Have East Asian Stock Markets Calmed Down?
Evidence from a Regime-Switching Model

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Abstract

The 1997-98 East Asian crisis was accompanied by high volatility of East Asian stock returns. This paper examines whether the volatility has already come down to the level of the years before the crisis. We use a regime-switching model to account for possible structural change in the unconditional variance, for instance, due to the Asian crisis. We find that in June 2000 the stock markets of Indonesia, South Korea, Malaysia, and Thailand, but not the Philippines, were still in the high-volatility regime initiated by the 1997-98 crisis. Hence, markets have not yet calmed down. However, volatility is decreasing and the volatility gap between the crisis and the years before has been closed by about 60%. We explain this, including the exceptional position of the Philippines, in terms of the financial structural reforms in Asia.

Key words: Asian crisis, emerging markets, Markov-switching, regime-switching
GARCH, volatility persistence.

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1 Introduction

The collapse of the Thai baht in July 1997 marked the beginning of a period of economic crisis in East Asia. This "Asian crisis" was accompanied by severe output contractions, large devaluations of currencies with respect to the U.S. dollar and sharp drops in stock prices. The persistence and depth of the recession exceeded early expectations, and only in the second half of 1998 the level of national income bottomed out (IMF (1999a, p.15)). This is also reflected by the turnaround in the development of the stock price levels.

Another aspect of the length of the crisis and its aftermath concerns the economic uncertainty during and after the crisis. Economic uncertainty is partly reflected by the volatility of stock prices. Moreover, stock volatility is also a determinant of investment decisions and the inflow of foreign capital needed for economic recovery. Hence, besides the level of stock prices, also their volatility can be viewed as an indicator for the length of the crisis.

The current paper examines the length of the Asian crisis by analyzing this volatility of stock prices. Volatility surged dramatically during the crisis. Our purpose is to examine whether East Asian stock markets have already calmed down, that is, whether stock volatility is now (year 2000) the same as it was in the years before the crisis.

We use data on local currency stock market indices for five countries that are commonly viewed as the "crisis countries", namely Indonesia, South Korea, Malaysia, the Philippines and Thailand. The data period is January 1989 to June 2000, and we have weekly data. The model employed is regime-switching GARCH, which will be discussed later on in this introduction. We find that for four countries volatility has not yet come down to its pre-crisis level, although about 60% of the volatility gap between the crisis and the years before has been closed. The exception is the Philippines, where markets have calmed down.

To explain these results, we analyze the causes of an economic crisis. The literature has forwarded several explanations. One argument runs in terms of deteriorating macroeconomic fundamentals, such as current account deficit, government budget deficit, slowdown in output growth, loss in foreign exchange reserves and a high level of short-term external debt. These factors may result in a crisis (Kaminsky (1998)). Another argument is based on self-fulfilling crises, where fixed exchange rate systems collapse even for countries with good macroeconomic fundamentals (Eichengreen and Wyplosz (1993), Obstfeld (1996)).

The East Asian crisis, however, goes beyond these models, as it also involves structural distortions in the corporate and financial sectors. These partly originated from

moral hazard behavior. For instance, firms were supported by governments through public guarantees, so that firm managers were tempted to invest too much in risky projects. In a similar way, government and international support programs for the financial sector led national and international banks to lend excessively to projects that were unprofitable from a social point of view. In addition, there was a mismatch of maturity and liquidity between deposits and loans, as local banks transformed short-term debt into long-term illiquid loans to firms. These structural distortions made the East Asian countries vulnerable to adverse economic circumstances; see Corsetti, Pesenti and Roubini (1999), Krugman (1998) and Rodrik and Velasco (1999) for a detailed analysis on the causes of the Asian crisis.

Because of the weak structural situation in East Asia, the crisis countries have carried out important structural reforms, often stimulated by the IMF. This is a lengthy process and it is still going on; see Kawai (2000). We will argue that this can be seen as one of the reasons behind our empirical results concerning the persistence of stock volatility, including the exceptional position of the Philippines.

From an econometric point of view, the question is what type of model one should use to analyze the persistence of the Asian crisis in stock volatility. In the existing literature one often uses the generalized autoregressive conditional heteroskedasticity (GARCH) model to examine study persistence (see Bollerslev, Chou and Kroner (1992) for an overview). One typically finds high or even permanent persistence of shocks in volatility. Also for our data the GARCH results point at an integrated GARCH (IGARCH) model, where shocks have an even permanent effect on volatility. This would mean that, for instance, the surge in volatility due to the Asian crisis affects volatility for a long time, or even permanently. We think such a result needs some further investigation.

The high estimated volatility persistence of shocks according to GARCH may be the result of structural change in the variance process. For example, if the variance is high but constant for some time and low but constant otherwise, persistence of such high and low homoskedastic periods already results in volatility persistence. A GARCH model, which cannot capture persistence of such periods, puts all volatility persistence in the persistence of individual shocks; see also Lamoureux and Lastrapes (1990). This is related to Perron's (1989) work on the mean equation. He argues that structural breaks in the level make it more difficult to reject the unit-root hypothesis (permanent persistence of shocks in the mean) for an actually stationary process. It is likely that breaks in the variance lead to spuriously high persistence of shocks in the variance in a similar way.

Structural change in the volatility process can be of particular importance for the East Asian markets that we consider. Financial market liberalization, other policy shifts and sudden crises occur more often in these markets than in their developed counterparts. (See Bekaert and Harvey (1997), De Santis and Imrohoroglu (1997) and Huang, Nark and Yang (1999) for more details on specific features of emerging market returns.) Moreover, the recent Asian crisis may also have led to a break in the unconditional variance.

Our focus on the volatility persistence of the Asian crisis combined with the potential importance of breaks for the estimated persistence of shocks makes that we want to allow for breaks in the volatility process. A popular way to do this is by using a Markov regime-switching model. This model was introduced by Hamilton (1989) to study switches between expansions and recessions in the U.S. business cycle. Instead of introducing regimes for the mean, we use the Markov model to describe switches between high and low variance periods.

As there may still be volatility dynamics after accounting for variance regimes, we use GARCH processes to govern the variance within both regimes. Hence, we have a regime-switching GARCH model, as in Gray (1996) and Klaassen (2001). It has two sources of volatility persistence, namely regime persistence and GARCH persistence within the regimes. This makes regime-switching GARCH more flexible regarding the estimation of the volatility persistence of the Asian crisis compared to standard, single-regime GARCH.

The remainder of the paper is organized as follows. In section 2 we describe the econometric methodology of regime-switching GARCH and its estimation. Section 3 reports the data along with the estimation results and answers the central question of the paper. Section 4 concludes.

2 Econometric Methodology

In this section we present the regime-switching GARCH model that we will use to study the persistence of the East Asian crisis in stock return volatility. We also briefly outlay the estimation methodology.

