Spillovers across High Yield Markets*

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Abstract

This paper studies the time-variant interactions among US stocks, emerging market bonds and US low-grade corporate bonds. All of these assets are characterized by a similar average return, but returns are far from being perfectly correlated. Therefore, investing in these different assets provides substantial diversification benefits. What is more, most correlations among assets do not increase, rather decrease, during financial crisis.

JEL classification: G11; G14; G15.

Keywords: Asset allocation; Financial crisis; Time-varying correlations; Regime-switching models; Emerging market bonds; Corporate bonds; Stock market.

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This paper studies the most important assets in the high yield market and interactions among them. These assets are US stocks, emerging market bonds and US low-grade corporate bonds. All of them are characterized by a similar average return, which makes them close substitutes for long-term investors. However, returns are far from being perfectly correlated, hence, investing in different assets provides diversification benefits. The size of potential diversification benefits is determined by the correlations among asset returns.

In what follows a thorough analysis of returns, volatilities and their correlations is performed. In particular the possibility that returns, volatilities and correlations depend on the state of the economy is explored. One such hypothesis to be tested is that in times of a crisis in one market correlations and volatilities in all markets are high and returns are low. Whereas in "normal" periods volatilities and correlations are rather low.

The present work is not only relevant for portfolio choice and risk management, but also for issuers of bonds, like companies and governments in emerging markets. Given that high yield markets are integrated, news in one market is expected to affect the other markets quickly. For example, the recent accounting scandals in the US clearly have affected the US stock market, but might also have had strong impacts on emerging market bonds.[1] This paper looks carefully at such interactions.

The US stock market has been extensively studied in the literature, but not much research has been done on low-grade corporate bonds and emerging market bonds. In particular, I am not aware of any detailed study on spillovers across these markets. Nevertheless, these markets become more and more integrated and therefore spillovers are most likely to increase as well. For example, from 1998 to 2002 investment in emerging market bonds by "cross-over" high-grade investors has more than tripled, whereas the investment by dedicated emerging market funds has gone down to one third (World Bank, 2003). Basic evidence for linkages across high yield markets can also be found in ECB (2003) and IMF (2003). Erb et al. (2000) touch the issue by providing basic statistics on emerging market bonds and some correlation analysis. Blume et al. (1991) give many interesting insights into the return and risk of low-grade corporate bonds. There are some detailed studies on linkages among markets. They do not tackle the assets of interest in this study, but the interaction among different asset classes is recognized and explicitly modeled. Fleming et al. (1998) investigate volatility linkages and Rigobon and Sack (2003) identify the contemporaneous interactions between prices. Both studies use data for the US stock, treasury bond and bill markets. Closer to our point of interest is Kaminsky and Reinhart (2002) who study co-movements in several assets for various countries. However, they limit themselves to a fairly small sample period of two years and a half. Whereas these authors date peaks in interest rates and spreads and perform a principal component analysis, the present analysis applies more formal techniques to investigate linkages across markets.

Models which allow for switches in regimes are very well suited for the proposed investigation on spillovers. Hamilton and Susmel (1994) apply such a model to volatility of returns on the US stock market. Ramchand and Susmel (1998) analyze regime dependent cross correlations among stock markets. Edwards and Susmel (2003) estimate regime-switching models for the interest rate volatility of various emerging countries.

In section I the data is described. Section II proposes a multivariate model to estimate time-varying correlations directly. In order to define high and low volatility states endogenously, section III uses univariate regime switching models. Section IV applies bivariate regime switching models. A bivariate regime switching model allows to test whether correlations among assets change with changes in the volatility states. Section V discusses in detail some periods of high volatility, namely the Mexican (1994), Asian (1997), Russian (1998), and Brazilian crisis (1999) and the accounting scandals in the US (2001 and 2002). Finally, section VI concludes.

I. Data description

Daily data from 4/1/1994 till 26/6/2003 is used. All series are from Bloomberg. For the stock market the S&P index, a value-weighted index of the 500 largest companies listed at the New York stock exchange, is taken.

Emerging market bonds are represented by JP Morgan's EMBI Global (emerging market bond index global). This index tracks sovereign US dollar denominated bonds for emerging economies. Emerging economies are economies which are classified as low and middle income countries by the World Bank. The bonds included have at least two and a half years to maturity, a face value of over 500 million US dollar and they are liquid in the sense of having daily price quotes from at least one broker. JP Morgan also provides other emerging market indices, like the EMBI+ or the EMBI Brady Broad. However, correlations between these indices are around 0.99, implying any one can be chosen without substantially influencing the results. EMBI Global has been taken, because it is the one with the longest time series available.[2]

High yield corporate bonds are bonds rated below BBB or Baa3, i.e. rated to be distinctly speculative or predominately speculative. These bonds are also known as junk bonds, non-investment grade bonds and low-grade bonds. In the present analysis one particular high yield corporate bond is used, namely the bond rated B2. This bond's average daily return is very close to the average daily return of stocks, which make them easy to compare. Note, however, that the yields on corporate bonds are highly correlated. Correlations between distinctly speculative bonds (BB1 to B3) range from 0.83 to 0.95.

All three series, S&P index, EMBI Global and B2 corporate bond yield are plotted in figure 1. Eye-balling the graphs it can be seen that both, the stock market and the emerging bond market index increased substantially over the sample period. However, there have been major downwards moves, some of them occurring at the same time. Low-grade corporate bond yields are showing pronounced spikes, most of them are related to price decreases in the other markets.

The subsequent analysis concentrates on three asset classes, represented by the S&P 500 index (denoted as SP), the emerging market bond index ($EMBI$) and the index for low-grade corporate bonds rated B2 ($B2$). Daily holding period returns are shown in figure 2. Holding an asset for n days is said to give an n-days holding period return. The holding period return for n days at date t, hpr_t, is defined as an asset's price at time t, over its price at $t-n$, $hpr_t = 100 * \left(\frac{P_t}{P_{t-n}} - 1\right)$. Holding period returns are easily computed for SP and $EMBI$, where price data is available, but for $B2$ only yields are given. However, for bonds with long maturities there is an approximate way of computing holding period returns from yields. The corporate bonds used here have maturities of ten years, therefore, this approximation is appropriate. For y_t being the yield of an asset (e.g. 1.01, measured for n/360), the n-days holding period return at t is given by $hpr_t = 100 * \left(\frac{y_{t-n}}{y_t} + y_{t-n} - 1\right)$.

Table I gives basic statistics for holding period returns at several frequencies. Average daily returns are around 0.037% for stocks and corporate bonds and 0.044% for emerging market bonds. Note the large negative skewness for emerging market bonds. Risk averse investors want to be compensated for negative skewness (see e.g. Harvey and Siddique, 2000). This may explain the higher average return on emerging market bonds compared to stocks or corporate bonds. Excess kurtosis is widely present in all assets.

[Insert table I about here]

Figure 2 provides plots of daily returns for all three assets. No clear pattern can be observed for the movements of returns, although the extreme changes during financial crisis are clearly visible. Periods of high volatility are followed by more tranquil periods. In the subsequent sections conditional volatilities are, therefore, estimated with a GARCH specification. GARCH models have been extensively used in the financial literature to model time-varying volatilities (for a survey see Bollerslev et al., 1992). Unconditional correlation coefficients are given in table II. The different asset classes are not very highly correlated. Therefore, investing in all three asset classes reduces the volatility of such a portfolio substantially, as can be seen in table III. However, correlations may increase dramatically in times of financial distress. It is exactly during crisis periods when diversification is most valuable. If correlations increase precisely in these moments, diversification benefits are limited. In order to investigate this possibility, covariances are allowed to be time-variant as well.

[Insert tables II and III about here]

II. Time-varying correlations

A. A multivariate model

The estimated model follows closely Bollerslev et al. (1988). Daily holding period returns for the different assets at date t are denoted by the vector y_t,

$$\mathbf{y_t} = [SP_t, EMBI_t, B2_t]'. \tag{1}$$

The model is then

$$\mathbf{y}_t = \mathbf{c} + \boldsymbol{\phi}\mathbf{y}_{t-1} + \boldsymbol{\varepsilon}_t \tag{2}$$

$$vech(\mathbf{H}_t) = \boldsymbol{\Psi} + \mathbf{A}vech(\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}) + \mathbf{B}vech(\mathbf{H}_{t-1})$$

$$\boldsymbol{\varepsilon}_t \sim N(0, \mathbf{H}_t),$$

with $\mathbf{c}$ being a vector of constants and $\boldsymbol{\phi}$ the vector of parameters on lagged returns. Parameters in the volatility equations are given by matrices $\boldsymbol{\Psi}$, $\mathbf{A}$ and $\mathbf{B}$. Diagonality is imposed on matrices $\mathbf{A}$ and $\mathbf{B}$. Innovations are denoted by $\boldsymbol{\varepsilon}_t$ and $vech(\cdot)$ stacks the lower portion of a symmetric matrix into a vector.

The models for all frequencies are reasonably well specified. Table IV shows basic statistics for standardized residuals and squared standardized residuals. Standardized residuals for asset i are denoted by $u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{H_{ii,t}}}$.

[Insert table IV about here]

The estimated standard deviations of daily returns are shown in figure 3. As expected, several periods of high volatility are identified for each asset class. Although some of these high volatility periods coincide across assets, many of them are asset specific. In table V correlation coefficients for estimated conditional volatilities are shown. Indeed, there is some correlation of volatilities, but it is not very high. To check for robustness, correlation coefficients for squared returns are also computed and shown in table V. The above mentioned results are reinforced.

[Insert table V about here]

Conditional correlation coefficients of daily returns are plotted in figure 4. It can be seen that correlation coefficients are clearly not constant over time. Correlation coefficients change substantially, even being negative for many days. Simply looking at the graphs no evidence arises that correlations are particularly high during some periods. However, the next section analysis in great detail if correlations indeed do not increase during financial market turbulences.

B. Correlations during financial crisis

It has been seen in table II that unconditional correlation coefficients are not very high. However, these correlations may increase dramatically in times of financial distress. It is exactly during crisis periods when diversification is most valuable. If correlations increase precisely in these moments, diversification benefits are limited. In what follows the terms financial crisis and periods of very high volatility are used as synonyms.

