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Exchange rate regime, volatility and international correlations on bond and stock markets

Vincent Bodart[a], Paul Reding[b,*]

[a] *IRES, Catholic University of Louvain, Louvain-la-Neuve, Belgium*
[b] *Department of Economics, University of Namur, Rempart de la Vierge, 8, 5000 Namur, Belgium*

Abstract

Focusing on the recent experience of the EMS, the paper examines the behavior of domestic daily returns on bond and stock markets with the objective of identifying whether there exist significant differences in the patterns of volatilities and international correlations between ERM and non-ERM countries and across alternative episodes of ERM exchange rate variability. The paper provides substantial evidence that a credible peg is associated with a decline in bond market volatility. The analysis also shows that an increase in exchange rate volatility is accompanied by a decline in international correlations between bond and, to a lesser extent, stock markets.

JEL classifications: C22; F31; F33; G15

Keywords: Exchange rate regime; Volatility; International correlation

1. Introduction

Conditional volatilities of asset returns as well as their international correlations are important parameters for the day to day risk management in financial institutions and the pricing of contingent claims. Although it is often recognized that variances and covariances of returns evolve through time, their determinants are not yet well identified and documented. It is the purpose of this paper to show that the exchange rate regime and the associated degree of exchange rate volatility is an

* Corresponding author. e-mail: paul.reding@fundp.ac.be

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important determinant. Our analysis is essentially empirical. It focuses on bond, stock, and exchange markets and uses the recent experience of the European Monetary System (EMS) as field of investigation.

The theoretical literature does not offer strong predictions on the influence of exchange rate stability on the *volatility* of asset prices. A frequent argument is that, for a given set of random shocks, fixing the exchange rate induces higher volatility of interest rates, money supplies, prices and output (Frenkel and Mussa, 1980; Artis and Taylor, 1994; Flood and Rose, 1995; Rose, 1995). This 'volatility transfer hypothesis' is however, theoretically not well grounded. Real shocks of domestic origin, in aggregate demand or supply, have magnified effects on output and prices under a fixed exchange rate regime (Marston, 1985; Henderson and McKibbin, 1993); conversely, when domestic and foreign money demand shocks dominate, fixing the exchange rate dampens the volatility of asset prices' fundamentals; when foreign real shocks prevail, the net outcome is ambiguous. In addition, the degree of credibility of the peg matters: an imperfectly credible exchange rate may result in higher volatility of domestic interest rates and asset prices than what would be the case in a permanently fixed and credible regime (Flood and Hodrick, 1986). One may also argue that, if volatility in the exchange market is due to uninformed 'noise traders' or 'chartists', it can be eliminated by fixing the exchange rate, without thereby in any way transferring uncertainty to other sectors of the economy (Krugman and Miller, 1993).

In contrast to the ambiguity of the theoretical analysis, a large body of empirical studies suggests that stabilizing the exchange rate reduces the volatility of asset prices. Flood and Rose (1995) and Rose (1995) conclude their investigation of various episodes of fixed and flexible exchange rates over the 1960–1991 period for OECD countries by noting that there is no evidence of a substantial tradeoff between exchange rate volatility and the volatility of macroeconomic fundamentals (e.g. interest rates, money supplies, output, prices). Baxter and Stockman (1989) are unable to find systematic differences in the volatility of real macroeconomic aggregates when they compare the pre-1973 and post-1973 periods for a sample of OECD and non-OECD countries. Regarding the EMS experience, Fratianni and von Hagen (1990) as well as Commission of the European Communities (1990, ch. 6) document that the EMS had a stabilizing impact on nominal and real exchange rates, inflation and output. Artis and Taylor (1994) confirm this reduction in the conditional variances of nominal and real exchange rates over the 1979–1992 period and show that there is no simultaneous increase in the conditional variance of interest rates. Results of our own empirical investigation point in the same direction and indicate that the reduced exchange rate volatility enjoyed during the credible EMS period has been associated with lower volatility in bond and stock returns.

Much less attention has been devoted to the relation between exchange stability and *international correlations* of assets returns. Again, theory only offers ambiguous conclusions, along two strands of arguments. A first line of reasoning is based on the fundamental approach of asset prices and suggests that credibly fixing the exchange rate increases cross-country correlations. In a credible peg, common fundamentals across countries have a maximum weight in the determination of asset returns. News about present and future monetary policies therefore affect bond prices symmetrically. Only 'portfolio shocks' which bear on the respective credit risk premia required by investors are responsible for a less than perfect correlation between bond returns. A strong synchronization of business cycles, the absence of disruptive exchange rate shocks on the countries' tradable sectors and the symmetry in monetary policies also provide for a high correlation between stock market returns. A contrario, doubts about the credibility of the exchange rate and frequent revisions in the probability of realignment imply a high variability of interest differentials and therefore low correlations of asset returns. The second strand of arguments is based on the contagion explanation of changes in asset prices. It suggests that international correlations increase, instead of decrease, when exchange markets are more volatile. Because of noise trading or herd behavior, contagion effects are highest in volatile markets (King and Wadhwani, 1990), when a large dispersion of expectations about the fundamentals induces investors to look at asset prices abroad for information about the likely trends in the domestic market. International correlations are then higher in periods of increased market volatility. As credibly fixed exchange rates reduce uncertainty about fundamentals (e.g. monetary policy), contagion effects become less likely and noise-induced correlations fall. The opposite becomes true when low credibility of the exchange rate peg induces volatility spillovers between countries.

Empirical evidence on the determinants of international correlations of asset returns is rather limited and mostly focused on the stock market. In a recent study, Longin and Solnik (1995) single out the degree of capital market integration and abnormal volatility on the US stock market as factors increasing stock market correlations. Lin and Ito (1994) also document that correlations increase when a large price shock occurs. King et al. (1994) emphasize the role of common factors, but have to conclude that most of these are unobservable. We are however not aware of any empirical research studying the impact of the exchange rate regime on the international correlations of asset returns. Our paper is a first step towards filling this gap. We show that a reduction in exchange rate volatility leads to an increase in international correlations of bond and stock market returns.