2.1 Regime-Switching GARCH Model

The regime-switching GARCH model has four elements, namely the mean, regime process, variance and the probability distribution, which we subsequently describe. Two of them, the regime process and variance, are crucial to interpret our empirical

results, as they are used to account for breaks in the variance due to the East Asian crisis and to allow for persistence of shocks in the variance.

Let r_t denote the percentage stock market return from time $t-1$ to t, that is, $r_t = 100(ln(P_t) - \ln(P_{t-1}))$, where P_t denotes the stock market index at time t. It is commonly assumed that there is low or even no predictability in stock returns. As our main emphasis is on volatility, we thus use a simple AR(1) model, with a presumably small autoregressive parameter θ, to describe the mean equation of r_t:

$$r_t = \mu + \theta(r_{t-1} - \mu) + \varepsilon_t, \tag{1}$$

where the innovation ε_t has zero mean conditional on the information set of the data generating process, to be defined below.

The second element of our model concerns the regimes. Let s_t be the unobserved regime (state) at time t. The second regime is identified as the high variance one, which will presumably capture the crisis period, among other periods. The persistence of regimes is governed by regime-staying probabilities. Let $p_{t-1}(s_t|\tilde{s}_{t-1}) = p(s_t|I_{t-1}, \tilde{s}_{t-1})$ denote the probability of going to regime s_t at time t conditional on the information set of the data generating process. The first part of this information set, I_{t-1}, denotes the information set $(r_{t-1}, r_{t-2}, \dots)$ that is known to the econometrician. The second part, $\tilde{s}_{t-1}$, is the regime path $(s_{t-1}, s_{t-2}, \dots)$, which the econometrician does not observe. The subscript $t-1$ is short-hand notation for conditioning on I_{t-1}.

Following Hamilton (1989), we assume that s_t follows a first-order Markov chain with constant staying probabilities

$$p_{t-1}(s_t \,|\, \widetilde{s}_{t-1}) = p(s_t \,|\, s_{t-1}) = \begin{cases} p_{11} & \text{if } s_t = s_{t-1} = 1 \\ p_{22} & \text{if } s_t = s_{t-1} = 2. \end{cases} \tag{2}$$

If p_{11} and p_{22} are high, then regimes are persistent.

The formulation of the conditional variance within each regime is the third element of the model. One possible candidate comes from a direct application of the GARCH(1,1) model in a regime-switching framework:

$$V_{t-1}\{\varepsilon_t|\tilde{s}_t\} = \omega_{s_t} + \alpha_{s_t}\varepsilon_{t-1}^2 + \beta_{s_t}V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}, \tag{3}$$

where the current regime determines the parameters, that is, the intercept ω_{s_t}, the ARCH parameter α_{s_t} and the GARCH parameter β_{s_t}, so that the previous regimes $\tilde{s}_{t-1}$ only appear in the lagged variance term. We use a basic GARCH(1,1)-type specification (for instance, without asymmetric effects of individual shocks on volatility) for the sake of simplicity and because our main emphasis is on regime and volatility persistence, for which equation (3) suffices.

The above specification, however, appears practically infeasible to estimate. This is due to the fact that $V_{t-1}\{\varepsilon_t|\tilde{s}_t\}$ in (3) depends on the entire regime path $\tilde{s}_t$, because it depends on s_t and $V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}$, where the latter is dependent on s_{t-1} and $V_{t-3}\{\varepsilon_{t-2}|\tilde{s}_{t-2}\}$, and so on. Since the number of possible regime combinations grows exponentially with t, the econometrician, who does not observe regimes, has to integrate out an enormous number of paths when computing the sample likelihood. This makes estimation intractable.

Two different approaches are offered in the literature to avoid this problem of path-dependence. First, Cai (1994) and Hamilton and Susmel (1994) essentially remove the GARCH term, the source of the path-dependence, and use only ARCH terms. Thus, they use a regime-switching ARCH model.

As a second approach, Gray (1996) and Klaassen (2001), who adjusts Gray's model, introduce a way to solve the problem of path dependence without giving up the GARCH terms. They thus generalize regime-switching ARCH to GARCH. In essence, they integrate out the regime path $\tilde{s}_{t-1}$ in the source of the path-dependence, $V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}$. This makes $V_{t-1}\{\varepsilon_t|\tilde{s}_t\}$ independent of $\tilde{s}_{t-1}$, so that there is no problem of path-dependence any more.

We apply the Klaassen (2001) specification to solve the path-dependency problem here, as his specification makes more efficient use of the conditioning information I_{t-1} and $\tilde{s}_t$ when integration out $\tilde{s}_{t-1}$, and because Klaassen's approach is more convenient for unconditional variance calculation and forecasting; see Klaassen (2001) for further details. In formula, the regime-switching GARCH variance specification is

$$V_{t-1}\{\varepsilon_t|\tilde{s}_t\} = \omega_{s_t} + \alpha_{s_t}\varepsilon_{t-1}^2 + \beta_{s_t}E_{t-1}[V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}|s_t], \qquad (4)$$

where $E_{t-1}[V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}|s_t]$ is the expectation of $V_{t-2}\{\varepsilon_{t-1}|\tilde{s}_{t-1}\}$ with respect to $\tilde{s}_{t-1}$ conditional on I_{t-1} and s_t. This expectation implies that $V_{t-1}\{\varepsilon_t|\tilde{s}_t\} = V_{t-1}\{\varepsilon_t|s_t\}$, which only depends on the current variance regime s_t instead of the complete regime path $\tilde{s}_t$. Hence, there is no problem of path-dependence. We denote this approach by GARCH(1,1;1,1), because it has a GARCH(1,1) type specification in both the first and the second regime. To guarantee positivity of $V_{t-1}\{\varepsilon_t|s_t\}$ for all t, we assume $\omega_{s_t} > 0$ and $\alpha_{r_s}, \beta_{s_t} \geqslant 0$. The "unconditional" variance $\sigma_{s_t}^2 = V\{\varepsilon_t|s_t\}$ is assumed to exist for both regimes s_t (see Klaassen (2001) for necessary conditions and a formula for the unconditional variance).

Equation (4) and the regime process governed by (2) capture several important features regarding the focus of the paper, the volatility persistence of the East Asian crisis. First, the large shocks in the crisis can be persistent because of both regime persistence and GARCH-type dynamics. This makes our model different from standard

regime-switching models with constant regime specific variances, where only the first mechanism is present, and different from single-regime GARCH models, which only have the second mechanism.