In tables VI to IX conditional correlation coefficients during periods with high volatility and "normal" periods are shown. For comparison, unconditional and average conditional correlations are provided as well. On a daily frequency the average conditional correlation for SP and EMBI is around 0.32, for SP and B2 around 0.15 and for EMBI and B2 around 0.21. Panel A of table VI shows these correlation coefficients in times of high volatility, namely when the volatility of each asset return is larger than the average volatility. As argued above, it is important to know if correlations increase in times of high volatility in order to assess diversification benefits. All markets may be in a high volatility state, but as long as correlations between returns are low, diversification benefits remain substantial. However, in times of financial crisis both, volatilities and correlations may be very high. On contrast, if correlations stay fairly low even during high volatility states then diversification provides substantial value also during financial distress. In fact, correlations during high volatility periods are lower than the average correlations. What is more, the correlation between SP and B2 is even negative. At days when the conditional volatility of returns is even higher, namely twice the average volatility, also EMBI and B2 are negatively correlated. However, the correlation between SP and EMBI increases above the average correlation to 0.43, but is still far from being perfectly correlated. Panel B of table VI shows correlation coefficients for periods of low volatility. Correlations are close to or above the average correlation. Given that correlations are negative for high volatility periods, this is not surprising. Panel C and D of table VI provide correlation coefficients for periods of high volatility in only one market. It is very well possible that there is a crisis in one market, which then spills over to the other markets. For example, a stock market crash may lead to high volatility in stock returns, and then impact on emerging market bonds. The results are strikingly similar for all correlations. During periods of high volatility, correlations are lower than average, whereas during periods of low volatility correlations are relatively high. In times of financial crisis diversification benefits do not decrease, rather increase!

[Insert table VI about here]

Conditional correlations and volatilities are estimated with the model explained in subsection II.A. This model is estimated by maximum likelihood. Nevertheless, to check for robustness, correlations and volatilities are also computed with a rolling window of 22 days. The above results are confirmed, as can be seen in table VII. The only exception is the correlation between SP and EMBI, on days when the volatility of EMBI is high. At these days the correlation coefficient is larger than on average, opposed to smaller, as in table VI.

[Insert table VII about here]

Tables VIII and IX perform the same analysis for weekly and monthly holding period returns. The results with weekly returns confirm the results for daily data. Correlations are lower than average, when volatilities are high, and higher than average when volatilities are low. In general, the same conclusions are drawn with monthly returns. However, the correlation between SP and EMBI is higher (lower) than average when volatilities in both markets are high (low). Nevertheless, returns are far from being perfectly correlated.

[Insert tables VIII and IX about here]

III. Univariate regime switching models

A. A volatility model

Instead of defining high and low volatility states ex-post, it is possible to estimate the probability to be in each of these states endogenously. Hamilton (1989) was the first to propose such a regime switching model. Hamilton and Susmel (1994) applied this methodology to conditional volatility. A similar model will be used in this section as well. The switching ARCH (SWARCH) model for each asset, $y_{\mathbf{t}} \epsilon \{SP_t, EMBI_t, B2_t\}$, is given by

$$
\begin{aligned}
y_t &= c + \phi y_{t-1} + \varepsilon_t, \qquad (3) \\
h_t/\gamma_{s_t} &= a_0 + \sum\nolimits_{i=1} a_i \varepsilon_{t-i}^2 / \gamma_{s_{t-i}} \\
i &= 1, 2, ..., q, \text{ and } s_t = 1, 2, ..., K, \\
\varepsilon_t &\sim N(0, h_t),
\end{aligned}
$$

where γ's are scale parameters to capture the change in regime. One of these scale parameters is unidentified, and therefore set equal to 1. In this model changes in regime occur only in the volatility equation. The mean parameters, c and ϕ, are assumed to be constant. The state of the economy, the regime, are denoted by s_t and are assumed to be the outcome of a K-state Markov chain:

$$PROB(s_t = j | s_{t-1} = i) = p_{ij}. \qquad (4)$$

The probability that state i will be followed by state j is described by p_{ij}. This transition probabilities from one state to another are assumed to be constant. The switching model is estimated by maximum likelihood. The model also allows to compute probabilities of being in a certain state. Smoothed probabilities, $p(s_t = j|y_t, y_{t-1})$, are then inferences about the state of the economy at date t, using data over the full sample.

B. Estimation results

Weekly holding period returns are used to estimate the regime switching models. Weekly frequency allows to capture the interesting features of the data, without the potential noise of daily data. Monthly data does not provide enough observations to identify different states carefully. Estimation results of an AR(1)-SWARCH(3,1) models for all returns are presented in table X.[3]

[Insert table X about here]

The number of regimes, K, has been tested for all returns.[4] All assets are best described by a model with three regimes, $K = 3$. Concerning lagged innovations, only the parameter a_1 is significant, that is, only innovations lagged by one period affect volatility. Therefore, the best model is a SWARCH(3,1). As can be seen in table X, no serial correlation is left in the residuals. All switching parameters, γ_{st}, are significantly different from one in all series. Volatility is around 3 to 4 times higher in regime 2, the moderate volatility state. However, in regime 3, volatility is more than ten times the volatility of a normal period. For emerging market bonds, volatility multiplies by 40 in times of a crisis. The estimated values for the transition probabilities are reported in table XI. A few probabilities hit the non-negative constraint and are therefore imposed to be zero.[5]

[Insert table XI about here]

Figure 5 shows the smoothed probabilities for being in the high volatility state. It is clearly visible that the three asset classes share periods of high volatility. In particular during the Russian crisis, in August 1998, probabilities to be in the high volatility state are estimated one or close to one for all assets. US stocks and corporate bonds share the high volatility regime during the accounting scandals, in July 2002. However, the interesting question is if correlations among these assets increased during periods of high volatility. Table XII reports correlation coefficients for the different states. The economy is said to be in a certain state if the smoothed probability of being is this state exceeds 0.5 (see Hamilton, 1989). There is strong evidence that correlations decrease in times of high volatility.

[Insert table XII about here]

Applying regime-switching models to characterize volatility states, and computing correlations conditional on these states, confirms the results obtained in the previous section. Nevertheless, in this framework it is not possible to test if correlations decrease significantly in periods of high volatility. The next section proposes a bivariate regime switching model to address this issue.

IV. Bivariate regime switching models

A. A volatility model

The here described bivariate regime switching model allows to estimate volatility states and correlations across states jointly. However, the estimation of this model is rather complex and intensive in computation time. Weekly holding period returns are used and the sample size is restricted to start in January 1996, and ends, as in the previous sections, in June 2003. For this shorter sample period assets are reasonably well described by two regimes, a high and low volatility state. In the bivariate model, with two volatility states for each assets, there are four primitive states s_t^*. Take for example a bivariate system for stocks and corporate bonds:

$s_t^* = 1$: Stocks - low volatility; bonds - low volatility.

$s_t^* = 2$: Stocks - low volatility; bonds - high volatility.

$s_t^* = 3$: Stocks - high volatility; bonds - low volatility.

$s_t^* = 4$: Stocks - high volatility; bonds - high volatility.

The system can be written as

$$\begin{aligned} \mathbf{y}_t &= \mathbf{c} + \boldsymbol{\phi}\mathbf{y}_{t-1} + \boldsymbol{\varepsilon}_t \\ \boldsymbol{\varepsilon}_t &\sim N(0, \mathbf{H}_t), \end{aligned} \qquad (5)$$

where $\mathbf{y}_t = [y_t^{(1)}, y_t^{(2)}]$ is a 2x1 vector of returns for two assets; $\mathbf{c} = [c_1, c_2]$, $\boldsymbol{\phi} = [\phi_1, \phi_2]$, and $\boldsymbol{\varepsilon}_t = [\varepsilon_t^{(1)}, \varepsilon_t^{(2)}]$ is a vector of disturbances which follows a bivariate normal distribution with zero mean and time-varying conditional covariance matrix $\mathbf{H}_t$. The conditional covariance matrix $\mathbf{H}_t$ is a constant correlation matrix, with the diagonal elements following a SWARCH process. The SWARCH equations are similar to the univariate model of the previous section, as outlined in equation (3). The correlation coefficient, ρ_{st}, is state dependent. To keep the system tractable correlations in state 1 and 2 are equal; accordingly, correlations in state 3 and 4 are the same. In other words, correlations vary only with the state of the first asset in the system. The probability law causing the economy to switch from one state to another follows a Markov chain, P^*, with a typical element given by $PROB(s_t^* = j | s_{t-1}^* = i) = p_{ij}^*$. This is a very general specification, as discussed in Hamilton and Lin (1996). It allows to test for volatility synchronization as well as for independence of volatility states across assets (see e.g. Susmel and Edwards, 2003).

B. Estimation results

Bivariate models for $[SP, EMBI]$; $[SP, B2]$ and $[EMBI, B2]$ are estimated by maximum likelihood.[6] The estimation results are given in table XIII. Likelihood ratio test for the hypothesis of volatility synchronization are reported as well. Indeed, volatility is found to be synchronized for the stock market and the corporate bond market. The implied restrictions are imposed on the model reported here. Volatility is significantly different from unity during high volatility states. What is more, volatility is around 3 to 6 times higher in the high volatility state than during normal weeks. For example, in the model $[SP, EMBI]$, volatility of the stock market in the high volatility state is 2.8 times the volatility of the stock market in the low volatility regime, as given by parameter γ_{21}. Similarly, volatility of emerging market bonds is 6.6 times the volatility in normal periods, as denoted by parameter γ_{22}.

[Insert table XIII about here]

Correlations between the stock and emerging bond market, as well as the emerging and corporate bond market, are significantly lower in the high volatility state than in the low volatility state. In the model $[SP, EMBI]$ the correlation coefficient for the low volatility state, ρ_1, is 0.7 and for the high volatility state, ρ_2, is 0.3. In the model $[EMBI, B2]$ the correlation coefficient for the low volatility state is 0.4 and for the high volatility state is zero. Correlations for the stock and corporate bond market are close to zero in both states.

Transition probabilities for all models are given in table XIV. Some of the probabilities hit the non-negativity constraints and have been set equal to zero.

[Insert table XIV about here]

Smoothed probabilities for all models are given in figures 6 to 8. Panel A contains the probabilities for being in the first primitive state, $s_t^* = 1$, that is both assets are in a low volatility state. Panel B contains probabilities for the second primitive state, $s_t^* = 2$, and so on. The here estimated models capture very well crisis periods. Smoothed probabilities are high for all assets during major financial crisis. Nevertheless, the estimated correlations during these crisis periods decrease, rather than increase, compared to low volatility periods. All assets share common states. Volatility is in a particular state for all assets during the same, or adjacent, weeks. In particular, volatility of US stock and corporate bond markets are synchronized. However, as Panel B and C of figures 6 and 8 show, emerging market bonds do not share all volatility states with US stocks and US low-grade corporate bonds.

The predominant joint state is the first one, with low volatility in both assets. The expected duration of this state is $1/(1 - p_{11}) = 13.4$ weeks for the model $[SP, EMBI]$;

24 weeks for the model $[SP, B2]$ and 26 weeks for the model $[EMBI, B2]$. The expected duration of the high volatility state for both assets, $s_t^* = 4$, is 18 weeks, 7 weeks and 5 weeks, respectively.

V. A close look at financial crisis

In the 1990's and early 2000's several financial crisis have occurred. It is worthwhile to look at some of them in more detail. Table XV gives holding period returns, standard deviations and correlation coefficients for days around the major financial crisis. Conditional correlations and volatilities are estimated by a multivariate GARCH model, as outlined in section II. Panel A of table XV discusses the Mexican crisis, defined as the day of the devaluation of the Mexican peso at December 20, 1994. Volatility increased substantially for EMBI, but did not increase in the other markets. What is more, correlation between EMBI and SP and EMBI and B2 decreased significantly. The correlation between stock and corporate bond returns did not change.