Evidence of systematic differences in the volatilities and international correlations of asset prices across exchange regimes does obviously not necessarily mean that the exchange rate regime is the ultimate cause of these differences. The exchange rate regime may indeed be endogenous. For example, the adoption of a more flexible exchange rate may reflect the preferences of monetary authorities for a less disciplined, more variable and less symmetric monetary policy.[1] It may also be a response to changes in the pattern of fiscal policy or other real shocks. This

[1] Recent empirical results do not, however, point in this direction: evidence provided by Flood and Rose (1995) and Rose (1995) show that the variability of monetary policy instruments (monetary base) is not increased when a country switches to a flexible exchange rate.

issue of the ultimate causes is quite complex,[2] the exchange rate regime summarizing the interactions of many factors. The aim of our paper is therefore limited to identifying the exchange rate regime as the proximate cause of the observed regularities in volatilities and correlations of asset prices.

The rest of the paper is organized as follows. Section 2 presents the data and sketches the empirical methodology. Section 3 and Section 4 present the results of our investigation into the effects of changes in exchange rate variability for EMS countries on conditional volatilities and conditional correlations of bond and stock returns, respectively. Section 5 concludes.

2. Methodology and data

Our analysis is focused on the experience of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) over the period from January 2 1989 to December 19 1994.

We isolate the effect of the exchange rate regime on the volatilities and international correlations of bond and stock returns by comparing the systematic patterns of those volatilities and correlations across different European countries and EMS episodes. Indeed, by comparing ERM and non-ERM countries, comparing one country's experience getting in or coming out of the ERM and taking explicitly into account shifts in one country's exchange market volatility between sub-periods, we are able to assess whether significant differences can be identified in the behavior of volatilities and international correlations on the bond and stock markets. Such significant differences can then presumably be attributed to an 'exchange regime effect'.

Two groups of countries are considered: the first group is composed of 'hardcore EMS countries' (Germany, France and Belgium) which have maintained a fixed bilateral exchange rate during the whole sample period; the other set includes 'drop-out countries' (Italy, the UK and Sweden) which abandoned the peg with the DEM in fall 1992 and which have been on a float thereafter. The individual experience of those six countries is then compared across sub-periods characterized by different exchange rate regimes and varying exchange rate volatility. The first period (s1) ranges from January 2 1989 to September 14 1992 (965 observations) and corresponds to the most tranquil period of the EMS. We label it the 'credible peg period'. Indeed, up to the end of the period, the credibility of the peg was not questioned by the market. The second period (s2) is the 'turbulent EMS period'. It begins on 15 September 1992, when the Italian lira and the British pound abandon the Exchange Rate Mechanism (ERM) of the European Monetary System, and ends on 30 July 1993 (231 observations). The third period (s3) corresponds to the 'New EMS'. It starts on 2 August 1993, when EMS bands for exchange rate

[2] The causality may be reversed: the exchange rate regime itself may be responsible for changes in structural characteristics of the economy, e.g. the degree of real wage flexibility, as discussed in Isard (1995).

fluctuations have been extended to 15% around parity, and ends on December 19 1994 (361 observations). For the UK and Sweden, the period ranging from January 2 1989 to September 14 1992 is divided in two sub-periods, as both countries switched to a fixed peg after the start of the period. For the UK, the rupture takes place on October 8 1990 when the British pound joined the exchange rate mechanism of the EMS. For Sweden, the change in the exchange rate regime took place in May 1 1991 when the Swedish monetary authorities decided to anchor the krona to the deutsche mark.

Volatilities and correlations are computed on daily returns for bonds with a maturity exceeding 7 years, for stock indices and for foreign exchange. The data set includes 1555 daily observations for the period from January 2 1989 to December 19 1994.[3] Daily returns are computed as the change in the logarithm of the asset price between two consecutive business days. All exchange rates are bilateral rates against the German mark, defined as domestic currency per unit of German mark. Daily returns on the bond and stock markets are expressed in domestic currency. Expressing all returns in a common currency would automatically have introduced a direct link between exchange rates and returns and would possibly have biased our results in favor of a direct influence of exchange rate volatility on the volatilities and correlations of returns.

As now standard in the literature, volatilities and international correlations are modeled as the estimated variance and correlation parameters of the conditional joint distributions of returns.[4]

3. Analysis of volatility patterns

We now turn to the analysis of conditional volatilities. Estimates of conditional variances are obtained by estimating over the whole sample period an univariate GARCH(1,1) model for each series of daily returns:

$$R_t = a_0 + a_1 * R_{t-1} + e_t$$
$$h_t = c_0 + c_1 * e_{t-1}^2 + c_2 * h_{t-1}$$
$$e_t | I_t = N[0,h_t] \quad (1)$$

[3]All data were obtained from Datastream. Bond returns are computed as logarithmic growth rates of Datastream's government bond total return 'Tracker' indices of 7–10 year maturity: these indices are based on a large sample of the most liquid issues of fixed coupon bonds. Stock market prices are also defined on a total return basis and refer to the following indices: the DAX100 for Germany, the CAC40 for France, the BEL20 for Belgium, the FTSE100 for the UK, the Milan Banca Commerciale index for Italy and the Stockholm Fonsbors General index for Sweden. Spot exchange rates are quoted bilateral rates with the DEM. All prices and exchange rates are daily closing prices and are expressed in domestic currency. All data start at 2 January 1989, except the series for the Italian bond returns which starts at 2 May 1991.

[4]Only the predictable part of volatilities and international correlations influences agents' behavior. It is therefore the influence of exchange rate volatility on this predictable part which we should be interested in measuring.

where R_t is the daily return on a given market, e_t the innovation whose conditional distribution, given the time t information set I_t, is normal with zero mean and (time-varying) variance h_t.

