The Asian financial crisis: the start of a regime switch in volatility

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Abstract

Using a Markov switching model applied to the VIX and VDAX implied volatility indexes, we find that the volatility of the U.S. S&P100 index and German DAX index switched from a low-value state to a high-value state around the events of the Asian financial crisis. Moreover, the U.S. and German markets have stayed in the high-volatility state for the next five years. We also show that there has been a structural change in the stock index volatility vs returns relationship.

Key words: implied volatility, financial crisis, Markov switching model, stock market.

JEL classification: C13, C22, F30, G15

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1 Introduction

There is a strong feeling among academic and practitioners that ‘market conditions’ have changed significantly since the Asian financial crisis of 1997.\footnote{The unfolding of these events, which started with the devaluation of the Thai baht, is detailed in Kaminsky and Schmukler (1999) or Krugman (2000), for example.} According to many market participants, the Asian and Russian crises (and the collapse of the LTCM hedge fund) dealt a significant blow to the overall liquidity of the stock and bond markets, see Persaud (2001) for example. In this paper, we investigate whether a regime switch in volatility for the stock markets in the U.S. and Germany occurred around the summer of 1997 and we also assess if volatility has stayed in a high-value state since then. Indeed, we find that the volatility of the U.S. S&P100 index and German DAX index switched from a low-value state to a high-value state around the events of the Asian financial crisis (i.e. mid to end of 1997). Moreover, the volatility of both the U.S. and German markets has stayed almost continuously in the high-value state for the next five years. Our empirical methodology relies on a two-state Markov switching model that is applied to the VIX and VDAX implied volatility indexes.\footnote{See for example Brooks and Persand (2001) for a recent application of Markov switching models in finance.} To our knowledge, this is the first application of Markov switching models to implied volatility indexes. The VIX and VDAX indexes are computed by the Chicago Board of Options Exchange (CBOE) and Deutsche Boerse respectively: the VIX (VDAX) is a weighted average of the implied volatilities computed from call and put near-the-money, near-to-maturity, option contracts on the underlying S&P100 (DAX) index.\footnote{By construction, the VIX (VDAX) gives the implied volatility of a hypothetical at-the-money option with a constant maturity of 22 (30) trading days to expiry.} Both implied volatility indexes are routinely discussed by market practitioners and academics as they give the perceived (i.e. computed from traded options) short-term volatility of the S&P100 and DAX indexes, see e.g. Fleming and Whaley (1995), Blair, Poon, and Taylor (2001) or Claessen and Mittnik (2002). In a second step, we also show that, both for the U.S. and German markets, the relationship between volatility changes and stock market returns underwent a significant change around the summer of 1997. For both indexes, an asymmetric effect is at play, although the asymmetric effect is much stronger before the Asian crisis than after the summer of 1997.

The rest of the paper is structured as follows. After this introduction, we present the Markov switching model in Section 2 and focus on the relationship between volatility changes and stock market returns in Section 3. Finally, Section 4 concludes.
2  A two-regime volatility model for the VIX and VDAX indexes

To assess the possible switch in regime for stock market volatility, we use a two-state Markov switching model such as introduced by Hamilton (1989). Because we focus on the volatility measures given by the VIX and VDAX implied volatility indexes, the Markov switching model is applied directly to the time series of the observed daily VIX and VDAX levels. In this framework, it is thus assumed that the implied volatility index ($y_t$ say) switches regime according to an unobserved variable $s_t$: regime 1 ($s_t = 1$) is the low-volatility state, while regime 2 ($s_t = 2$) is the high-volatility state.\(^4\) At time $t$, the volatility state is thus $s_t \in \{1, 2\}$ and the dynamics of $s_t$ is governed by a Markov process:

$$P(s_t = 1|s_{t-1} = 1) = p_{11}, \quad P(s_t = 2|s_{t-1} = 1) = 1 - p_{11}, \quad P(s_t = 2|s_{t-1} = 2) = p_{22} \quad \text{and} \quad P(s_t = 1|s_{t-1} = 2) = 1 - p_{22},$$

where $p_{11}$ ($p_{22}$) is the probability of being in the low-volatility (high-volatility) state at time $t$ given that the low-volatility (high-volatility) state is observed at time $t - 1$. In state $m$, the dynamics of the implied volatility index $y_t$ is characterized by an AR(1) process:\(^5\)

$$y_t = \alpha_m + \beta_m y_{t-1} + \epsilon_t,$$

where $\epsilon_t \sim N(0, \sigma_m^2)$. We estimate the parameters of the model using the MSVAR package (maximum likelihood, EM algorithm) of H.-M. Krolzig in the OX 3.2 econometric framework.\(^6\) The daily VIX and VDAX data are available for the January 3, 1992 - December 31, 2002 time period and these are plotted in the top panel of Figures 1 and 2. A look at the pattern of the VIX and VDAX indexes clearly hints at two volatility regimes with the switch occurring near the summer of 1997 (around observations 1,400 - 1,450).