[Insert table XV about here]

Panel B shows the same information for the Asian crisis, dated as the US stock market crash of October 27, 1997, which followed a series of devaluations in Asia. The picture here is different. In the run-up to the crisis correlation coefficients across all markets are high. After the crisis only the correlation between SP and EMBI stays high, whereas the correlations with B2 turn strongly negative. Volatility jumps up for both SP and EMBI, and to a less extent for B2, as well. The Asian crisis was probably one of the major financial crisis in the 1990's. Asset returns during this period are correlated, but they are far from perfectly correlated. In addition, some correlations turn negative after the peak of the crisis.

Panel C analyses the Russian crisis, dated as the devaluation of the Russian ruble at August 17, 1998. Correlations are low before the crisis and stay low afterwards or even turn negative. Only the volatility of EMBI jumps up, without much volatility change in the other markets.

On January 13, 1999 the Brazilian real was devalued. Correlations among assets turn highly negative for SP and B2 and EMBI and B2, whereas the correlation between SP and EMBI stays around 0.3. There is not much change in volatility for SP and B2, but the volatility of EMBI jumps up.

In 2001 and 2002 several accounting scandals occurred in the US. It is interesting to check whether these events had some impact on asset markets. The events are dated as December 2, 2001 and July 21, 2002, when Enron and Worldcom, respectively, filed for bankruptcy. Correlations and volatilities did not change too much around the beginning of December 2001, when Enron filed for bankruptcy. In July 2002, when Worldcom filed for bankruptcy, volatility of the stock market is relatively high, whereas volatility of emerging market bond returns are relatively low. Correlations between EMBI and B2 are moderately positive and between SP and B2 are moderately negative.

Looking carefully at the daily behavior of volatilities and correlations during financial periods shows that markets do not move together very closely. Idiosyncratic shocks seem to be the main driving forces in each market. Although in the run-up to the Asian crisis correlations across all markets were relatively high, most of these correlations turned negative immediately after the crisis occurred.

VI. Conclusions and further research

This paper studies the most important assets in the high yield market and interactions among them. These assets are US stocks, emerging market bonds and US low-grade corporate bonds. All of them are characterized by a similar average return, which makes them close substitutes for long-term investors. However, returns are far from being perfectly correlated, hence, investing in different assets provides diversification benefits. The size of potential diversification benefits is determined by the correlations among asset returns.

Unconditional correlation coefficients are not very high. However, correlations may increase dramatically in times of financial distress. It is exactly during crisis periods when diversification is most valuable. If correlations increase precisely in these moments, diversification benefits are limited. It has been found that, in general, correlations are low (high) when volatilities are high (low). In times of financial crisis diversification benefits do not decrease, rather increase! All, univariate and bivariate regime switching models, as well as multivariate time-varying correlations models confirm these conclusions.

Looking carefully at the daily behavior of volatilities and correlations during financial periods shows that markets do not move together very closely. Idiosyncratic shocks seem to be the main driving forces in each market. One exception is the run-up to the Asian crisis with relatively high correlations across all markets. However, most of these correlations turned negative immediately after the crisis occurred.

The analysis performed in this paper opens the way for further research in several directions. In order to investigate financial crisis and the spillovers across markets further it might be helpful to identify structural shocks. This would then allow to trace back the market from which high volatility states originated. Modeling the excess kurtosis of returns, e.g. by a mixture of two normal distributions, and the potentially asymmetric impact of news, e.g. by an exponential GARCH, might be useful, too. Besides returns also yield spreads are likely to contain information on spillovers across markets and deserve some further analysis.

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Notes

[1]Two of the most prominent cases are the bankruptcy of Enron (December 2, 2001) and Worldcom (July 21, 2002).

[2]See Bank of England (1999) for a detailed discussion of emerging market indices.

[3]The GAUSS codes used for the estimation of these models follow closely J. D. Hamilton's codes. His code is available from his webpage at the University of California, San Diego at:

http://weber.ucsd.edu/%7Ejhamilto/.

[4]The hypothesis of two regimes is readily rejected for all assets. Most p-values are very small. However, the hypothesis of no regime switching cannot be tested direcly in this framework. Hansen (1992) proposed tests for the null hypothesis of no switching. Nevertheless, the small p-values suggest that also more formal tests will reject the null of no regime switching.

[5]Whenever a maximum likelihood estimate hits a non-negativity constraint the regularity conditions for computing asymptotic standard errors fail to hold. Nevertheless, when the respective parameter is imposed to be zero, there is no problem with respect to the regularity conditions for the remaining free parameters (see e.g. Hamilton and Lin, 1996).

[6]The GAUSS codes used for the estimation of these models follow closely R. Susmel's codes, available from his webpage at the University of Houston, at: http://www.bauer.uh.edu/rsusmel/.

A Figures and Tables

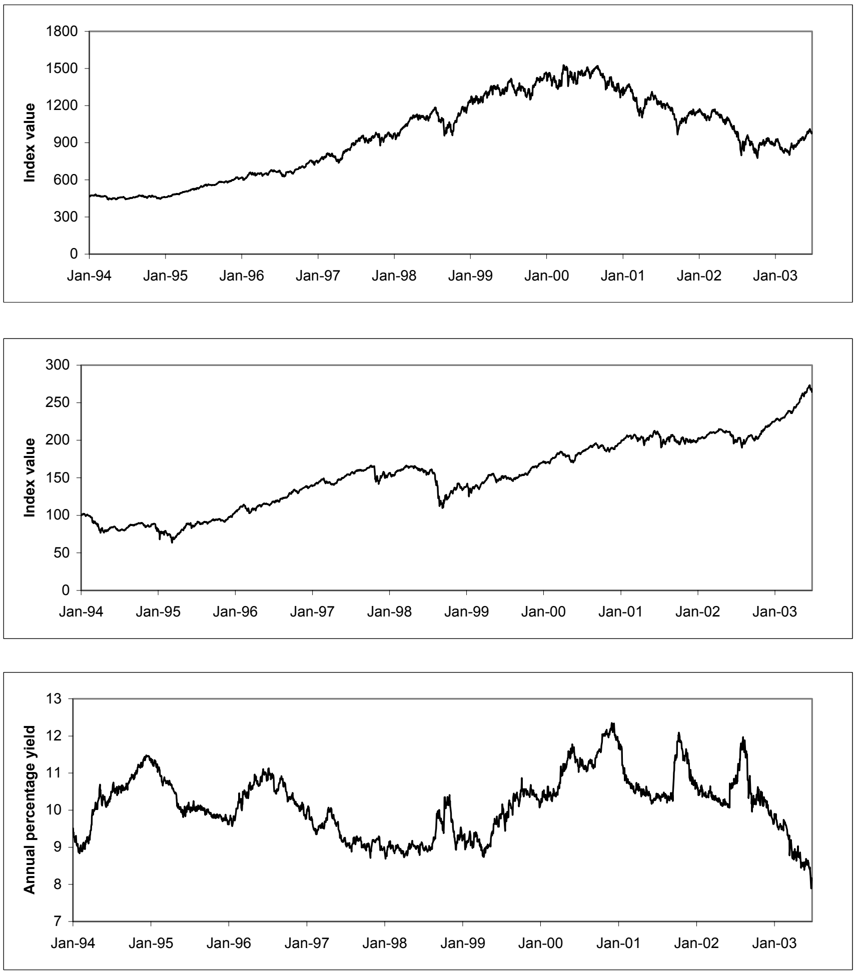

Figure 1: **Stock and bond market data.** Top panel: S&P 500 US stock market index. Second panel: JP Morgan Emerging Market Bond Index EMBI Global. Third panel: Yields of US low-grade corporate bond rated B2.

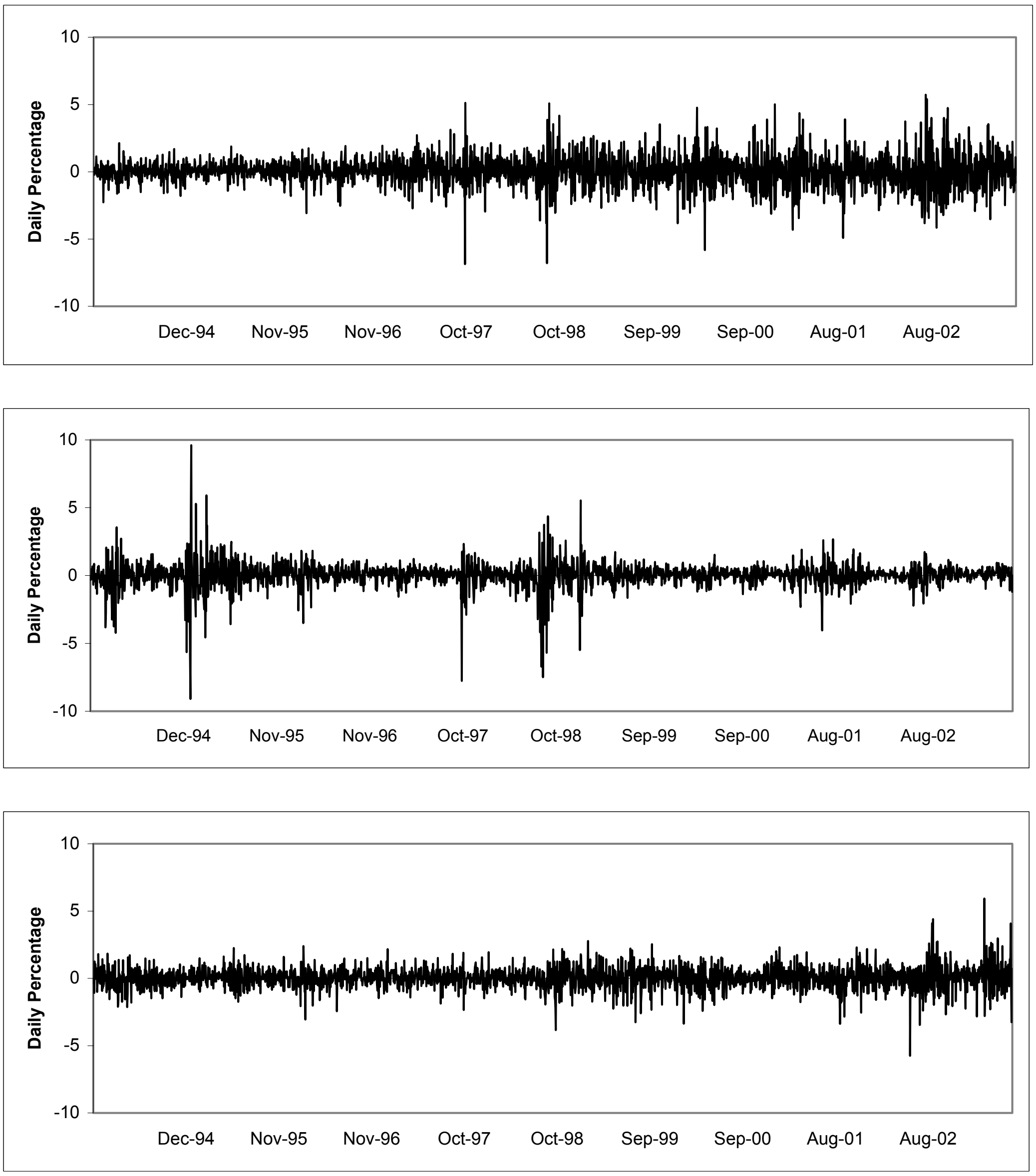

Figure 2: **Daily holding period returns.** Top panel: US stocks. Second panel: Emerging market bonds. Third panel: US low-grade corporate bonds rated B2.