This model has been estimated for each of the six countries and for each of the three markets.[5] For reasons of brevity, we do not report the detailed estimates and diagnostic tests obtained for each model.[6] For each series, the arithmetic mean of the estimated conditional variance is then computed over each sub-period. Fig. 1 shows how the average volatility of returns on each market has evolved for the six countries over the three (respectively four) sub-periods of ERM exchange rate variability.

Table 1 reports the ratios between two sub-periods' average conditional variances and indicates whether the ratio is significantly different from 1. Analysis of the conditional variances on the exchange market shows that there is a significant difference between the two 'hard core' and the three 'drop-out' ERM countries, as well as between the three sub-periods. Sub-period s_1, during which Belgium, France, Italy, the UK and Sweden were on a credible peg with the DEM, systematically exhibits the lowest volatility, the most strikingly so for the two 'hard core' countries. Sub-period s_2 sees a marked increase in conditional exchange rate volatility for every European country, although the three 'ERM drop-outs' are affected on a much larger scale. This obviously reflects the great uncertainty surrounding the future stance of these countries' exchange rate and monetary policy. During sub-period s_3, the credibility of Belgium's and France's peg with the DEM is also repeatedly put to test in the new ERM set-up: indeed the variability of their exchange rate is the highest during this period. For the three other countries exchange market volatility subsides during this 'New EMS' period, but remains higher than in the two 'hard-core' countries and fails to return to the low level of volatility they experienced during their fixed peg episode (s_1).

The results of Table 1 and Fig. 1 provide substantial evidence of a positive relationship between exchange rate and *bond market* volatility, in contrast to the implications of the 'volatility transfer' hypothesis. Fig. 1 makes clear that the countries with the lowest foreign exchange volatility also have the lowest volatility of bond returns, regardless of the sub-period. Table 1 confirms this result: the bond market is always the least volatile in 'hard core countries' (Belgium, France and Germany), even in turbulent exchange market periods.[7] Table 1 also shows that

[5]To facilitate estimation, a very limited number of outliers (nine data points) has been eliminated.

[6]Estimates are in line with what is commonly reported in the literature (high persistence in conditional variance, that is the sum of c_1 and c_2 is close to 1). Diagnostic tests show that the GARCH (1,1) model eliminates the autocorrelation in squared standardized residuals and strongly reduces (but does not eliminate) the excess kurtosis in the residuals. Except for a very limited number of cases (the French bond market in particular), the first order autoregressive specification adopted for the return process completely eliminates autocorrelations in the residuals. To test autocorrelation, we use the Diebold–Lopez (Diebold and Lopez, 1995) version of the Ljung–Box test which provides an adjustment for the GARCH effects in the innovations. The complete set of results is available from the authors.

[7]Taking sub-period s_2 as an example, one finds that exchange market turbulence is most heavily reflected in the conditional variance of bond returns for the two 'drop-outs' countries (Italy, Sweden).

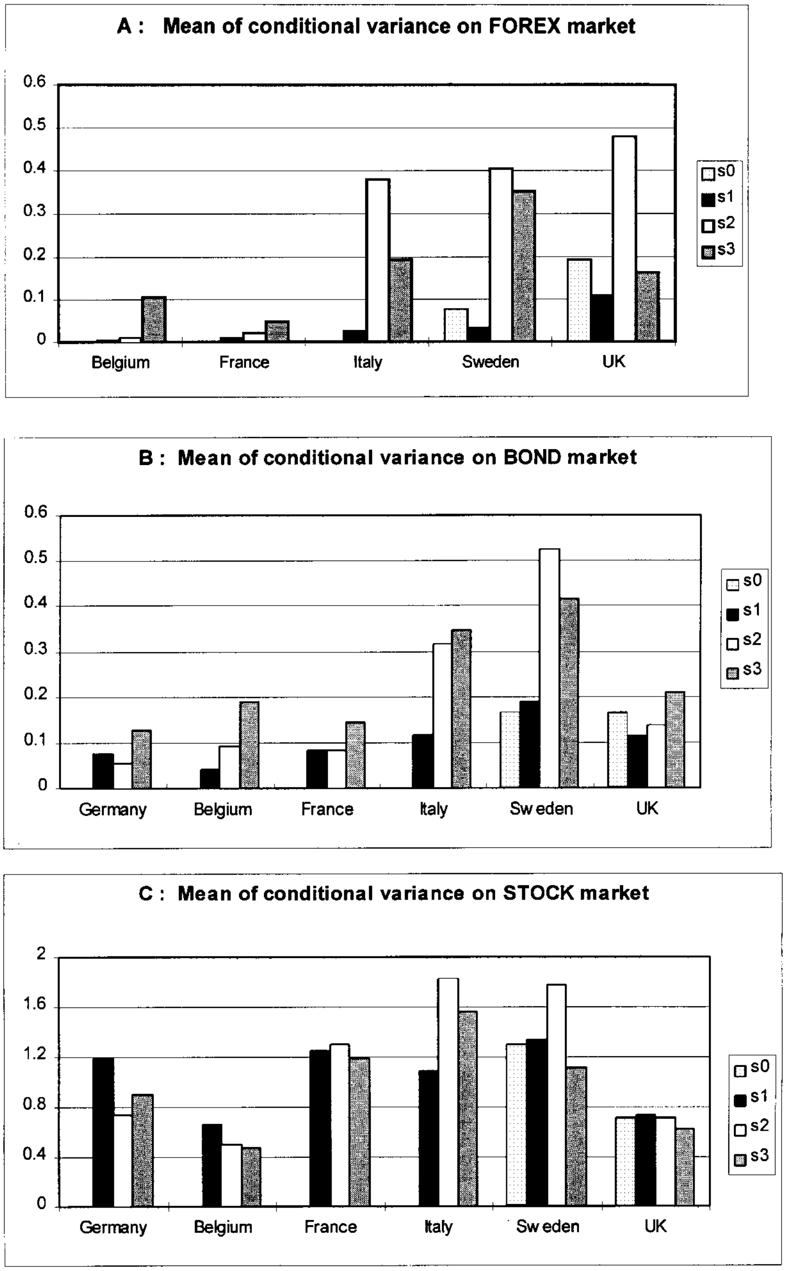

Fig. 1. Mean of conditional variances. Sub-periods: s0 = 1989:1:2–1991:4:30 for Sweden, 1989:1:2–1990:10:07 for UK; s1 = 1989:1:2–1992:9:14, except for Sweden and UK, where it starts at the end of s0; s2 = 1992:9:15–1993:7:31 and s3 = 1993:8:2–1994:12:19.