The second important feature of our model is that not all shocks have to be equally persistent, in contrast to a single-regime GARCH model. Shocks can even be "pressure relieving" by taking tensions away from the market. That is, they can be followed by a tranquil rather than volatile period, as shocks can be followed by a switch to the low volatility regime. Any regime-switching model can capture this to some extent. Our specification (4), with different parameters across regimes, however, allows for another source of neglecting large recent shocks. If the low-variance regime is also the short-persistence regime, the large shock will disappear from the volatility process very soon after a switch to the low-variance regime. Thus, the volatility persistence of shocks is allowed to be time-varying. In this sense, our model generalizes the regime-switching ARCH models of Cai (1994) and Hamilton and Susmel (1994) even if no GARCH terms are present, as their variance regimes only differ by a multiplicative of additive constant, respectively, not by differences in the ARCH parameters. See Klaassen (2001) for more discussion on the increased flexibility regarding volatility persistence.

The final element of the regime-switching GARCH model is the conditional distribution. We assume for simplicity that, conditional on I_{t-1} and $\tilde{s}_t$, the innovation ε_t follows a normal distribution with zero mean and variance $V_{t-1}\{\varepsilon_t | \tilde{s}_t\}$ or, equivalently, $V_{t-1}\{\varepsilon_t | s_t\}$:

$$\varepsilon_t | \tilde{s}_t, I_{t-1} \sim N(0, V_{t-1}\{\varepsilon_t | s_t\}). \tag{5}$$

Equations (1), (2), (4) and (5) describe our regime-switching GARCH(1,1;1,1) model. The standard, single-regime GARCH(1,1) model is a special case of our model, since that model results when all regime specific parameters in (4) are equal across regimes.

2.2   Estimation Methodology

To estimate the model, we follow the maximum likelihood procedure. We briefly describe it here; see Klaassen (2001) for further details.

Let $p_{t-1}(r_t)$ denote the density of the stock market return at time t evaluated at

r_t, conditional on observed information I_{t-1}.[1] We can write

$$p_{t-1}(r_t) = \sum_{s_t=1,2} p_{t-1}(r_t \mid s_t) \cdot p_{t-1}(s_t). \qquad (6)$$

The first term on the right-hand-side is the density of the stock market return at t evaluated at the value r_t, conditional on I_{t-1} and on the regime being s_t; it follows from (1), (4) and (5). The second term, $p_{t-1}(s_t)$, is the probability that the current regime is s_t, conditional on I_{t-1}; this term is needed to integrate out the unobserved regime in the first term. Hence, the density of r_t conditional on only observable information is a mixture of two normal densities with a time-varying mixing parameter.

The sample log likelihood $\sum_{t=1}^{T} \log(p_{t-1}(r_t))$ is then used to estimate the parameters in the regime-switching GARCH model. Klaassen (2001), using an algorithm based on Gray (1996), shows that one can build the log likelihood in a first-order recursive manner, which speeds up the estimation process substantially.

3   Empirical Results

In this section we first describe the data. Then we estimate the model and analyze the differences between regime-switching GARCH and single-regime GARCH. The estimation results are the basis for our answer in subsection 3.3 to the question whether East Asian stock markets have calmed down.

3.1   Data

Our sample consists of local currency stock market indices for five East Asian emerging markets, namely Indonesia, South Korea, Malaysia, Philippines, and Thailand. These countries are often considered as the Asian crisis countries (IMF (1999a, p.17) and Kawai (2000)). We have weekly data for these indices P_t, leading to data on weekly percentage returns r_t from January 5, 1989 to June 1, 2000, that is, 596 observations. For Indonesia, however, the returns are only available from October 11, 1990 onwards (504 observations). Despite this data problem, Indonesia is included for completeness and because it is well-known that Indonesia suffered a lot from the crisis, not only in an economic sense, but also from a social and political point of view.

The source of our data is the International Finance Corporation's Emerging Market Database (IFC-EMDB). We choose to use the IFC indices rather than other local stock

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[1]Note that we use the same symbol p_{t-1} for several probabilities (for instance, see (2)). The specific meaning of p_{t-1} is uniquely determined by the symbols in its argument. This results in a concise notation, which will prove useful in the remaining part of the paper.

price indices for several reasons. First, these indices are constructed on a consistent basis by the IFC, making cross-country comparison more meaningful.[2] Second, these indices include the most actively traded stocks in the local markets and cover at least 60 percent of local market capitalization. Third, the IFC-EMDB has been used in numerous other studies, including Choudhry (1996), Bekaert and Harvey (1997) and Huang et al. (1999).

Panels A and B of figures 1-5 provide some insight into the data for each country. Panel A plots the level P_t of the stock index. The sharp fall in stock prices caused by the crisis is clearly visible; it lasted through about August 1998, when the indices reached their lowest value after the crash. This supports the general view that the second half of 1998 provided the signs of a bottoming out of economic activity (IMF (1999a, p.15)). Panel A also visualizes the impressive recovery following the crisis.

Panel B gives the squared returns r_t^2. Not surprisingly, the crisis and its aftermath mark a period of very high volatility. Panel B also shows substantial evidence of volatility clustering, although the evidence is not so clear for the Philippines. This is confirmed by the usual tests for conditional heteroskedasticity (not reported): the first-order autocorrelation of the squared returns and the Box-Pierce combination of the autocorrelations up to order ten are significant, except for the Philippines (we always use a significance level of 5%). The insignificant tests for the Philippines are mainly caused by the fact that some large shocks are followed by tranquil periods (see figure 4B).

3.2 Estimation Results

To model the increase in volatility during the crisis and the volatility clustering, let us first use single-regime GARCH(1,1). Its specification follows as a special case from the model of subsection 2.1. For Indonesia and the Philippines we use a t-distribution instead of the normal one in (5) to correct for the presence of outliers.

The left columns for each country in table 1 present the GARCH(1,1) estimates. The likelihood ratio tests of the GARCH model versus the constant variance model ($\alpha = \beta = 0$) are 96.97, 115.64, 204.42, 28.44 and 167.09, for Indonesia, Korea, Malaysia, Philippines and Thailand, respectively. Hence, not surprisingly, the ARCH and GARCH parameters are jointly highly significant.

The single-regime GARCH results show that the sums of the estimated ARCH and GARCH parameters are high, as all five sums exceed 0.97. The sums are even close to one, which would imply integrated GARCH. This suggests that there is high or even

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[2]See International Finance Corporation (1998) for details on data methodology and definitions.

permanent volatility persistence of individual shocks, meaning that for instance the Asian crisis affects volatility for a long time, or even permanently. However, as argued in the introduction, the high sum of ARCH and GARCH parameters may also point at parameter instability due to regime shifts in the volatility process, for example caused by the Asian crisis. The high volatility persistence of shocks could then be a spurious impression from the single-regime GARCH model. This possibility is, for example, stressed by the Box-Pierce statistic of order ten for the Indonesian series through June 1997, so excluding the crisis. It is 14.48 with a p-value of 0.15, so that the evidence of volatility persistence of shocks disappears, or is at least weaker than the single-regime GARCH results suggest.