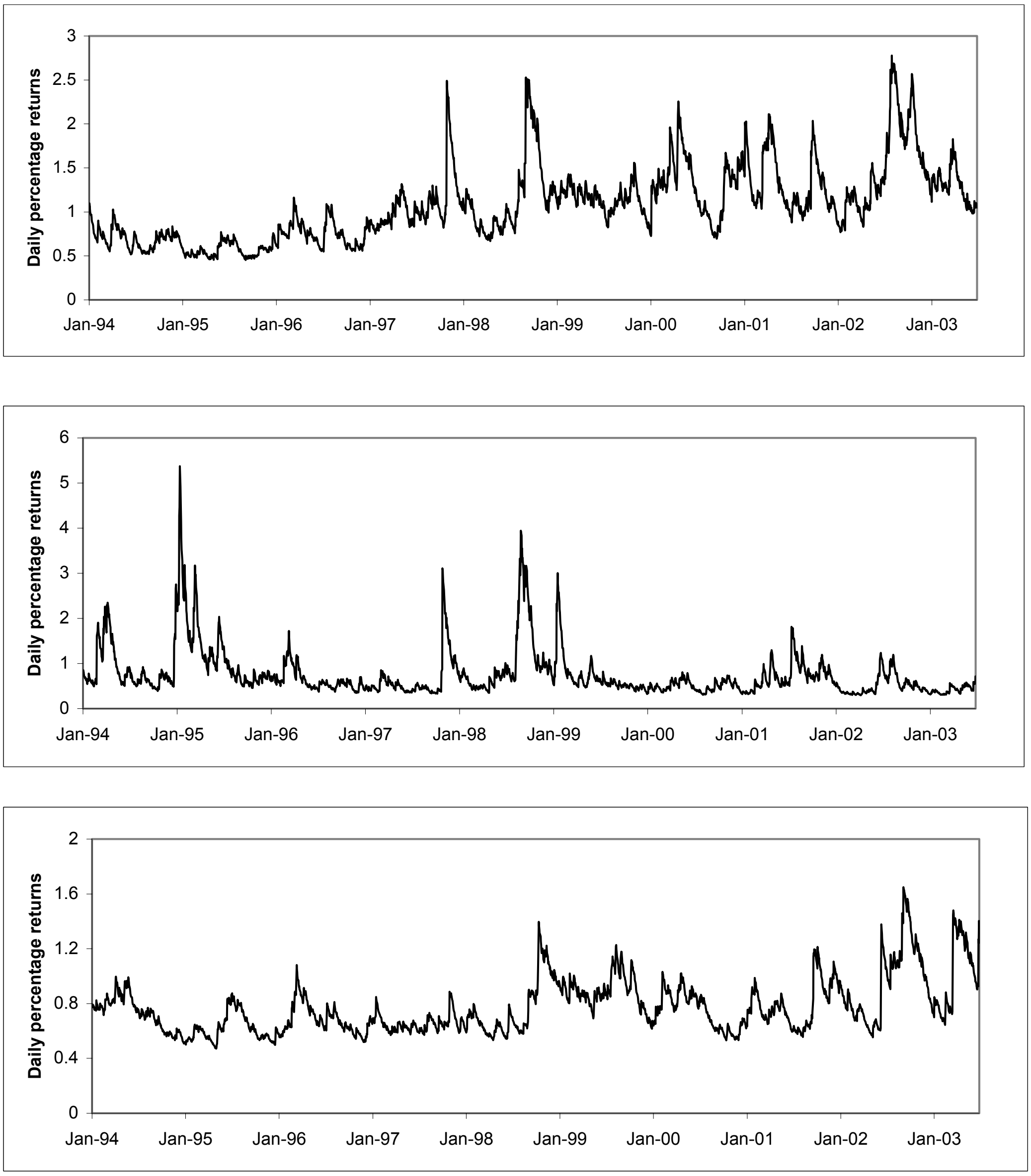

Figure 3: **Daily conditional standard deviations from multivariate GARCH model.** Top panel: US stocks. Second panel: Emerging market bonds. Third panel: US low-grade corporate bonds rated B2.

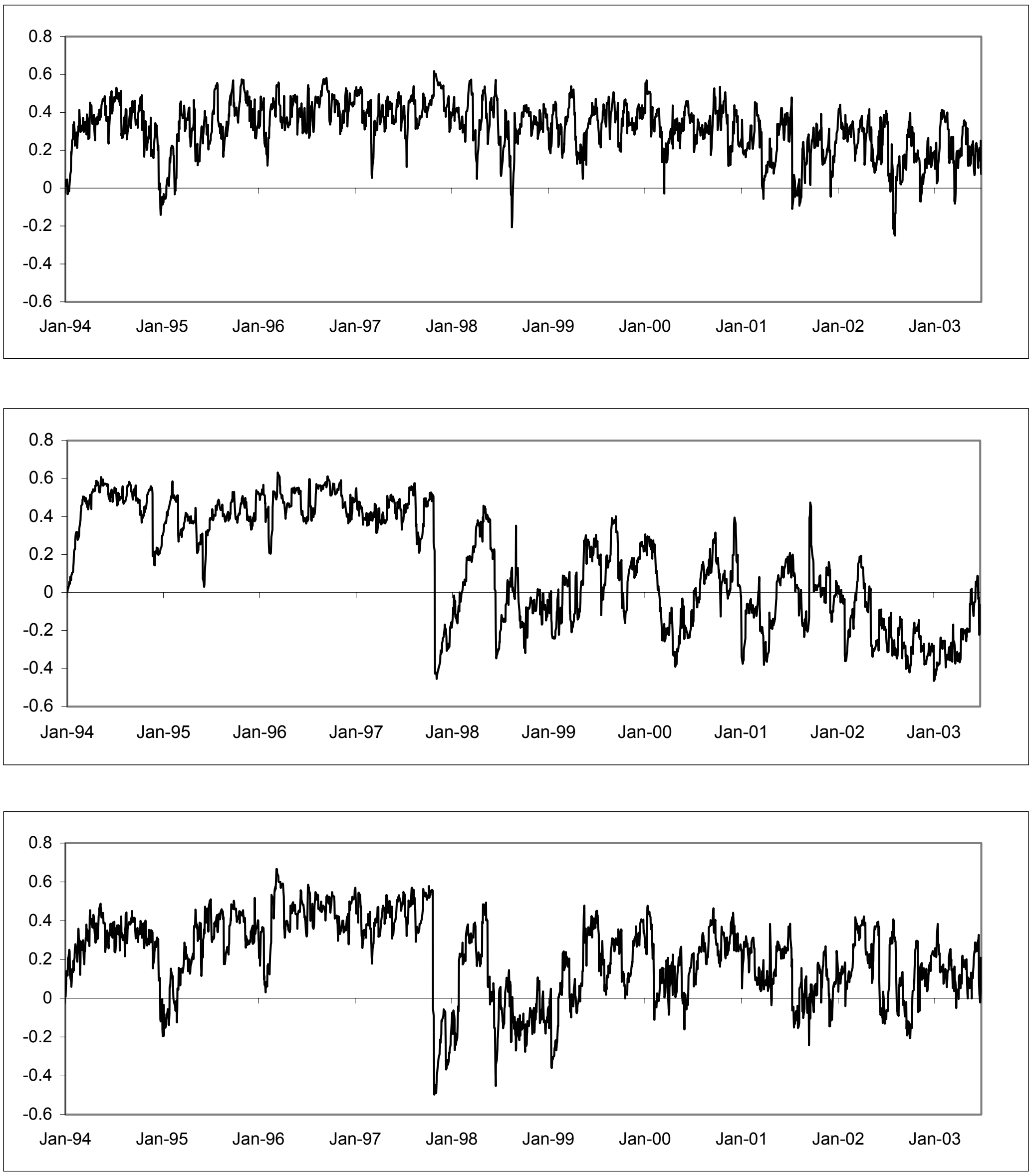

Figure 4: **Time-varying correlation coefficients for daily returns, estimated with a multivariate GARCH model.** Top panel: US stocks and emerging market bonds. Second panel: US stocks and US low-grade corporate bonds rated B2. Third panel: Emerging market bonds and US low-grade corporate bonds rated B2.