Table 1
Comparison of conditional variances between sub-periods

	GE	BE	FR	IT	SW	UK
A. Bond market						
sub.0/sub.1	–	–	–	–	0.88	1.48[b]
sub.2/sub.1	0.71[b]	2.35[b]	1.01	2.73[b]	2.78[b]	1.22[a]
sub.3/sub.1	1.66[b]	4.74[b]	0.75[b]	3.01[b]	2.2[b]	1.87[b]
sub.3/sub.2	2.34[b]	2.02[b]	1.76[b]	1.10	0.79[a]	1.53[b]
B. Stock market						
sub.0/sub.1	–	–	–	–	0.97	0.98
sub.2/sub.1	0.62[b]	0.76[a]	1.04	1.67[b]	1.32[b]	0.97
sub.3/sub.1	0.75[b]	0.72[b]	0.95	1.43[b]	0.82[b]	0.89
sub.3/sub.2	1.22	0.94	0.92	0.85	0.63[b]	0.92
C. Foreign exchange market						
sub. 0/sub.1	–	–	–	–	2.39[b]	1.79[b]
sub. 2/sub.1	–	2.68[b]	2.70[b]	15.53[b]	12.91[b]	4.45[b]
sub. 3/sub.1	–	36.00[b]	6.14[b]	7.92[b]	11.22[b]	1.53[b]
sub. 3/sub.2	–	13.45[b]	2.28[b]	0.51[b]	0.86	0.34[b]

[a] Ratio significantly different from 1 at the 5% level.
[b] Ratio significantly different from 1 at the 1% level.
Note. The table reports the ratios between the means of the conditional variances estimated for two sub-periods, as referred to in col. 1. The different sub-periods are: sub. 0 = 1/2/89–10/8/90 for UK, 1/2/89–4/30/91 for Sweden; sub. 1 = 1/2/89–9/14/92 except for UK and Sweden, where it starts at the end of sub. 0; sub. 2 = 9/14/92–8/2/93; sub. 3 = 8/2/93–12/19/94. The null hypothesis of no difference between the variances is tested using an *F*-test.

bond market volatility was, for each country, at its minimum during the credible period of the EMS (sub-period s_1). By contrast, increases in exchange rate volatility are for any country typically associated with higher bond market volatility. This is the case for Italy and Sweden after they decided to drop out of the ERM. It is also the case for Belgium and France during the ‘New EMS’ period (sub-period s_3), when both countries had trouble to maintain the credibility of their peg to the DM: actions undertaken by the authorities to resist speculative activity were successful in limiting the degree of exchange rate volatility but contributed to a spillover of volatility to the bond market.

Evidence of any systematic relationship between the exchange rate regime and the volatility of *equity market* returns is more difficult to identify in our results. From the volatility patterns displayed in Fig. 1, one cannot infer that the three ‘hard core’ countries have the lowest volatility of equity returns. In addition, Table 1 does not provide clear-cut evidence that increases in exchange rate variability are accompanied by increases in stock market volatility. The only weakly supporting evidence of a positive relationship between exchange and stock market volatility is the experience of Italy and Sweden during the turbulent period of EMS as both markets were the most volatile over that sub-period.

4. Correlation analysis

This section investigates the extent to which changes in the exchange rate regime affect the conditional international correlations among asset markets. The analysis focuses on the correlation of returns on the bond and stock markets between Germany and the other European countries. Following Bollerslev (1990), we use a bivariate model with time-varying conditional variance, but constant conditional correlation. Time-variation in variances is modeled using a GARCH (1,1) specification. The model is then given by:[8]

$$\begin{aligned} R_t &= a_0 + a_1 * R_{t-1} + e_t, \\ h_t &= c_0 + c_1 * e_{t-1}^2 + c_2 * h_{t-1}, \\ h_t^{i,G} &= r * \left[h_t^i * h_t^G \right]^{0.5}, \\ e_t | I_t &= N[0, h_t], \end{aligned} \tag{2}$$

where R_t is the 2×1 vector of daily returns on a given market, e_t is the 2×1 vector of innovations assumed to be conditionally normal with zero mean and time-varying conditional variance vector h_t, $h_t^{i,G}$ is the conditional covariance among returns, r is the constant conditional correlation among returns, and I_t denotes the set of information available at time t.

The potential effect of the exchange rate regime on the international correlations among markets is tested in two alternative ways. First, we examine whether the correlations among markets vary across ERM sub-periods. Second, we examine to what extent the correlations are affected by 'abnormal volatility' on the foreign exchange markets. This second approach also enables us to isolate the effect of the exchange rate regime from the other factors that could influence the international correlations among asset returns.