To gain flexibility regarding volatility persistence, the regime-switching GARCH model of section 2 adds a second source of volatility persistence to standard GARCH by allowing for two persistent regimes with different volatility levels. We choose the GARCH(0,0;1,1) variant, which has constant variance in the first regime and GARCH(1,1) in the second, for the following reasons. First, the likelihood ratio tests for adding an ARCH term to the first regime, that is, for GARCH(0,1;1,1) versus GARCH(0,0;1,1), are 2.06, 3.13, 1.51, 0.00 and 0.00 for the five countries, all below the critical value of 3.84. Hence, we document no evidence of volatility persistence of the (small) shocks that occur in the low-volatility regime. Second, testing GARCH(0,0;1,1) versus ARCH(0;0), that is, constant variance in both regimes, yields likelihood ratios of 7.80, 0.37, 13.32, 2.02 and 17.44. So in three out of five countries, we find volatility persistence of shocks in the high-volatility regime. For two countries, Korea and the Philippines, we find no volatility persistence within regimes, so that for them using only regimes appears sufficient to capture the volatility clustering in the data. For uniformity, however, we also use a GARCH(0,0;1,1) model for them.

The two results just presented indicate that the single-regime GARCH suggestion that all shocks are highly or even permanently persistent needs to be refined: shocks that occur in periods of low unconditional volatility are not persistent (at least our data yield no significant evidence), but shocks in periods of high unconditional volatility can be persistent. Hence, volatility persistence varies over time and is not constantly high as GARCH suggests. This conclusion corroborates Klaassen's (2001) finding for exchange rates, and also Choudhry (1996) reports time-variation in volatility persistence. The results provide an empirical motivation for the use of a regime-switching model that allows for different variance dynamics across regimes instead of the regime-switching models of Cai (1994) and Hamilton and Susmel (1994), where the variance dynamics are the same across regimes; see also subsection 2.1.

Table 1 gives the estimation results for GARCH(0,0;1,1) (right column for each country). The estimate of the autoregressive coefficient θ is significant for two countries; this motivates the inclusion of an autoregressive term in the mean equation (1). The estimated unconditional variance in the first regime is about one-fifth of the one in the second regime. Finally, the log-likelihood of GARCH(0,0;1,1) is always somewhat better than that of GARCH(1,1), which is not trivial because the latter model is not nested in the former.[3]

More important, the GARCH-type dynamics for the high-volatility regime are less pronounced than implied by the single-regime GARCH model. It again indicates the usefulness of regimes to explain part of the volatility clustering. This is further stressed by the difference between the log-likelihoods of ARCH(0;0), which uses regimes without GARCH, and of GARCH(1,1), using GARCH without regimes: -2.72, 4.29, -4.42, 2.06 and 7.03. Hence, using only regimes sometimes results in a better fit than single-regime GARCH.

The persistence of the regimes follows from the estimated staying probabilities p_{11} and p_{22}. The average of the p_{11} is 0.992, which implies an expected duration of the low-variance regime of $(1 - p_{11})^{-1} = 119$ weeks (see Hamilton (1989)); the average p_{22} is 0.989, so that the expected duration of the high-variance regime is 91 weeks. So both regimes persist for about two years.

The C panels of figures 1-5 provide further insight into the regimes. Each plot visualizes the regime probabilities for a country, that is, the estimated smoothed probability that the process is in the high variance regime.[4] Not surprisingly, according to the model all stock indices were in the high-volatility regime in the second half of 1997 and in 1998, the crisis period. The Thai stock market is the first one that moved to that regime. It happened already in 1996, well before the abandonment of the baht-dollar peg on July 2, 1997. This corroborates the view that the problems of high inflation, a widening current account deficit and rapid credit growth, among other things, already

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[3]We do not claim that the differences between GARCH (1,1) and GARCH(0,0;1,1) are statistically significant, since we have not tested for that. Such a test is not easy. First, the models are not nested. Second, testing for the presence of a second regime is not standard, as under the null of a single regime the regime-staying probabilities are not identified; see Hansen (1992). Testing for the presence of two (or more) regimes goes beyond the purpose of our paper. The main emphasis is on whether the impact of the East Asian crisis is still persistent in the volatility proces. To analyze that, we need a model that is more flexible than single-regime GARCH with respect to volatility persistence, because the estimated high persistence may be spuriously caused by periodic changes in the unconditional variance and because volatility persistence is not constant over time. The use of two regimes is an attractive way to achieve this, as explained before.

[4]The smoothed probability of a particular regime at time t is the conditional probability that the process was in that regime at time t using all information available to the econometrician, that is, I_T. See Klaassen (2001) for details on its computation.

became apparent during 1996, and that the turbulence spread from Thailand to the other countries (Kaminsky and Schmukler (1999))

The East Asian crisis is not the only high-volatility period.[5] The regime plots also indicate a surge in volatility in the second half of 1990. This mainly originates from the Gulf crisis. Several other events may also have increased volatility, for instance, the removal of the base lending rate in Malaysia in January 1991, for the Philippines the attempted military coup in November 1989 and the bank debt restructuring agreement in February 1990, and for Thailand the political turbulence caused by a corruption scandal and a coup at the end of 1990 and the beginning of 1991 (Bekaert and Harvey (1999)).

Another high-volatility period is the 1994 turbulence. That is commonly attributed to several factors (IMF (1994, p.28-29)). For instance, the stock market buoyancy in the second half of 1993 increased price-earnings ratios in several emerging markets by 50 percent, raising concerns about the sustainability of equity prices and the potential existence of a speculative bubble. Positive market sentiment was also reversed by the rising growth prospects and increased long-term interest rates throughout the industrial countries, which led investors away from emerging markets. Thus, the regime probability plots support the realism of our estimation results.

Finally, the bottom part of table 1 contains diagnostics for the specification of the single-regime GARCH and regime-switching GARCH models. The diagnostics are based on the normalized residuals. They show that the first-order autocorrelations and the Box-Pierce statistics are insignificant in most cases, so that we have no reason to extend the dynamic specification of the model.

3.3 Have East Asian Stock Markets Calmed Down?

To answer this question, we first examine the regime probability plots again. During the crisis period, all stock returns were in the high-volatility regime. It is striking that four out of five countries (Philippines is the exception) are still in that regime (at the end of our sample: June 2000). Hence, volatility is still higher than before the crisis.

Next, we look at the estimated conditional variances in the D panels. They bring an encouraging fact, as for the four countries that are still in the high-volatility regime the variances are coming down. To get some insight into how much the variance has been

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[5]However, for Indonesia, and to a lesser extent Korea, the Asian crisis is the only period in the high-volatility regime. For accurate estimation of the regime-switching process, one would need more switches. However, this appears no problem for our answer to the focus question of this paper. As shown in subsection 3.3, this answer will be mainly based upon the estimated GARCH dynamics in the high-volatility regime, and because the process is for about 150 weeks in that regime, the variance dynamics in the high-volatility regime are reasonably well estimated.