For the VIX index, the estimation gives $\alpha_1 = 0.296$, $\alpha_2 = 1.656$, $\beta_1 = 0.980$, $\beta_2 = 0.943$, $\sigma_1 = 0.681$, $\sigma_2 = 2.163$, $p_{11} = 0.97$ and $p_{22} = 0.95$. This yields an unconditional mean of 14.8 for the VIX index in state 1 (low-volatility state), and of 29.05 in state 2 (high-volatility state). For the VDAX index, we have that $\alpha_1 = 0.207$, $\alpha_2 = 0.715$, $\beta_1 = 0.985$, $\beta_2 = 0.977$, $\sigma_1 = 0.442$, $\sigma_2 = 1.710$, $p_{11} = 0.96$ and $p_{22} = 0.96$. This gives an unconditional mean for the VDAX index of 13.8 in state 1, and of 31.09 in state 2. Both implied volatility indexes are however characterized by an extremely slow mean reversion as the $\beta_m$ coefficients are close to one.\(^7\) Moreover, the VIX and VDAX indexes are much more variable when they

\(^4\)The empirical analysis given below hints clearly at a low- and high-volatility state, hence we already use the corresponding notation at this stage.

\(^5\)The AR(1) process (random walk) is suggested by the Efficient Market Hypothesis for option prices. Our results, see below, show that $\beta_m$ is close to, but smaller than one. We do not focus on that issue in this short paper.

\(^6\)See also Krolzig (1997) or Frances and van Dijk (2000) for a discussion of the model and its estimation by maximum likelihood.

\(^7\)Unit root tests, not reported here, show that the null hypothesis of a unit root for either implied volatility index is rejected.
are in the high-value state than when they are in the low-value state: the volatility of volatility is much higher when volatility is high than when volatility is low.

The bottom panels of Figures 1 and 2 plot the probability of \( s_t \) being in state 2 (high-volatility). A look at both figures indicates quite clearly that volatility in both the U.S. and German markets was strongly affected by the events of the summer of 1997 (starting around observation 1,400). Indeed, up to June 1997, the VIX and VDAX indexes were deeply rooted (with a few exceptions) in the low-volatility state. From July 1997 onwards, the volatility pattern reverses itself almost completely as both implied volatility indexes now stay almost continuously in the high-volatility state (with one exception for both indexes during the summer of 2000). Of course, the Asian financial crisis delivered only the first blow to the financial markets, as the next five years saw successively the Russian crisis and the LTCM collapse, the fall of the NASDAQ, the start of the bear market in the U.S. and Europe and the terrorists’ attacks on September 11, 2001. This empirical evidence thus lends credence to the market practitioners’ view that market conditions (volatility in our case) did indeed change significantly from the Asian crisis onwards. Moreover, market volatility has not reverted back (with a few exceptions) to its initial low-volatility state that was observed up to the summer of 1997. Note also that both stock markets are equally affected by the regime switch in volatility.

### 3 Volatility changes and stock market returns

The asymmetric relationship (leverage effect) between stock returns and volatility has been documented in many studies, e.g. Black (1976), French, Schwert, and Stambaugh (1987) or Whaley (2000) and Giot (2003) for implied volatility indexes. In the framework of the regime switch in volatility of Section 2, we assess the asymmetric contemporaneous relationship between (implied) volatility changes and stock market returns for the U.S. and German markets and test the stability of this relationship across both sub-periods (i.e. before and after July 1997). Thereafter, we define \( rOEX_t = \ln(OEX_t) - \ln(OEX_{t-1}) \) as the daily return on the S&P100 index and \( rDAX_t = \ln(DAX_t) - \ln(DAX_{t-1}) \) as the daily return on the DAX index. For the implied volatility indexes, we define their daily relative changes as \( \%VIX_t = \ln(VIX_t) - \ln(VIX_{t-1}) \) and \( \%VDAX_t = \ln(VDAX_t) - \ln(VDAX_{t-1}) \). All returns and relative changes are computed over the January 3, 1992 - December 31, 2002 time period. For the January 3, 1992 - June 30, 1997 and July 1, 1997 - December 31, 2002 sub-periods, we then estimate separately the following regressions:

\[
\%VIX_t = \beta_0^- D_t^- + \beta_0^+ D_t^+ + \beta_1^- (rOEX_t D_t^-) + \beta_1^+ (rOEX_t D_t^+) + \epsilon_t \tag{2}
\]

for the S&P100 index, and

\[
\%VDAX_t = \beta_0^- D_t^- + \beta_0^+ D_t^+ + \beta_1^- (rDAX_t D_t^-) + \beta_1^+ (rDAX_t D_t^+) + \epsilon_t \tag{3}
\]
for the DAX index where $D^-_t$ is a dummy variable that is equal to 1 (0) when the index return (either $rOEX_t$ or $rDAX_t$) is negative (positive) and $D^+_t = 1 - D^-_t$. Estimation results for the U.S. and German markets are given in the middle and bottom panels of Table 1, while the top panel of this table gives the estimation results for the full January 3, 1992 - December 31, 2002 time period. For the full period and both sub-periods, there is a significant asymmetric relationship between the stock index returns and the stock index volatility. Furthermore, the slopes (i.e. $\beta^+_1$ and $\beta^-_1$) in Equations 2 and 3 are significantly different in both sub-periods. Therefore the reaction of volatility to positive or negative market returns does exhibit a structural change around the Asian crisis. Quite interestingly, the leverage effect is much weaker after the summer of 1997 than before: volatility, in reaction to negative market returns, rises much faster in the low-volatility state than in the high-volatility state. As for the Markov switching model in Section 2, the U.S. and German markets exhibit the same characteristics.