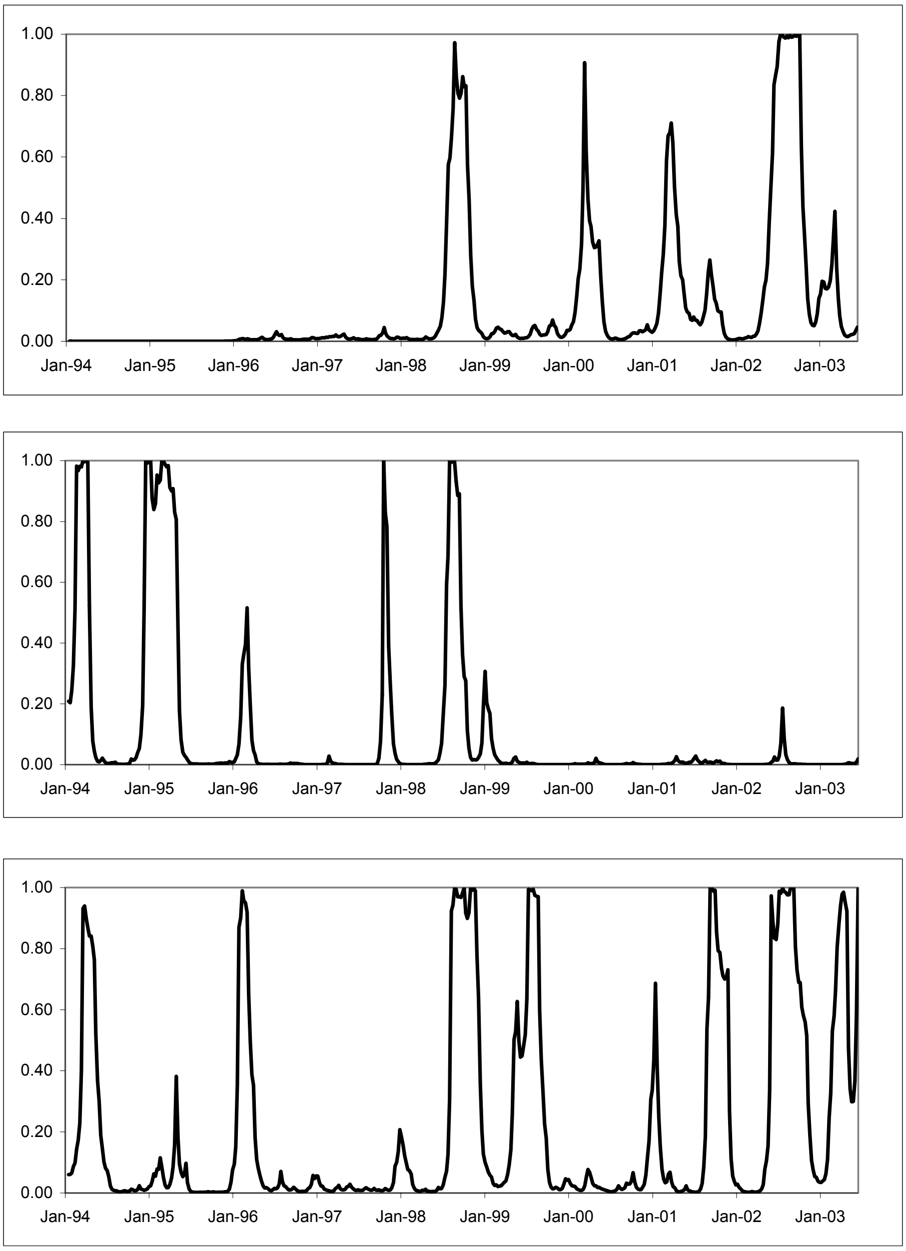

Figure 5: **Smoothed probabilities, from univariate regime switching models, that market was in the high volatility regime for the indicated week.** Top panel: US stocks. Second panel: Emerging market bonds. Third panel: US low-grade corporate bonds rated B2.

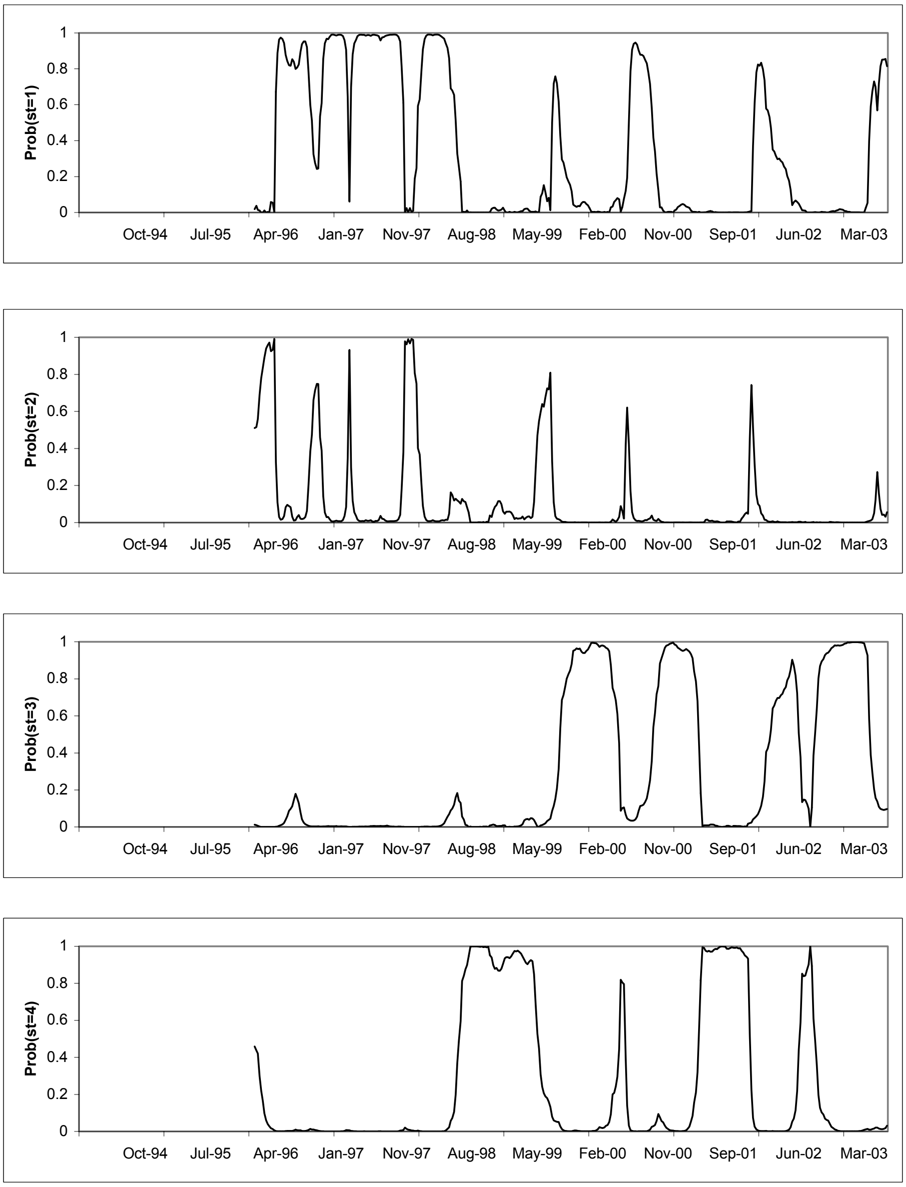

Figure 6: **US stocks and emerging market bonds. Smoothed probabilities, from a bivariate switching model, that market was in the respective volatility state for each indicated week.** Top panel: US stocks and emerging market bonds are both in the low volatility state. Second panel: US stocks are in the low, emerging market bonds are in the high volatility state. Third panel: US stocks are in the high, emerging market bonds are in the low volatility state. Fourth panel: US stocks and emerging market bonds are both in the high volatility state.

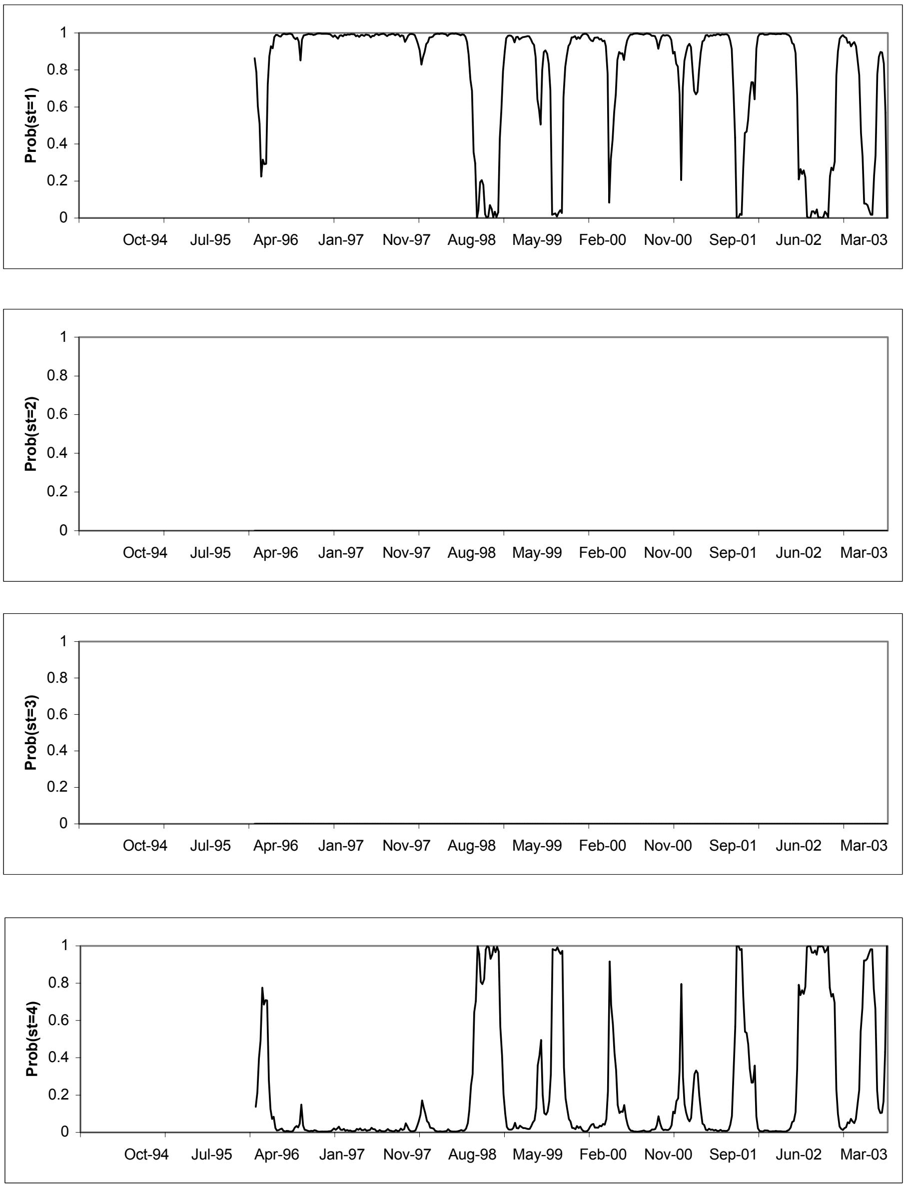

Figure 7: **US stocks and US low-grade corporate bonds. Smoothed probabilities, from a bivariate switching model, that market was in the respective volatility state for each indicated week.** Top panel: US stocks and US low-grade corporate bonds rated B2 are both in the low volatility state. Second panel: US stocks are in the low, US low-grade corporate bonds are in the high volatility state. Third panel: US stocks are in the high, US low-grade corporate bonds are in the low volatility state. Fourth panel: US stocks and US low-grade corporate bonds are both in the high volatility state.