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reduced, we relate the variance over the first part of 2000 (up to June) to the variance during the crisis as follows. For the crisis period, we compute the relative increase in volatility by averaging the estimated conditional volatilities per country over July 1997 through August 1998, subtracting the respective average estimated variances from before the crisis and dividing by the latter. The increments are 567% (Indonesia), 191% (Korea), 334% (Malaysia), 211% (Thailand). The similarly computed increments over the first part of 2000 are 177%, 110%, 83%, and 98%, respectively. Thus, the variance gaps have been closed by 69%, 42%, 75%, and 54%, respectively.

In summary, the East Asian stock markets have not yet calmed down from the crisis, with the exception of the Philippines. However, the variances are coming down and the increase in variance in the crisis period has been reduced by about 60%.

Part of the prolonged stay in the high-volatility regime may be explained by the contagion from two other crises that followed the Asian one, namely the Russian (August, 1998) and Brazilian (early 1999) financial stress. All crises have made investors uncertain about the prospects of stock returns in emerging markets in general and it takes time to gain their confidence again. Further, investors may have overreacted during the crisis, possibly due to herding behavior, so that it seems natural that the variance is lower some time after the crisis.

It is, however, unlikely that both psychological arguments provide a complete explanation for our two results: why is the increase in variance due to the crisis then not completely gone some years after the crisis? To get a better understanding, it is worthwhile to analyze the crisis and its aftermath from a more economic structural point of view. One of the main reasons behind the crisis was the weakness of the domestic institutions, in particular the financial ones. This is illustrated by Kwack (2000), who provides data on indicators such as equity-to-total asset ratios for banks, bank claims on the private sector, and nonperforming bank loans. An essential element in the strategy for sustainable recovery concerns the restructuring of the financial sector, so as to strengthen the banks' balance sheets. This is usually a lengthy process. Governments and financial managers first have to recognize the problem and build a consensus on how to proceed. Then the necessary measures have to be implemented. In this respect, significant progress has been made, as Kawai (2000) argues. However, the process of restructuring has not yet resulted in a sound banking system. Hence, stock investors think that the underlying causes of the crisis have not yet been completely resolved. Together with the psychological arguments given above, this provides an explanation for our empirical results that there has been a substantial reduction in stock volatility, but that the stock return process is still in the high volatility regime.

Concerning the latter result, we have one exception: for the Philippines the stock return process has returned to the low volatility regime. Apparently, the crisis was not that severe in the Philippines. This result is in line with the conclusion of the IMF consultation with the Philippines; see IMF (1999b). The IMF argues that this can be attributed to a better position for the Philippines at the beginning of the crisis. This is probably because the crisis in the 1980s in the Philippines gave them already a lesson, so that the Philippines had already had a decade of reform policies prior to the 1997-1998 crisis (Intal, Milo, Reyes and Basilo (2000)). For instance, the capital adequacy ratio, defined as the ratio of net worth to risky assets, between 1992 and 1997 was always much higher than the BIS requirements of 8 percent (Intal and Llanto (1998)); see Kwack (2000) for evidence regarding other fundamental indicators. It thus appears that the banks' balance sheet positions in the Philippines were stronger than in the four other troubled countries in the crisis. This provides an explanation for the relatively moderate impact of the crisis on the Philippines and, in terms of our econometric model, the relatively early exit from the high-volatility regime.

4   Conclusion

In this paper we examine whether East Asian stock markets have calmed down or, more specifically, whether the surge in volatility during the 1997-1998 Asian crisis still affects stock return volatility in the year 2000. We use a regime-switching GARCH model. This model allows for the possibility that the crisis has caused a temporary rise in the unconditional variance of stock returns (switch from a low to a high-volatility regime) and it uses GARCH dynamics to govern the conditional variance within a regime. The model is more flexible regarding the volatility persistence of shocks than standard, single-regime GARCH, which is important given the focus of the paper.

We use data on weekly stock index returns for Indonesia, South Korea, Malaysia, Philippines and Thailand from January 1989 to June 2000. The main result is two-fold. First, the stock returns are still in the high-volatility regime in June 2000 (with the exception of the Philippines), so that most East Asian stock markets have not yet calmed down. Second, the increment in volatility caused by the crisis has been removed by about 60%.

We argue that both results can be explained from psychological and economic structural reasons. It takes time for investors to regain confidence in Asian equities after a severe crisis, so that volatility will stay high for some time after the crisis. However, subsequent volatility is presumably lower than during the crisis, where volatility was probably also affected by an overreaction of investors. From a more structural point

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of view, we explain our empirical results from the fact that the weakness of financial institutions in Asia has only been resolved partially, as restructuring the financial system in East Asia is a lengthy process. Hence, investors are not yet convinced that the reasons underlying the crisis have disappeared completely. The exceptional position of Philippines in our results (lowest impact of crisis) is consistent with this view, as the Philippines have already restructured their financial institutions for a decade, leading to a more sound financial system at the beginning of the crisis.

The experience of the Philippines provides a stimulus for the policy makers of the other countries in the region. Our results suggest that structural reform works. Hence, if the crisis countries continue with their policy reforms, their markets will calm down within the foreseeable future and will be less vulnerable to future crises.

The paper reports two other, more technical findings. First, the persistence of shocks in volatility varies over time. In volatile periods we find substantial persistence for some series, but we find no persistence of the (small) shocks that occur in tranquil periods. This is in contrast with the constantly high or permanent persistence of all shocks that is implied when using a standard, single-regime GARCH model. We show that the latter is presumably caused by ignoring movements of the unconditional variance (switches in regimes). Our second technical result is that the volatility regimes already explain a large part of the volatility clustering phenomenon in the data. Nevertheless, there remains some dynamics in the volatility process within regimes. The advantage of regime-switching GARCH is that it can capture both.

Our analysis can be extended and applied in various ways. For instance, to examine the economic sources of regime switches and the occurrence of crises, one can let the regime-switching probabilities depend on variables such as interest rates, price/earnings ratios, solvency ratios of banks and firms, and the current account. Moreover, given the similarities between the stock returns of the East Asian markets considered and the plausible correlation of the regime-switches, it may be worthwhile to do this in a multivariate framework. Perhaps there are a few factors that govern a large part of the volatility process for all countries. In this respect, one could substitute the regime-switching GARCH model for the standard GARCH part in factor-GARCH models, such as the ones described in Diebold and Nerlove (1989). These issues are left for future research.

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Table 1: Estimation results.