4.1. Sub-period analysis

We first investigate whether the correlation between Germany and the other European countries has significantly varied across the different episodes of the Exchange Rate Mechanism of the European Monetary System. The empirical strategy is to incorporate dummy variables corresponding to the three sub-periods into the covariance term equation of each bivariate model and then to test for their individual and joint significance. The covariance term in model (2) is thus augmented as follows:

$$h_t^{i,G} = [r + d2 * \mathrm{ERM}_2 + d3 * \mathrm{ERM}_3] * \left[h_t^i * h_t^G \right]^{0.5},$$

[8] For the German stock market, a dummy variable is incorporated into the conditional mean equation to allow for the presence of outliers.

where $ERM_2 = 1$ for observations in the second sub-period (s_2) and zero otherwise, and $ERM_3 = 1$ for observations in the third sub-period (s_3) and zero otherwise.[9]

Quasi-maximum likelihood estimations for the bond market and the stock market are reported in Table 2 and Table 3, respectively. Tables 2 and 3 report the value of the correlation coefficient and the coefficient of the dummy variables with their estimated asymptotic standard errors. Tables 2 and 3 also include a joint test for the significance of the dummy variables, as well as a series of diagnostic tests to check for the descriptive validity of the model.[10]

The evidence reported in Table 2 suggests that a smaller exchange rate volatility increases cross-country correlations of returns on the *bond market*. First, whatever the ERM episode considered, cross-country correlations with the German bond market are stronger for the two 'hard-core' countries than for the three 'drop-out' countries. This result is consistent with the fact that, over most of the period considered, monetary authorities in France and Belgium have largely coordinated their monetary policy with the monetary policy in Germany. Second, the coefficients of the sub-period dummies indicate a marked and widespread decline of correlations during the turbulent period of the EMS (sub-period 2) relative to the previous sub-period. Following Rose and Svensson (1994), one can attribute this weakening of correlations with Germany to the credibility shock that affected simultaneously all ERM countries during that period, leading operators in financial markets to anticipate greater asymmetries among future monetary policies. Interestingly, Table 2 also indicates that the correlation between German and UK bond markets was higher during the short period in which the British pound was part of the ERM.

Our empirical evidence also suggests that ERM exchange rate variability had an impact on the cross-country correlations of *stock prices*. Results reported in Table 3 tend to show that international correlations of equity returns are stronger for France and Belgium which have the lowest exchange rate volatility. The evidence is however less clear-cut than for bond returns. Furthermore, cross-period comparisons show that in most cases international correlations between stock markets weakened during the more turbulent periods of the EMS (relative to the credible period). For Italy and Sweden, the decline in stock market correlations was the most pronounced during sub-period s_2 when they experienced the highest foreign exchange volatility. For France, the correlation with the German stock market was

[9] For the UK and Sweden, an additional dummy variable ERM_1 is incorporated into the covariance term equation: $ERM_1 = 1$ for observations in the short period during which each country was on a fixed peg with the DEM.

[10] In most cases, the diagnostic tests reported in Tables 2 and 3 fail to detect any serious misspecifications of the model, thereby suggesting that there is little unexplained dependence in the data. In particular, the Ljung–Box test performed on the squared normalized residuals is reduced substantially compared to its value for raw squared returns, which indicates that the GARCH (1,1) model does a very good job of tracking the strong temporal dependence in the variance. We have also computed the coefficient of skewness and kurtosis on the standardized residuals, which indicate that strong deviations from normality remain. Standard errors are corrected for the non-normality of residuals.

Table 2
Effect of exchange rate regime on bond market correlations

	FR	BE	UK	SW	IT
r	0.6078[a]	0.5163[a]	0.2080[a]	0.3225[a]	0.4829[a]
	(28.16)	(18.45)	(4.70)	(9.87)	(10.70)
d1	–	–	0.1202[a]	−0.0047	–
	–	–	(1.94)	(−0.08)	–
d2	−0.2317[a]	−0.0739	0.0430	−0.0841	−0.4086[a]
	(−3.47)	(−1.16)	(0.50)	(−1.46)	(−4.54)
d3	−0.0766[a]	0.1029[a]	0.1225[a]	0.0642	0.0849
	(−2.44)	(2.10)	(2.20)	(1.34)	(1.66)
H_0: d1 = d2 = d3 = 0	14.61[a]	8.99[a]	6.02	6.38	32.29[a]
src for country in col.	35.3068[a]	11.3711	15.1528	18.5193	4.8010
src for Germany	16.6346	16.6021	16.1743	16.1534	8.9700
het for country in col.	7.8726	3.3967	4.1292	23.2327[a]	12.0672
het for Germany	11.0866	11.4027	11.0978	11.3923	8.9418
cross	17.1422	6.7216	6.0547	13.9062	12.1774

[a]denotes significance at the 5% marginal level of significance.
Note: *r* is the correlation coefficient with Germany; d1, d2 and d3 are coefficients of ERM sub-period dummies. For parameter estimates, robust asymptotic standard errors are reported in parentheses. The test for H_0 is a chi-square statistic. 'src' is the value of the chi-square statistics of the Diebold–Lopez (Diebold and Lopez, 1995) version of the Ljung–Box test for up to 12th-order serial correlation of residuals. 'het' is the value of the chi-square statistics for the standard Ljung–Box test for up to 12th-order serial correlation of the squares of the normalized residuals. 'cross' is the value of the chi-square statistics of the standard Ljung–Box test for up to 12th-order serial correlation of he cross-product of normalized residuals. The estimation period is 1/3/89–12/19/94.