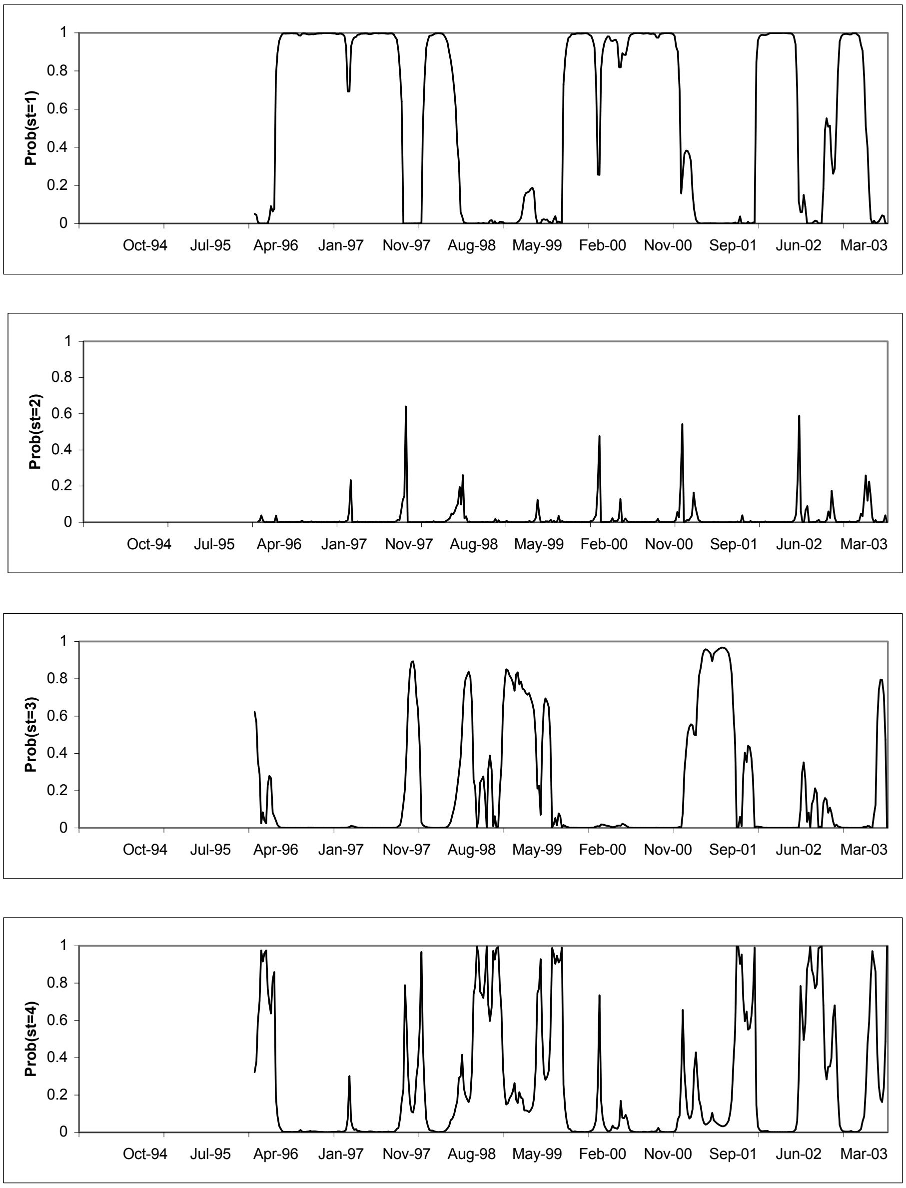

Figure 8: **Emerging market bonds and low grade corporate bonds. Smoothed probabilities, from a bivariate switching model, that market was in the respective volatility state for each indicated week.** Top panel: Emerging market bonds and US low-grade corporate bonds rated B2 are both in the low volatility state. Second panel: Emerging market bonds are in the low, US low-grade corporate bonds are in the high volatility state. Third panel: Emerging market bonds are in the high, US low-grade corporate bonds are in the low volatility state. Fourth panel: Emerging market bonds and US low-grade corporate bonds are both in the high volatility state.

Table I
Summary statistics for holding period returns

SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations), for weekly returns 11/01/1994 to 24/06/2003 (494 observations) and for monthly returns 01/02/1994 to 01/06/2003 (113 observations). SD, Skew and Kurt denote standard deviation, skewness and kurtosis, respectively. Critical values for the autocorrelation functions at 1% are 0.05 (daily), 0.12 (weekly) and 0.24 (monthly). Q(5) and Q(10) are the Ljung-Box Q-statistics for 5 and 10 lags, respectively.

	Mean	SD	Skew	Kurt	Q(5) p-value	Q(10) p-value	Autocorrelation with lag 1	2	3	4	5
(A) Daily returns											
SP	0.037	1.138	0.015	6.273	0.18	0.19	-0.010	-0.021	-0.040	-0.009	-0.029
EMBI	0.044	0.922	-0.987	22.009	0.00	0.00	0.154	-0.086	-0.014	0.005	0.041
B2	0.036	0.793	-0.076	7.579	0.00	0.00	-0.078	-0.031	-0.008	-0.008	-0.034
(B) Weekly returns											
SP	0.183	2.524	0.048	5.934	0.00	0.00	-0.153	-0.004	0.116	-0.128	0.006
EMBI	0.226	2.283	-1.017	14.782	0.00	0.00	-0.117	0.203	0.035	-0.104	0.062
B2	0.233	1.648	0.425	8.060	0.00	0.00	-0.108	0.124	0.078	-0.065	0.081
(C) Monthly returns											
SP	0.750	4.515	-0.267	2.753	0.89	0.69	0.030	-0.032	0.045	-0.039	0.094
EMBI	0.975	4.604	-1.706	10.140	0.60	0.60	0.110	-0.110	-0.020	0.002	-0.080
B2	0.951	3.559	0.442	6.055	0.76	0.96	-0.010	-0.027	-0.074	0.090	-0.086

Table II

Unconditional correlation coefficients

SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations), for weekly returns 11/01/1994 to 24/06/2003 (494 observations) and for monthly returns 01/02/1994 to 01/06/2003 (113 observations).

	SP	EMBI	B2
(A) Daily returns			
SP	1.00		
EMBI	0.28	1.00	
B2	-0.08	0.08	1.00
(B) Weekly returns			
SP	1.00		
EMBI	0.29	1.00	
B2	0.01	0.20	1.00
(C) Monthly returns			
SP	1.00		
EMBI	0.51	1.00	
B2	0.32	0.39	1.00

Table III

Basic statistics for each market and an equally weighted portfolio

SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The portfolio is constructed as an equally weighted average of returns on SP, EMBI and B2. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations), for weekly returns 11/01/1994 to 24/06/2003 (494 observations) and for monthly returns 01/02/1994 to 01/06/2003 (113 observations).

	Mean	Std. dev.	Skewness	Kurtosis
(A) Daily returns				
Equally weighted portfolio	0.039	0.628	-0.519	8.694
SP	0.037	1.138	0.015	6.273
EMBI	0.044	0.922	-0.987	22.009
B2	0.036	0.793	-0.076	7.579
(B) Weekly returns				
Equally weighted portfolio	0.216	1.508	-0.526	4.802
SP	0.183	2.524	0.048	5.934
EMBI	0.226	2.283	-1.017	14.782
B2	0.233	1.648	0.425	8.060
(C) Monthly returns				
Equally weighted portfolio	0.873	3.102	-0.243	5.723
SP	0.750	4.515	-0.267	2.753
EMBI	0.975	4.604	-1.706	10.140
B2	0.951	3.559	0.442	6.055

Table IV
Basic statistics for residuals from multivariate GARCH model
Statistics are based on standardized residuals and squared standardized residuals, resulting from a multivariate GARCH model for returns on US stocks, US low grade corporate bonds rated B2 and emerging market bonds. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations), for weekly returns 11/01/1994 to 24/06/2003 (494 observations) and for monthly returns 01/02/1994 to 01/06/2003 (113 observations). Q(20) denotes the Ljung-Box test for serial correlation with 20 lags. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2.

	SP	EMBI	B2
(A) Daily data			
Mean	-0.055	-0.078	0.000
Variance	1.000	0.989	0.994
Skewness	-0.381	-0.917	-0.266
Kurtosis	4.836	7.657	8.393
Q(20), p-value	0.152	0.018	0.066
Q(20) for squared residuals, p-value	0.926	0.004	0.613
(B) Weekly data			
Mean	-0.110	-0.088	-0.017
Variance	0.986	0.998	1.011
Skewness	-0.231	-1.426	0.192
Kurtosis	3.594	8.682	6.730
Q(20), p-value	0.155	0.943	0.088
Q(20) for squared residuals, p-value	0.406	0.993	0.832
(C) Monthly data			
Mean	-0.055	-0.038	-0.043
Variance	0.947	1.067	1.041
Skewness	-0.309	-1.972	-0.181
Kurtosis	2.611	11.693	4.407
Q(20), p-value	0.399	0.618	0.981
Q(20) for squared residuals, p-value	0.398	1.000	0.460

Table V

Correlation coefficients of squared returns and conditional volatilities

SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations), for weekly returns 11/01/1994 to 24/06/2003 (494 observations) and for monthly returns 01/02/1994 to 01/06/2003 (113 observations). Conditional volatilities are estimated by a multivariate GARCH model for returns on SP, EMBI and B2.

	Squared Returns			Conditional Volatilities		
	SP	EMBI	B2	SP	EMBI	B2
(A) Daily						
SP	1.00			1.00		
EMBI	0.14	1.00		0.12	1.00	
B2	0.19	0.02	1.00	0.52	-0.05	1.00
(B) Weekly						
SP	1.00			1.00		
EMBI	0.03	1.00		-0.04	1.00	
B2	0.18	0.00	1.00	0.57	-0.03	1.00
(C) Monthly						
SP	1.00			1.00		
EMBI	0.36	1.00		0.12	1.00	
B2	0.23	0.18	1.00	0.46	0.47	1.00

Table VI
Conditional correlations of daily returns from a multivariate correlation model
Conditional correlations and volatilities are estimated by a multivariate GARCH model for returns on US stocks, US low grade corporate bonds rated B2 and emerging market bonds. Returns are measured in percent. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations).

		Correlation SP, EMBI	Obs.	Correlation SP, B2	Obs.	Correlation EMBI, B2	Obs.
Unconditional		0.28	2475	-0.08	2475	0.08	2475
Conditional, average		0.32	2474	0.15	2474	0.21	2474
(A) Days with high volatility in both markets							
Volatility is larger than the average volatility		0.30	183	-0.14	538	0.12	235
Volatility is larger than twice the average volatility		0.43	53	-0.21	89	-0.19	5
(B) Days with low volatility in both markets							
Volatility is smaller than the average volatility		0.32	2291	0.23	1936	0.22	2239
Volatility is smaller than twice the average volatility		0.31	2421	0.16	2385	0.21	2469
(C) Days with high volatility in one market							
Volatility is larger than the average volatility of:							
	SP	0.27	894				
	EMBI	0.27	462				
	SP			-0.11	894		
	B2			0.00	906		
	EMBI					0.09	462
	B2					0.13	906
Volatility is larger than twice the average volatility of:							
	SP	0.22	254				
	EMBI	0.28	239				
	SP			-0.22	254		
	B2			-0.17	167		
	EMBI					0.02	239
	B2					0.03	167
(D) Days with low volatility in one market							
Volatility is smaller than the average volatility of:							
	SP	0.34	1580				
	EMBI	0.33	2012				
	SP			0.29	1580		
	B2			0.23	1568		
	EMBI					0.24	2012
	B2					0.26	1568
Volatility is smaller than twice the average volatility of:							
	SP	0.33	2220				
	EMBI	0.32	2235				
	SP			0.19	2220		
	B2			0.17	2307		
	EMBI					0.23	2235
	B2					0.23	2307

Table VII

Conditional correlations of daily returns from a rolling window

Returns are measured in percent. Conditional correlations and volatilities are estimated with a rolling window of 22 days. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations).