4 Conclusion

In this paper, we used a two-state Markov switching model applied to the VIX and VDAX implied volatility indexes to show that the volatility of the U.S. S&P100 index and German DAX index switched from a low-value state to a high-value state around the summer of 1997, i.e. when the events of the Asian financial crisis started to unfold. Our empirical results also show that, over the next five years, stock market volatility did not revert back (with a few exceptions) to its initial low-volatility state that was the rule before mid-1997. This empirical evidence thus lends credence to the market practitioners’ view that stock market volatility did indeed switch to a high-value state from the Asian crisis onwards. In the second part of the paper, we highlighted the structural change in the asymmetric stock index volatility vs returns relationship; we found that the leverage effect is much weaker after the summer of 1997 than before.

References


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8We report the White’s heteroscedastic consistent standard errors in all cases.

9The null hypothesis $H_0 : \beta^+_1 = \beta^-_1$ is rejected in all cases.

10An estimation of Equations 2 and 3 over the January 3, 1992 - December 31, 2002 time period with appropriately defined dummy variables does not reject the null hypothesis of structural change for the $\beta^+_1$ and $\beta^-_1$ coefficients.


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Table 1: S&P100 and DAX: changes in stock index volatility vs returns

|                      | January 3, 1992 - December 31, 2002 |                 |                |  |          |
|-----------------------|-----------------------------------|-----------------|-----------------|  |          |
|                       | $\beta_0^+$                       | $\beta_0^-$     | $\beta_1^+$     | $\beta_1^-$ | $R^2$    |
| VIX                   | -0.957 (0.150)                    | 0.169 (0.151)   | -2.832 (0.181)  | -4.214 (0.186) | 0.53     |
| VDAX                  | -0.449 (0.147)                    | -0.422 (0.145)  | -1.423 (0.154)  | -2.446 (0.144) | 0.35     |

|                      | January 3, 1992 - June 30, 1997   |                 |                |  |          |
|-----------------------|-----------------------------------|-----------------|-----------------|  |          |
|                       | $\beta_0^+$                       | $\beta_0^-$     | $\beta_1^+$     | $\beta_1^-$ | $R^2$    |
| VIX                   | -1.285 (0.273)                    | -0.423 (0.257)  | -2.217 (0.591)  | -6.846 (0.564) | 0.41     |
| VDAX                  | -0.589 (0.210)                    | -1.077 (0.221)  | -0.885 (0.305)  | -3.729 (0.352) | 0.35     |

|                      | July 1, 1997 - December 31, 2002  |                 |                |  |          |
|-----------------------|-----------------------------------|-----------------|-----------------|  |          |
|                       | $\beta_0^+$                       | $\beta_0^-$     | $\beta_1^+$     | $\beta_1^-$ | $R^2$    |
| VIX                   | -0.763 (0.223)                    | -0.214 (0.222)  | -3.007 (0.206)  | -3.975 (0.198) | 0.66     |
| VDAX                  | -0.647 (0.234)                    | -0.209 (0.218)  | -1.464 (0.191)  | -2.122 (0.154) | 0.43     |

S&P100 and DAX indexes: changes in (implied) volatility vs stock index returns. This table gives the estimated coefficients of $\%\text{VIX}_t = \beta_0^- D_t^- + \beta_0^+ D_t^+ + \beta_1^- (r\text{OEX}_t, D_t^-) + \beta_1^+ (r\text{OEX}_t, D_t^+) + \epsilon_t$ and $\%\text{VDAX}_t = \beta_0^- D_t^- + \beta_0^+ D_t^+ + \beta_1^- (r\text{DAX}_t, D_t^-) + \beta_1^+ (r\text{DAX}_t, D_t^+) + \epsilon_t$, where $D_t^-$ is a dummy variable that is equal to 1 (0) when the stock index return is negative (positive) and $D_t^+ = 1 - D_t^-$. White’s heteroscedastic consistent standard errors are given in parenthesis.
Figure 1: VIX index and Markov switching probability of state 2 (high volatility) for the S&P100 index. The time period is January 3, 1992 - December 31, 2002.
Figure 2: VDAX index and Markov switching probability of state 2 (high volatility) for the DAX index. The time period is January 3, 1992 - December 31, 2002.