Table 3
Effect of exchange rate regime on stock market correlations

	FR	BE	UK	SW	IT
r	0.5957[a]	0.4640[a]	0.3402[a]	0.4708[a]	0.4252[a]
	(29.07)	(15.86)	(9.66)	(12.97)	(10.68)
d1	–	–	0.1646[a]	0.0818	–
	–	–	(3.55)	(1.80)	–
d2	−0.0740	−0.1035	0.0067	−0.1370	−0.2645[a]
	(−1.40)	(−1.28)	(0.08)	(−1.74)	(−3.61)
d3	−0.1100[a]	0.0349	0.0777	−0.0168	−0.0659
	(−3.34)	(0.80)	(1.57)	(−0.38)	(−1.24)
H_0: d1 = d2 = d3 = 0	12.76[a]	3.24	15.23[a]	9.58[a]	13.11[a]
src for country in col.	12.6945	9.8429	14.2493	19.6167	19.9784
src for Germany	6.5348	6.7856	6.8823	6.5080	7.0423
het for country in col.	5.0592	1.5272	5.8545	2.4958	6.3205
het for Germany	17.7773	17.4871	18.8920	22.3241[a]	21.6162[a]
cross	13.6667	15.8135	10.4835	9.5746	28.6482[a]

Note: see note to Table 2.

the weakest during the 'New EMS' period when the French franc was the most volatile. Table 3 also reports that the correlations of the UK and Swedish stock markets with Germany were higher during the short period when they anchored their exchange rate to the deutsche mark.

Obviously, other factors than the exchange regime are at work in shaping international correlations on asset markets. For example, the marked increase in the correlations of bond returns during the most recent period of the EMS relative to the turbulent period cannot be totally attributed to the change in the exchange rate regime but is, at least partly, due to common factors affecting simultaneously world bond markets, as documented in Borio and McCauley (1995) and International Monetary Fund (1994). The analysis in the next section provides an alternative approach to isolate the effects of the exchange rate regime.

4.2. Threshold analysis

We investigate to what extent 'abnormal volatility' on the foreign exchange market has affected the international correlations among the bond and stock markets. Abnormal volatility is a country specific variable which is measured as the excess of the conditional volatility of daily returns on the foreign exchange market over a threshold.

The empirical strategy is to augment the base model (2) by incorporating a threshold variable into the covariance term equation:

$$h_t^{i,G} = [r + d * K_t] * \left[h_t^i * h_t^G\right]^{0.5}. \quad (3)$$

K_t is a dummy variable that takes the value 1 when the estimated conditional variance of daily returns on the foreign exchange market exceeds an exogenous threshold, and 0 otherwise. K_t therefore identifies those days when the volatility on the exchange market is expected to be higher than on average. The conditional variance is described by a univariate GARCH (1,1) process (see Appendix A, Table A.1). We follow Longin and Solnik (1995) in setting the country specific threshold arbitrarily at the unconditional variance, measured as the sample variance of the unpredictable part of forex daily returns over the whole observation period.[11] According to this approach, the number of observations when K_t takes the value 1 is the following for the five countries: 254 (FR), 164 (BE), 496 (UK), 570 (SW) and 528 (IT). Strikingly, markets expect more frequently abnormal volatility in countries where *absolute* exchange rate variability has been shown to be the highest (see Fig. 1). For every currency, most days of abnormal volatility are concentrated in the second and third sub-periods.

The coefficient d in Eq. (3) is expected to be significantly negative: international

[11] A better alternative is to use the unconditional variance as implied by the GARCH models in Appendix A. Most models, however, are integrated, which implies that the implied unconditional variance does not exist. Following Bollerslev (1990), we then calculate the unconditional variance as the sample variance over the observation period.

Table 4
Effect of exchange rate volatility on bond market correlations

	FR	BE	UK	SW	IT
r	0.5814[a]	0.5521[a]	0.2881[a]	0.2996[a]	0.5018[a]
	(28.74)	(20.46)	(8.57)	(10.76)	(16.62)
d	−0.1607[a]	−0.2008[a]	−0.0384	0.0690	−0.1477[a]
	(−2.56)	(−2.46)	(−0.65)	(1.59)	(−2.34)
src for country in col.	35.9419[a]	11.6271	14.9019	18.5247	5.1576
src for Germany	16.7354	16.9803	16.2003	16.1157	8.9427
het for country in col.	7.9119	3.3997	4.0622	23.2001[a]	8.7632
het for Germany	11.1382	11.6656	11.0834	11.3863	9.7037
cross	16.9269	6.8694	6.0530	13.9650	12.1671

Note: r is the correlation coefficient with Germany; d is the exchange rate volatility threshold coefficient. See also note to Table 2.

correlations are on average smaller those days when foreign exchange markets are excessively volatile. The results of the estimations for the *bond market* are reported in Table 4. One can observe that, with the exception of Sweden, the coefficient d is negative for all countries and individually significant at the 5% level for the two 'hard-core' ERM countries — France and Belgium — and Italy. For these three countries, the value of the coefficient is large, which indicates that abnormal volatility on the foreign exchange market may cause a large drop in the correlation of domestic bond markets with Germany. The results reported in Table 5 also show that international correlations among *stock markets* decline when excess volatility is expected on the foreign exchange market. The coefficient d is negative for all countries of the sample, but Italy is the only statistically significant case.

Several studies have identified asymmetric effects in abnormal volatility situations (see e.g. Longin and Solnik, 1995). We take this issue up in Appendix B, where we check whether the effects of exchange rate volatility on correlations

Table 5
Effect of exchange rate volatility on stock market correlations

	FR	BE	UK	SW	IT
r	0.5408[a]	0.4759[a]	0.4311[a]	0.4121[a]	0.4474[a]
	(35.04)	(17.58)	(15.33)	(23.32)	(10.92)
d	−0.0524	−0.1612	−0.0680	−0.0420	−0.2216[a]
	(−1.35)	(−1.69)	(−1.32)	(−1.27)	(−3.95)
src for country in col.	13.8214	9.9607	14.3937	19.7273	20.0902
src for Germany	6.5963	6.7078	6.9544	6.5129	7.0061
het for country in col.	4.8540	1.5324	5.9108	2.4173	6.7098
het for Germany	18.5322	17.6488	16.7419	23.6687[a]	21.7172[a]
cross	14.3741	15.7344	10.9850	10.0768	28.3933[a]

Note: r is the correlation coefficient with Germany; d is the exchange rate volatility threshold coefficient. See also note to Table 2 depend on the sign and the magnitude of exchange rate shocks. The results appear to be in line with our previous analysis: large exchange rate shocks significantly reduce the bond market correlations with Germany for France, Belgium, and Italy; for the stock markets, this result only holds for the UK and Italy (see Tables B.1 and B.2). In addition, asymmetric effects of large exchange rate shocks are present in a limited number of cases.