	Correlation SP, EMBI	Obs.	Correlation SP, B2	Obs.	Correlation EMBI, B2	Obs.
Unconditional	0.28	2475	-0.08	2475	0.08	2475
Conditional, average	0.35	2453	0.08	2453	0.19	2453
(A) Days with high volatility in both markets						
Volatility is larger than the average volatility	0.41	169	-0.28	518	0.1	256
Volatility is larger than twice the average volatility	0.64	63	-0.31	117	-0.19	11
(B) Days with low volatility in both markets						
Volatility is smaller than the average volatility	0.35	2284	0.18	1935	0.2	2197
Volatility is smaller than twice the average volatility	0.34	2390	0.1	2336	0.19	2442
(C) Days with high volatility in one market						
Volatility is larger than the average volatility of:						
SP	0.31	862				
EMBI	0.37	485				
SP			-0.26	862		
B2			-0.09	895		
EMBI					0.02	485
B2					0.06	895
Volatility is larger than twice the average volatility of:						
SP	0.26	275				
EMBI	0.4	260				
SP			-0.41	275		
B2			-0.26	236		
EMBI					-0.08	260
B2					-0.04	236
(D) Days with low volatility in one market						
Volatility is smaller than the average volatility of:						
SP	0.37	1591				
EMBI	0.35	1968				
SP			0.27	1591		
B2			0.18	1558		
EMBI					0.23	1968
B2					0.26	1558
Volatility is smaller than twice the average volatility of:						
SP	0.36	2178				
EMBI	0.35	2193				
SP			0.14	2178		
B2			0.12	2217		
EMBI					0.22	2193
B2					0.21	2217

Table VIII
Conditional correlations of weekly returns from a multivariate correlation model
Conditional correlations and volatilities are estimated by a multivariate GARCH model for returns on US stocks, US low grade corporate bonds rated B2 and emerging market bonds. Returns are measured in percent. The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations).

	Correlation SP, EMBI	Obs.	Correlation SP, B2	Obs.	Correlation EMBI, B2	Obs.
Unconditional	0.29	494	0.01	494	0.20	494
Conditional, average	0.42	492	0.03	492	0.07	492
(A) Weeks with high volatility in both markets						
Volatility is larger than the average volatility	0.28	33	0.01	76	0.03	44
Volatility is larger than twice the average volatility	0.27	6	0	14	0.01	2
(B) Weeks with low volatility in both markets						
Volatility is smaller than the average volatility	0.42	459	0.04	416	0.08	448
Volatility is smaller than twice the average volatility	0.42	486	0.04	478	0.07	490
(C) Weeks with high volatility in one market						
Volatility is larger than the average volatility of:						
SP	0.32	167				
EMBI	0.37	102				
SP			0.02	167		
B2			0.02	146		
EMBI					0.04	102
B2					0.05	146
Volatility is larger than twice the average volatility of:						
SP	0.19	38				
EMBI	0.35	47				
SP			0.01	38		
B2			0.01	29		
EMBI					0.03	47
B2					0.04	29
(D) Weeks with low volatility in one market						
Volatility is smaller than the average volatility of:						
SP	0.46	325				
EMBI	0.43	390				
SP			0.04	325		
B2			0.04	346		
EMBI					0.08	390
B2					0.08	346
Volatility is smaller than twice the average volatility of:						
SP	0.43	454				
EMBI	0.42	445				
SP			0.04	454		
B2			0.04	463		
EMBI					0.08	445
B2					0.08	463

Table IX
Conditional correlations of monthly returns from a multivariate correlation model
Conditional correlations and volatilities are estimated by a multivariate GARCH model for returns on US stocks, US low grade corporate bonds rated B2 and emerging market bonds. Returns are measured in percent. The monthly return is computed as the return from the first business day of one month to the first business day of the following month. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for monthly returns is 01/02/1994 to 01/06/2003 (113 observations).

	Correlation SP, EMBI	Obs.	Correlation SP, B2	Obs.	Correlation EMBI, B2	Obs.
Unconditional	0.51	113	0.32	113	0.39	113
Conditional, average	0.53	113	0.38	113	0.44	113
(A) Months with high volatility in both markets						
Volatility is larger than the average volatility	0.68	14	0.2	23	0.26	14
(B) Months with low volatility in both markets						
Volatility is smaller than the average volatility	0.51	99	0.43	90	0.46	99
(C) Months with high volatility in one market						
Volatility is larger than the average volatility of:						
SP	0.53	50				
EMBI	0.55	37				
SP			0.28	50		
B2			0.22	37		
EMBI					0.36	37
B2					0.31	29
(D) Months with low volatility in one market						
Volatility is smaller than the average volatility of:						
SP	0.54	63				
EMBI	0.52	76				
SP			0.46	63		
B2			0.44	84		
EMBI					0.47	76
B2					0.48	84

Table X
Parameter estimates from univariate regime switching models
The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. Returns are measured in percent. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations). SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The regime switching model for each asset return, $y_t \in \{SP_t, EMBI_t, B2_t\}$, is given by
$y_t = c + \theta y_{t-1} + \epsilon_t$,
$h_t/\gamma_{st} = a_0 + a_1\epsilon_{t-1}/\gamma_{st-1}$,
$s_t = 1,2,\dots,K$ and $\epsilon_t \sim N(0,h_t)$.
The probability that state i will be followed by state j is described by p_{ij}. Transition probabilities p_{ij} have to be restricted to fall between zero and one. These restrictions are imposed by parameterizing:
$p_{ij} = (\theta_{ij})^2 / (1+ (\theta_{i1})^2 + (\theta_{i2})^2 +\dots+ (\theta_{iK-1})^2)$ for j = 1,2, …,K-1 and
$p_{ij} = 1 / (1+ (\theta_{i1})^2 + (\theta_{i2})^2 +\dots+ (\theta_{iK-1})^2)$ for j = K, and estimating θ_{ij} for i = 1,2,…,K and j = 1,2,…,K-1 without restrictions.
Q(12) denotes the Ljung-Box test for serial correlation with 12 lags.
* indicates significance at the 5% level.
+ indicates significance at the 5% level where the null hypothesis is that $\gamma_{st} = 1$.

	SP		EMBI		B2	
	Par.	Std. Error	Par.	Std. Error	Par.	Std. Error
c	0.267	0.088*	0.457	0.065*	0.291	0.061*
ϕ	-0.113	0.047*	-0.010	0.035*	-0.131	0.047*
a_0	1.401	0.230*	0.706	0.195*	0.658	0.186*
a_1	-0.033	0.063	0.038	0.063	0	
θ_{11}	0.996	0.006*	0.929	0.028*	3.752	1.118*
θ_{12}	0.002	0.002	0.049	0.020*	1.139	0.991
θ_{13}	0		0		0.148	0.167
θ_{21}	0.004		0.067	0.029*	-0.003	0.063
θ_{22}	0.979	0.013*	0.930	0.025*	7.980	4.420
θ_{23}	0.113	0.060	0.122	0.062*	0.308	0.090*
γ_2	3.574	0.743+	4.627	1.012+	2.484	0.664+
γ_3	14.693	5.951+	41.836	14.534+	11.398	3.658+
Likelihood	-1094.073		-967.350		-891.326	
Likelihood SWARCH (2,1)	-1103.514		-983.167		-895.142	
Likelihood SWARCH (4,1)	-1093.142		-964.209			
Q(12)	18.629		11.463		18.927	
Q(12) for squared residuals	10.964		3.172		8.480	

Table XI
Transition probability matrices from univariate regime switching models
SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations). The estimated probability that state i will be followed by state j is described by p_{ij}. These transition probabilities are collected in a transition matrix for each asset.

	SP	
0.996	0.002	0
0.004	0.979	0.113
0	0.019	0.887
	EMBI	
0.929	0.049	0
0.067	0.930	0.122
0.004	0.021	0.878
	B2	
0.934	0.020	0.020
0.000	0.965	0.085
0.066	0.015	0.896

Table XII
Correlation coefficients from univariate regime switching models
Volatility states are estimated by regime switching models. A market is said to be in the high volatility state if the probability for being in the high volatility state exceeds 0.5. Otherwise, the market is said to be in the low volatility state. The table entries give the correlations for returns in the respective volatility states. SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations).

	Correlation SP, EMBI	Obs.	Correlation SP, B2	Obs.	Correlation EMBI, B2	Obs.
Unconditional	0.29	494	0.01	494	0.20	494
(A) One market is in the high volatility state						
SP	0.02	40	-0.31	40	0.18	40
EMBI	0.28	66	0.27	66	0.22	66
B2	0.24	110	-0.04	110	0.27	110
(B) One market is in the low volatility state						
SP	0.34	452	0.12	452	0.22	452
EMBI	0.33	426	-0.03	426	0.24	426
B2	0.32	382	0.08	382	0.17	382

Table XIII

Parameter estimates from bivariate regime switching models

The weekly return for each asset is computed as the return from Tuesday's price to the following Tuesday's price. Returns are measured in percent. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations). SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The bivariate regime switching model for two asset returns is given by $\mathbf{y}_t = \mathbf{c} + \boldsymbol{\theta}\mathbf{y}_{t-1} + \epsilon_t$, $\epsilon_t \sim N(0,\mathbf{H}_t)$. The diagonal elements of $\mathbf{H}_t$ follow $h_t/\gamma_{st} = a_0 + a_1\epsilon_{t-1}/\gamma_{st-1}$ for $s_t = 1,2,\ldots,K$. Correlation coefficients, denoted by ρ_{st}, are state dependent as well. The probability that state i will be followed by state j is described by p_{ij}. Transition probabilities p_{ij} have to be restricted to fall between zero and one. These restrictions are imposed by parameterizing:

$p_{ij} = (\theta_{ij})^2 / (1+ (\theta_{i1})^2 + (\theta_{i2})^2 +\ldots+ (\theta_{iK-1})^2)$ for $j = 1,2, \ldots,K-1$ and

$p_{ij} = 1 / (1+ (\theta_{i1})^2 + (\theta_{i2})^2 +\ldots+ (\theta_{iK-1})^2)$ for $j = K$, and estimating θ_{ij} for $i = 1,2,\ldots,K$ and $j = 1,2,\ldots,K-1$ without restrictions.

Q(12) denotes the Ljung-Box test for serial correlation with 12 lags.

* indicates significance at the 5% level.

+ indicates significance at the 5% level where the null hypothesis is that $\gamma_{st} = 1$.

