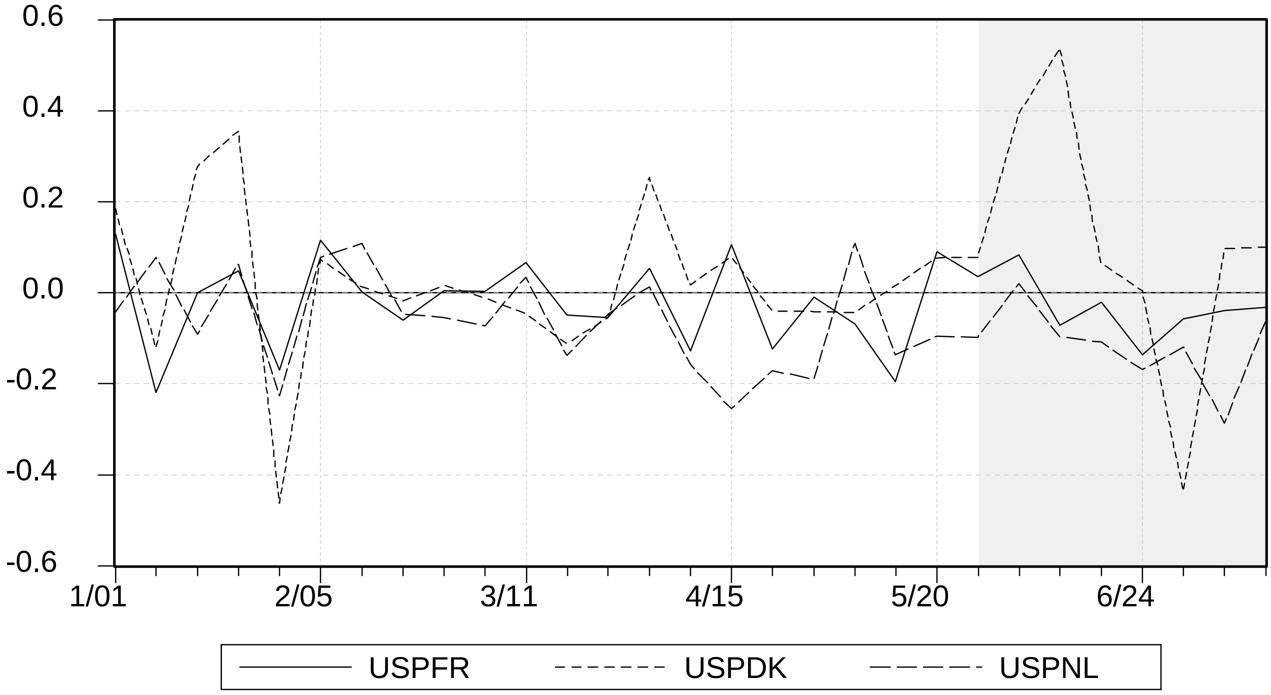

Figure 5: residuals from our structural model of interdependence of the pre-crisis and the post-crisis (shaded area) observations. Denmark(USPDN), France(USPFR) and the Netherlands(USPNL)