We can now use these results to assess more accurately to what extent the reported variations of correlations across sub-periods (Tables 2 and 3) are directly attributable to changes in the variability of ERM exchange rates. From Table 4 and Table 5, we calculate the average correlation coefficients for each sub-period (Tables 6). We see that the pattern of correlations closely mimics the pattern implied by the sub − periods dummies in Tables 2 and 3: abnormal exchange rate variability does explain in a sizeable way the decline of international correlations between domestic returns on the bond and stock markets. This therefore clearly confirms the role of exchange rate variability with respect to other factors which shape international correlations in asset returns.

5. Conclusion

The purpose of the paper was to assess the potential effects of the exchange rate regime and the associated degree of exchange rate variability on the conditional volatilities and international correlations on bond and stock markets. Our analysis focused on the recent experience of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) using domestic daily returns on the bond and stock markets of six European countries over the period from 2 January 1989 to 19 December 1994. We tested whether significant differences in the patterns of volatilities and international correlations could be identified across alternative sub-periods of ERM exchange rate variability or between those countries which

Table 6
Conditional correlations by sub-periods

	FR	BE	UK	SW	IT
A. Bonds					
sub.0	–	–	0.27	0.30	–
sub.1	0.58	0.55	0.29	0.30	0.50
sub.2	0.52	0.54	0.26	0.36	0.36
sub.3	0.52	0.47	0.28	0.37	0.41
B. Stocks					
sub.0	–	–	0.41	0.49	–
sub.1	0.57	0.48	0.43	0.49	0.45
sub.2	0.55	0.47	0.38	0.42	0.23
sub.3	0.55	0.41	0.41	0.41	0.27

Note: For a definition of the sub-periods, see Table 1.

were on a credible peg with the DEM over most of the period and those countries which dropped out of the ERM.

The important insights of the analysis can be summarized as follows. First, the analysis reports a marked linkage between the patterns of volatilities on the bond market and the foreign exchange market, but failed to detect any similar linkage on the stock market. This result confirms the presumption that the uncertainty surrounding the conduct of domestic monetary policy is a crucial determinant of the volatility of bond prices, whereas the volatility of stock prices is more related to the overall underlying macroeconomic uncertainty. Second, the evidence is not supportive of the 'volatility transfer' hypothesis. We do not find that the adoption of a credible peg with Germany has increased the volatility of the bond and stock markets; in contrast, there is substantial evidence that credibly fixing the exchange rate has resulted in a decline in bond market volatility. Third, the analysis makes clear that the degree of exchange rate variability exerts an influence on international bond and stock correlations. In particular, the analysis shows that an increase in ERM exchange rate variability causes a large drop in the conditional correlation of daily returns on the bond market between Germany and the other European countries. This result is consistent with the presumption that credibly fixed exchange rates maximize the international correlations of bond market by imposing a strong coordination of domestic monetary policies. While the analysis also suggests that stock correlations with Germany are affected by the degree of exchange rate variability, the evidence is however less significant. This result can be attributed to a larger influence of idiosyncratic shocks on the behavior of domestic stock prices.

In conclusion, the evidence from the recent experience of the ERM supports the conjecture that changes in the patterns of volatilities and international correlations on bond and stock markets can be, at least partially and in a proximate way, attributed to an 'exchange regime effect'.

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Appendix A: ARCH modeling of daily returns on foreign exchange markets

This appendix presents parameter estimates and diagnostic tests for univariate AR(1)-GARCH(1,1) models of daily returns on European foreign exchange markets.

Table A.1. GARCH(1,1) exchange rate model

	FR	BE	UK	SW	IT	IT[b]
Conditional mean						
c0	−0.0034	0.0001	0.0053	0.0010	0.0025	0.0089
	(−1.70)	(0.14)	(0.59)	(0.26)	(0.72)	(1.66)
c1	−0.0332	0.0172	0.0278	0.1001	0.0368	0.0472
	(−0.89)	(0.50)	(0.89)	(1.74)	(0.75)	(0.93)
c2	–	–	–	9.0616[a]	3.1553[a]	4.0585[a]
	–	–	–	(26.30)	(24.30)	(15.30)
Conditional variance						
v1	0.0004[a]	0.0001[a]	0.0033	0.0003	0.0003	0.0002
	(1.98)	(2.99)	(1.41)	(1.20)	(1.68)	(1.20)
v2	0.2000[a]	0.3135[a]	0.0921[a]	0.1219[a]	0.0990[a]	0.1278[a]
	(2.75)	(5.53)	(2.49)	(2.73)	(2.66)	(3.76)
v3	0.7795[a]	0.7387[a]	0.8957[a]	0.8896[a]	0.9046[a]	0.8890[a]
	(11.06)	(27.02)	(22.42)	(24.56)	(27.81)	(36.59)
Diagnosis						
skew	0.3744[a]	0.6357[a]	0.1938[a]	0.5512[a]	0.6781[a]	0.3747[a]
kurto	3.3503[a]	7.0986[a]	5.6909[a]	3.9814[a]	3.9102	3.1194[a]
src	15.4141	17.1039	11.7984	20.8128[a]	5.1042	6.8738
het	37.5289[a]	10.4235	9.7089	27.6851[a]	22.9632	15.1260

[a] Denotes significance at the 5% level of significance.
[b] The estimation period is 5/3/91–12/19/94.
Note. The table gives the coefficient estimates and diagnosis tests for the univariate AR(1)–GARCH (1,1) model of daily returns on the foreign exchange market (see Eq. (1) in the text). For Sweden and Italy, a dummy variable capturing the effect of outliers is added into the conditional mean equation. For coefficient estimates, robust asymptotic standard errors are reported in parentheses. 'skew' is the coefficient of skewness of the normalized residuals. For a definition of 'src' and 'het', see Table 2. The estimation period for Col. 1–5 is 1/3/89–12/19/94.