	[SP, EMBI]		[SP, B2]		[EMBI, B2]	
	Par.	Std. Error	Par.	Std. Error	Par.	Std. Error
c_1	0.359	0.123*	0.189	0.127	0.357	0.070*
c_2	0.425	0.076*	0.297	0.076*	0.284	0.073*
ϕ_1	-0.085	0.054	-0.128	0.056*	0.024	0.051
ϕ_2	-0.023	0.058	-0.102	0.052*	-0.082	0.050
a_{01}	3.226	0.435*	4.640	0.520*	1.052	0.127*
a_{11}	-0.156	0.068*	-0.096	0.070	1.410	0.144*
a_{02}	1.024	0.157*	-1.523	0.191*	0	
a_{12}	0.029	0.064	0		0	
θ_{11}	8.359	3.745*	4.814	1.065*	1.251	0.071*
θ_{12}	2.808	2.080	0		0	
θ_{13}	0.731	0.627	0		0	
θ_{14}	-0.020	0.240	0.407	0.096*	-1.094	0.850
θ_{21}	1.635	0.965	0		0	
θ_{22}	5.974	4.120	0		0	
θ_{23}	0		0		0	
θ_{24}	0.201	0.067*	0		0	
θ_{31}	1.396	0.893	0		0	
θ_{32}	0.257	2.227	0		0	
θ_{33}	5.897	2.329*	0		1.741	0.367*
θ_{34}	0.127	0.068	0		-1.342	1.187
γ_{21}	2.788	0.469+	3.025	0.675+	5.793	0.960+
γ_{22}	6.568	1.040+	5.601	1.137+	5.516	1.112+
ρ_1	0.692	0.059*	0.040	0.025	0.413	0.061*
ρ_2	0.306	0.057*	ρ_1		0	
Likelihood	-1590.51		-1653.99		-1435.21	
Likelihood, volatility synchronization	-1608.99		-1653.99		-1451.11	
LR, volatility synchronization (p-value)	<0.001		0.655		0.001	

Table XIV

Transition probability matrices from bivariate regime switching models

SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for weekly returns is 11/01/1994 to 24/06/2003 (494 observations). The estimated probability that state i will be followed by state j is described by p_{ij}. These transition probabilities are collected in a transition matrix for each group of assets.

[SP, EMBI]			
0.926	0.177	0.015	<0.001
0.035	0.799	0	0.038
0.026	0.001	0.958	0.015
0.013	0.022	0.028	0.946
[SP, B2]			
0.959	0	0	0.142
0	0	0	0
0	0	0	0
0.041	0	0	0.858
[EMBI, B2]			
0.961	0	0	0.081
0.039	0	0	0.000
0	0	0.847	0.122
0	1.000	0.153	0.797

Table XV

Returns, volatilities and correlations during some financial crisis

Conditional correlations and volatilities are estimated by a multivariate GARCH model. Central events in each crisis are highlighted. These events are the devaluations in Mexico (20/12/1994), Russia (17/08/1998) and Brazil (13/01/1999), as well as the US stock market crash following several devaluations in Asia (27/10/1997) and the file for bankruptcy of Enron (02/12/2001) and Worldcom (21/07/2002). SP denotes the S&P US stock market index, EMBI denotes JP Morgan's EMBI Global (emerging market bond index global) and B2 denotes the index of low-grade corporate bonds rated B2. The sample period for daily returns is 03/01/1994 to 27/6/2003 (2475 observations).

Date	Holding period return			Std. dev.	Correlation	Std. dev.	Correlation	Correlation	Std. dev.
	SP	EMBI	B2	SP	SP, EMBI	EMBI	SP, B2	EMBI, B2	B2
(A) Mexican crisis									
13/12/1994	0.15	0.46	0.36	0.75	0.32	0.58	0.20	0.29	0.59
14/12/1994	1.07	-0.11	-0.05	0.72	0.33	0.56	0.21	0.30	0.58
15/12/1994	0.08	-0.06	0.03	0.75	0.27	0.53	0.20	0.31	0.57
16/12/1994	0.76	-0.46	0.03	0.72	0.29	0.50	0.20	0.31	0.56
19/12/1994	-0.19	-0.12	-0.05	0.73	0.20	0.51	0.21	0.29	0.55
20/12/1994	-0.18	-1.22	0.11	0.71	0.23	0.48	0.21	0.31	0.55
21/12/1994	0.55	-3.28	0.03	0.69	0.22	0.68	0.22	0.19	0.54
22/12/1994	0.02	-2.67	-0.05	0.68	-0.01	1.40	0.22	0.09	0.53
23/12/1994	0.03	1.85	0.11	0.66	0.01	1.55	0.23	0.10	0.52
26/12/1994	0.00	0.00	0.03	0.64	0.01	1.67	0.24	0.10	0.52
27/12/1994	0.57	-5.64	0.61	0.62	0.03	1.54	0.25	0.10	0.51
(B) Asian crisis									
20/10/1997	1.21	0.18	0.23	0.89	0.48	0.42	0.51	0.56	0.65
21/10/1997	1.74	0.29	0.77	0.91	0.49	0.40	0.49	0.55	0.64
22/10/1997	-0.39	0.14	0.02	0.99	0.49	0.39	0.51	0.56	0.64
23/10/1997	-1.84	-1.75	1.21	0.97	0.49	0.37	0.50	0.55	0.63
24/10/1997	-0.95	-1.33	0.35	1.07	0.48	0.82	0.26	-0.05	0.67
27/10/1997	-6.87	-7.76	1.89	1.07	0.49	0.87	0.22	-0.10	0.66
28/10/1997	5.12	1.76	-2.34	2.16	0.62	3.11	-0.28	-0.43	0.77
29/10/1997	-0.29	-1.95	0.02	2.49	0.61	3.08	-0.43	-0.50	0.89
30/10/1997	-1.68	-1.98	0.46	2.40	0.59	2.97	-0.42	-0.45	0.87
31/10/1997	1.21	1.13	-0.83	2.35	0.60	2.81	-0.42	-0.45	0.85
03/11/1997	2.66	2.34	-1.14	2.28	0.60	2.63	-0.42	-0.46	0.85
(C) Russian crisis									
10/08/1998	-0.58	-3.05	-0.61	1.34	0.11	1.39	0.05	-0.04	0.58
11/08/1998	-1.31	-0.96	0.67	1.31	0.15	1.63	0.08	0.09	0.59
12/08/1998	1.43	-1.77	-0.08	1.31	0.17	1.51	0.03	0.06	0.59
13/08/1998	-0.86	3.17	-1.45	1.32	0.07	1.54	0.03	0.07	0.58
14/08/1998	-1.13	0.93	-0.08	1.29	-0.03	1.94	0.11	-0.23	0.66
17/08/1998	1.97	-4.18	-0.50	1.29	-0.04	1.79	0.13	-0.22	0.65
18/08/1998	1.62	-0.09	-0.60	1.34	-0.21	2.39	0.07	-0.04	0.64
19/08/1998	-0.29	-1.50	-0.49	1.36	-0.17	2.20	0.01	-0.05	0.65
20/08/1998	-0.59	-4.22	0.54	1.31	-0.15	2.11	0.03	0.01	0.65
21/08/1998	-0.95	-6.71	0.34	1.28	-0.05	2.51	0.01	-0.07	0.65
24/08/1998	0.64	-0.34	-0.80	1.26	0.08	3.32	0.00	-0.12	0.64

Table XV continued

Date	Holding period return SP	EMBI	B2	Std. dev. SP	Correlation SP, EMBI	Std. dev. EMBI	Correlation SP, B2	Correlation EMBI, B2	Std. dev. B2
(D) Brazilian crisis									
06/01/1999	2.21	0.30	0.96	1.05	0.29	0.76	-0.11	-0.15	0.91
07/01/1999	-0.21	-1.91	-0.39	1.17	0.26	0.70	-0.01	-0.14	0.90
08/01/1999	0.42	-0.95	-0.69	1.13	0.20	1.04	0.00	-0.03	0.88
11/01/1999	-0.88	-1.20	-0.18	1.09	0.18	1.00	-0.01	0.02	0.88
12/01/1999	-1.93	-1.57	1.79	1.09	0.24	1.02	0.01	0.05	0.86
13/01/1999	-0.41	-5.50	1.72	1.18	0.34	1.10	-0.14	-0.13	0.92
14/01/1999	-1.80	-1.65	0.99	1.15	0.22	2.33	-0.16	-0.35	0.99
15/01/1999	2.56	5.54	-0.72	1.22	0.24	2.16	-0.22	-0.36	1.00
18/01/1999	0.00	0.00	0.13	1.36	0.39	3.00	-0.24	-0.32	0.98
19/01/1999	0.70	2.28	-0.40	1.30	0.38	2.78	-0.23	-0.31	0.96
20/01/1999	0.37	0.68	-1.23	1.27	0.39	2.69	-0.24	-0.31	0.94
(E) Enron scandal									
26/11/2001	0.62	1.36	0.20	1.04	0.23	0.65	0.12	0.10	0.96
27/11/2001	-0.68	-0.63	0.96	1.01	0.25	0.78	0.13	0.10	0.94
28/11/2001	-1.83	-0.40	-0.14	1.00	0.29	0.81	0.09	0.01	0.94
29/11/2001	1.03	-1.04	1.92	1.10	0.31	0.76	0.09	0.02	0.91
30/11/2001	-0.07	-0.21	1.43	1.09	0.19	0.82	0.16	-0.15	0.98
03/12/2001	-0.84	1.65	0.64	1.05	0.20	0.76	0.14	-0.14	1.02
04/12/2001	1.32	-0.73	0.20	1.04	0.05	0.94	0.11	-0.01	1.01
05/12/2001	2.23	0.42	-2.54	1.06	-0.05	0.97	0.12	-0.02	0.98
06/12/2001	-0.28	-0.63	0.98	1.18	0.04	0.91	-0.11	-0.09	1.11
07/12/2001	-0.75	-0.33	0.12	1.14	0.06	0.90	-0.11	-0.11	1.09
10/12/2001	-1.59	0.18	0.99	1.12	0.09	0.84	-0.11	-0.11	1.06
(F) Worldcom scandal									
15/07/2002	-0.38	-0.57	-3.46	1.78	0.03	0.71	-0.31	0.06	0.91
16/07/2002	-1.84	-0.05	-0.56	1.71	0.06	0.74	-0.20	0.28	1.16
17/07/2002	0.55	0.09	0.03	1.73	0.07	0.68	-0.13	0.28	1.15
18/07/2002	-2.70	0.61	0.97	1.67	0.08	0.63	-0.13	0.28	1.12
19/07/2002	-3.83	0.00	0.23	1.78	-0.02	0.62	-0.18	0.31	1.11
22/07/2002	-3.29	-0.26	0.40	2.02	0.04	0.58	-0.17	0.30	1.08
23/07/2002	-2.70	-1.17	-0.99	2.15	0.11	0.56	-0.18	0.28	1.06
24/07/2002	5.73	-0.42	-1.52	2.20	0.23	0.71	-0.11	0.31	1.05
25/07/2002	-0.56	-1.03	0.26	2.62	0.12	0.67	-0.24	0.34	1.09
26/07/2002	1.69	-0.80	-2.40	2.52	0.13	0.75	-0.23	0.28	1.06
29/07/2002	5.41	-2.07	-1.20	2.46	0.07	0.75	-0.27	0.37	1.16