		INDONESIA		KOREA		MALAYSIA		PHILIPPIN.		THAILAND	
		G	RSG	G	RSG	G	RSG	G	RSG	G	RSG
Mean	μ	0.09	0.04	0.00	-0.11	0.27	0.30	0.20	0.19	0.26	0.19
		(0.16)	(0.15)	(0.15)	(0.15)	(0.12)	(0.12)	(0.16)	(0.16)	(0.19)	(0.17)
Autocorr.	θ	0.08	0.06	0.00	-0.02	0.05	0.04	0.14	0.16	0.12	0.13
		(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)
Uncond. var. regime 1	σ_1^2		9.78		10.34		4.39		8.12		8.62
			(1.45)		(0.77)		(0.48)		(0.81)		(0.70)
Uncond. var. regime 2	σ_2^2	27.47	77.79	19.30	45.83	14.35	25.61	14.43	27.62	23.21	50.12
		(15.59)	(54.72)	(5.30)	(7.29)	(4.95)	(7.17)	(3.29)	(7.24)	(5.96)	(7.84)
ARCH regime 2	α_2	0.09	0.20	0.06	0.05	0.10	0.09	0.05	0.09	0.13	0.21
		(0.03)	(0.12)	(0.02)	(0.05)	(0.02)	(0.04)	(0.03)	(0.08)	(0.03)	(0.07)
GARCH regime 2	β_2	0.90	0.72	0.92	0.73	0.89	0.87	0.92	0.47	0.84	0.47
		(0.03)	(0.17)	(0.03)	(0.18)	(0.02)	(0.05)	(0.05)	(0.53)	(0.04)	(0.16)
Regime stay. prob.	p_{11}		.998		.994		.987		.988		.991
			(.003)		(.005)		(.009)		(.008)		(.005)
	p_{22}		.997		.988		.990		.981		.989
			(.004)		(.010)		(.007)		(.013)		(.007)
Log-likelihood		-1406	-1404	-1676	-1672	-1570	-1568	-1613	-1610	-1739	-1723
Autocorr. $\widehat{\eta}_t$:	ρ_1	-0.01	0.02	-0.01	0.01	0.02	0.02	-0.01	-0.01	-0.01	-0.01
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	Q_{10}	17.72	18.95	8.87	8.40	8.78	8.98	19.94	18.80	12.08	10.21
		[0.06]	[0.04]	[0.54]	[0.59]	[0.55]	[0.53]	[0.03]	[0.04]	[0.28]	[0.42]
Autocorr. $\widehat{\eta}_t^2$:	ρ_1^s	0.07	0.03	0.01	0.01	-0.01	-0.01	-0.01	-0.03	-0.01	-0.05
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	Q_{10}^s	12.97	14.37	9.96	11.56	5.12	5.86	1.23	1.93	13.40	13.76
		[0.23]	[0.16]	[0.44]	[0.32]	[0.88]	[0.83]	[1.00]	[1.00]	[0.20]	[0.18]

Standard errors in parentheses and p-values in square brackets.

"G" denotes the single-regime GARCH(1,1) model; "RSG" denotes the regime-switching GARCH(0,0;1,1) model.

The regime specific unconditional variances σ_1^2 and σ_2^2 have been computed from the unconditional variance formula in Klaassen (2001).

For Indonesia and the Philippines we have used a t-distribution instead of the normal distribution in (5) for both models to correct for the presence of outliers. The estimated inverted degrees of freedom are for Indonesia 0.22 (0.04) for G and 0.22 (0.06) and 0.18 (0.09) for RSG, and for Philippines 0.17 (0.04) for G and 0 (-) and 0.23 (0.07) for RSG.

The log-likelihoods for GARCH (1,1) and GARCH(0,0;1,1) are not comparable in terms of standard likelihood ratio tests, because the models are not nested and testing for the presence of a second regime is not standard; see also footnote 3.

The normalized residual $\widehat{\eta}_t$ is defined as $\widehat{V}_{t-1}\{\varepsilon_t\}^{-1/2} \cdot \widehat{\varepsilon}_t$.

The first-order autocorrelation, ρ_1, is estimated as the slope coefficient in a regression of $\widehat{\eta}_t$ on $\widehat{\eta}_{t-1}$ and a constant. Q_{10} is the Box-Pierce type statistic that combines the first ten autocorrelations. The first-order autocorrelation in the squared returns, ρ_1^s, and the corresponding Box-Pierce statistic, Q_{10}^s, are similarly defined.

A: Stock market index (logarithmic scale)

B: Squared percentage return

C: Smoothed probability of high variance regime

D: Conditional variance of percentage return
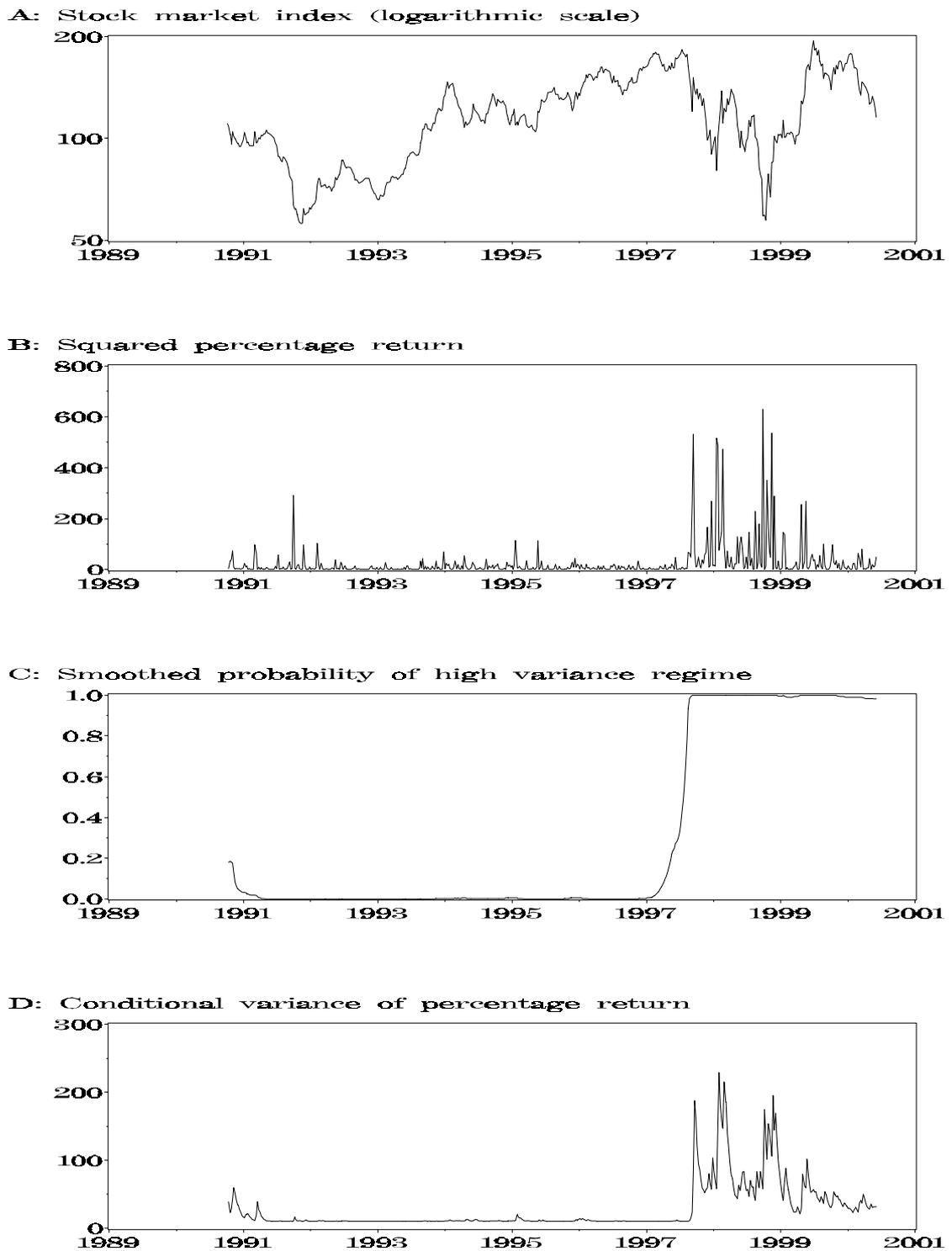
Figure 1: Indonesian stock market over the sample period October 1990 to June 2000.