Appendix B: Correlations and asymmetry in foreign exchange market shocks

In this appendix, we look at asymmetry in correlations. More precisely, we investigate whether the sign and magnitude of exchange rate shocks have a significant impact on the correlations of daily returns on the bond and stock markets between Germany and the other European countries. Following Longin and Solnik (1995), we investigate these issues by modifying the covariance term equation as follows:

$$h_t^{i,G} = [k_1 * dlsig_{t-1} + k_2 * dneg_{t-1} + k_3 * dpos_{t-1} + k_4 * dhsig_{t-1}] * \left[h_t^i * h_t^G\right]^{0.5}$$

where:

$$dlsig_{t-1} = 1 \; if \, e_{t-1}^{\mathrm{fx}} < -\sigma^{\mathrm{fx}}$$

$$dneg_{t-1} = 1 \; if \, e_{t-1}^{\mathrm{fx}} < 0$$

$$dpos_{t-1} = 1 \text{ if } e^{fx}_{t-1} > 0$$

$$dhsig_{t-1} = 1 \text{ if } e^{fx}_{t-1} > \sigma^{fx}$$

and σ^{fx} is the unconditional standard deviation of e^{fx}_t, the innovation in forex daily returns, as obtained from the respective models reported in Appendix A. General asymmetry in correlation, irrespective of the size of the shock, corresponds to the case: $k_2 \neq k_3$; differences between the impact of large and small shocks correspond to the case: $k_1 \neq 0$, $k_4 \neq 0$; asymmetry in the effects of large exchange rate shocks corresponds to the case: $k_1 + k_2 \neq k_3 + k_4$.

Tables B.1 and B.2 show that there is no significant asymmetry in correlations, whether in the bond or in the stock market. Only in a limited number of cases (France and Belgium for the bond market, Sweden for the stock market) is there evidence of asymmetric effects of large exchange rate shocks. Large shocks tend to reduce international correlations in asset returns. This is true for large *positive* shocks (corresponding to an unexpected depreciation of the domestic currency) in all countries but Sweden (although k_4 is only significant for France, Belgium, and Italy, on the bond market, and Italy on the stock market). Large negative shocks also reduce correlations for three countries out of five on the bond market and for all countries on the stock market (k_1 is however, only significant for the UK and Italy on the stock market).

Table B.1. Bond markets correlations and asymmetry in exchange market shocks

	FR	BE	UK	SW	IT[b]
k1	−0.0318	0.0876	−0.0617	0.0179	−0.1005
	(−0.56)	(1.27)	(−0.91)	(0.25)	(−0.64)
k2	0.5934[a]	0.5751[a]	0.2901[a]	0.3586[a]	0.5461[a]
	(24.79)	(18.22)	(7.74)	(9.87)	(15.90)
k3	0.5662[a]	0.5345[a]	0.2881[a]	0.2847[a]	0.4541[a]
	(24.32)	(18.31)	(6.22)	(7.59)	(11.39)
k4	−0.1608[a]	−0.3213[a]	−0.0672	0.0070	−0.2856[a]
	(−2.51)	(−3.67)	(−0.74)	(0.11)	(−2.77)
H_0: k2 = k3	0.7814	0.8074	0.0011	2.1194	3.2034
H_0: k1 + k2 = k3 + k4	4.2081[a]	16.5789[a]	0.0056	1.1442	2.6695
src for country in col.	35.5265[a]	11.3002	14.8915	18.6381	5.2347
src for Germany	16.8119	17.1347	16.1860	16.1289	8.9959
het for country in col.	7.6725	3.4313	4.0487	23.3843[a]	8.8301
het for Germany	11.4305	11.5563	11.1638	11.6041	10.1106
cross	17.0426	6.7342	6.0762	14.1591	12.1107

[a] Denotes significance at the 5% marginal level of significance.
[b] The estimation period is 5/3/91 to 12/19/94.
Note: For parameter estimates, robust asymptotic standard errors are reported in parentheses. The tests for H_0 are chi-square statistics. For a definition of 'src', 'het', and 'cross', see Table 2. The estimation period is 1/3/89 to 12/19/94 for Col. 1–4.

Table B.2. Stock market correlations and asymmetry in exchange market shocks

	FR	BE	UK	SW	IT
k1	−0.1026	−0.1968	−0.1553[b]	−0.1308	−0.2944[a]
	(−1.16)	(−1.53)	(−2.17)	(−1.76)	(−3.90)
k2	0.5729[a]	0.4842[a]	0.4650[a]	−0.4691[a]	0.4193[a]
	(20.40)	(14.77)	(15.05)	(12.92)	(11.62)
k3	0.5600[a]	0.4502[a]	0.4066[a]	0.4547[a]	0.4195[a]
	(17.68)	(11.29)	(11.52)	(10.40)	(10.66)
k4	−0.0001	−0.0364	−0.0820	0.0931	−0.1991[a]
	(−0.00)	(−0.29)	(−1.13)	(1.46)	(−2.48)
H_0: k2 = k3	0.1399	0.6764	1.6469	0.1078	0.0001
H_0: k1 + k2 = k3 + k4	0.9113	0.5521	0.0232	7.0894[a]	0.8305
src for country in col.	14.0081	9.8492	14.7836	19.5847	19.8928
src for Germany	6.5806	6.6826	6.9354	6.5125	7.0705
het for country in col.	4.7467	1.5616	5.9217	2.3700	5.8431
het for Germany	17.9721	17.7061	17.1694	23.7812[a]	20.3562
cross	13.9227	15.8151	11.0368	10.0158	26.7400[a]

Note: see Table B.1.

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