A: Stock market index (logarithmic scale)

B: Squared percentage return

C: Smoothed probability of high variance regime

D: Conditional variance of percentage return
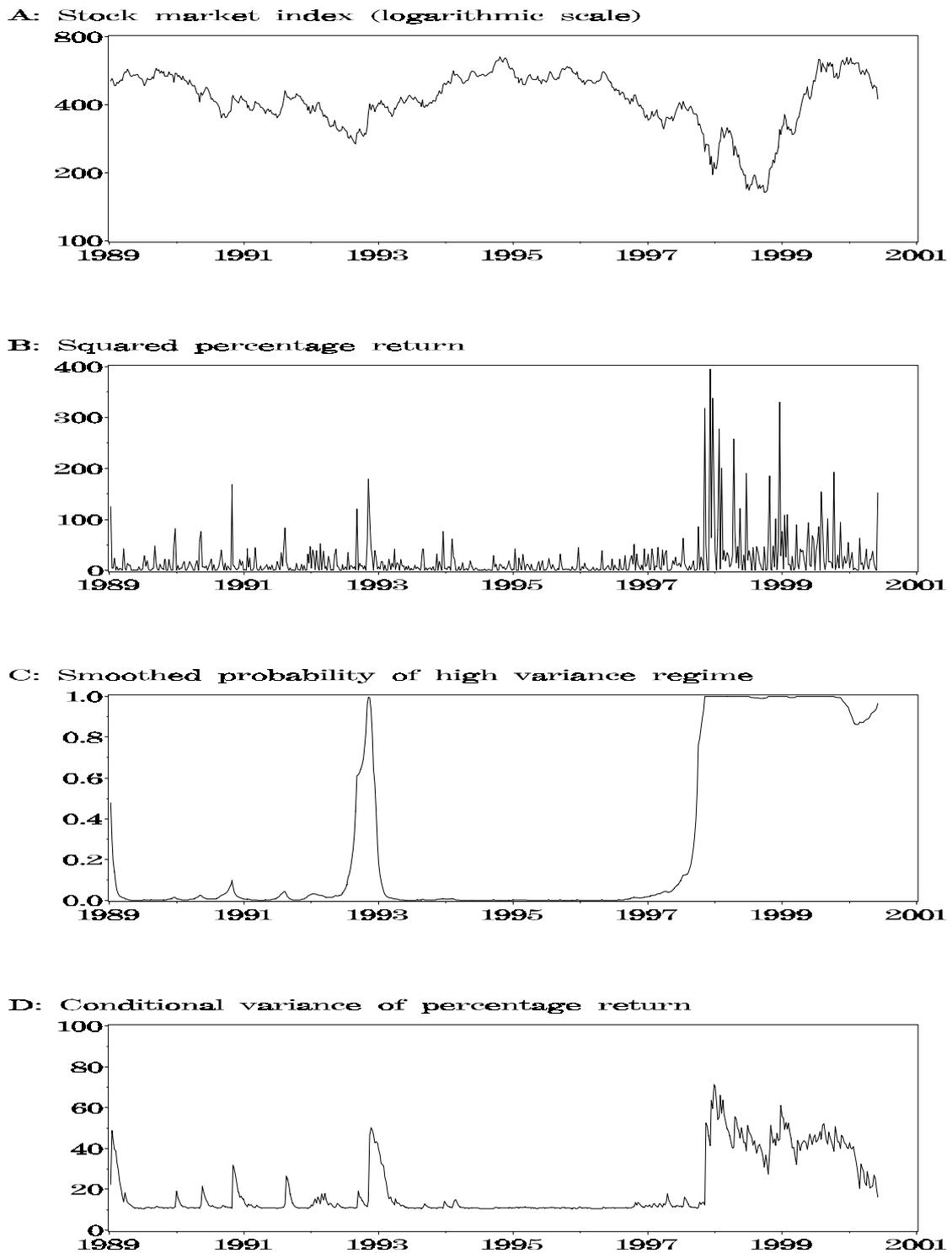
Figure 2: Korean stock market over the sample period January 1989 to June 2000.

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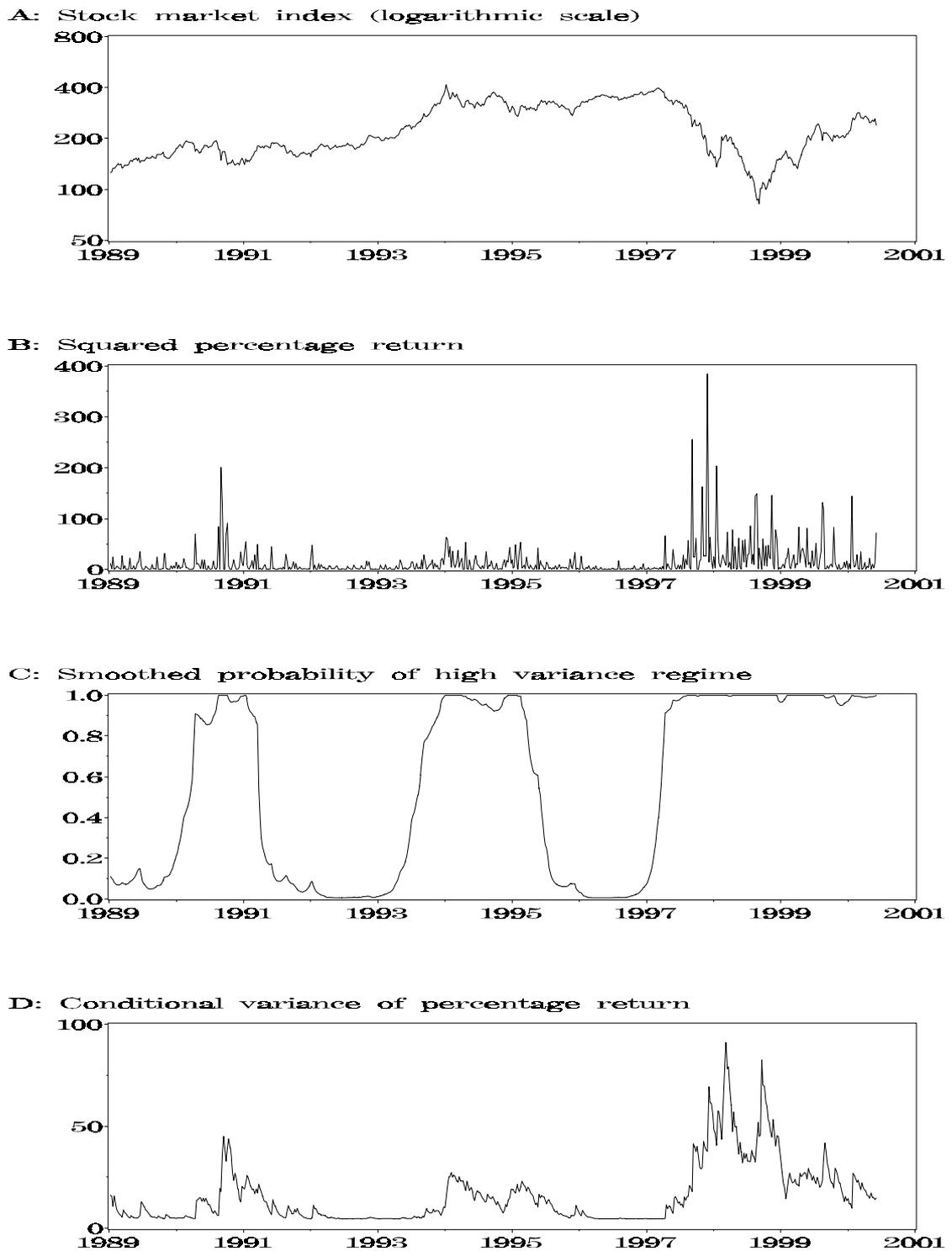
Figure 3: Malaysian stock market over the sample period January 1989 to June 2000.

A: Stock market index (logarithmic scale)

B: Squared percentage return

C: Smoothed probability of high variance regime

D: Conditional variance of percentage return
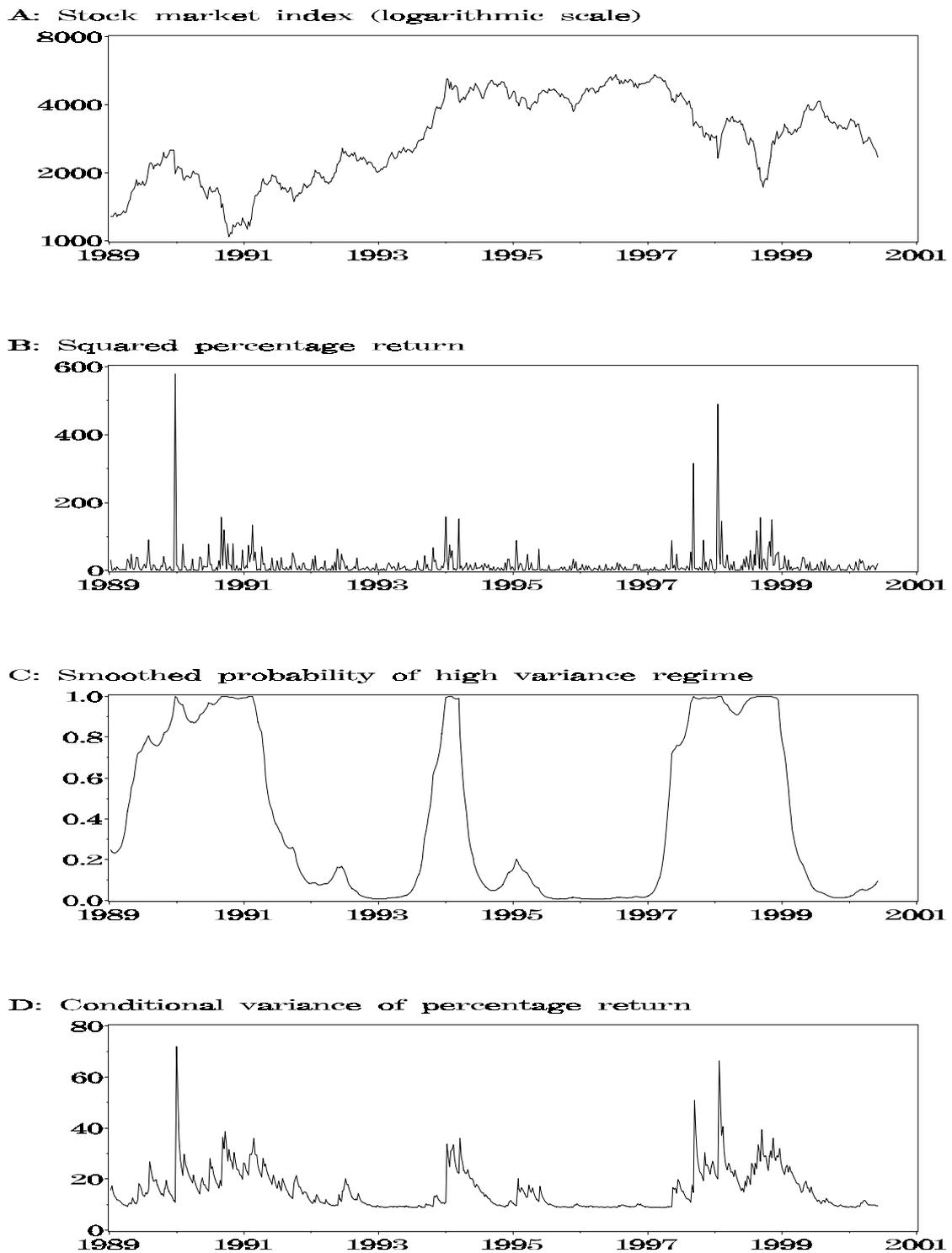
Figure 4: Philippine stock market over the sample period January 1989 to June 2000.

A: Stock market index (logarithmic scale)

B: Squared percentage return

C: Smoothed probability of high variance regime

D: Conditional variance of percentage return
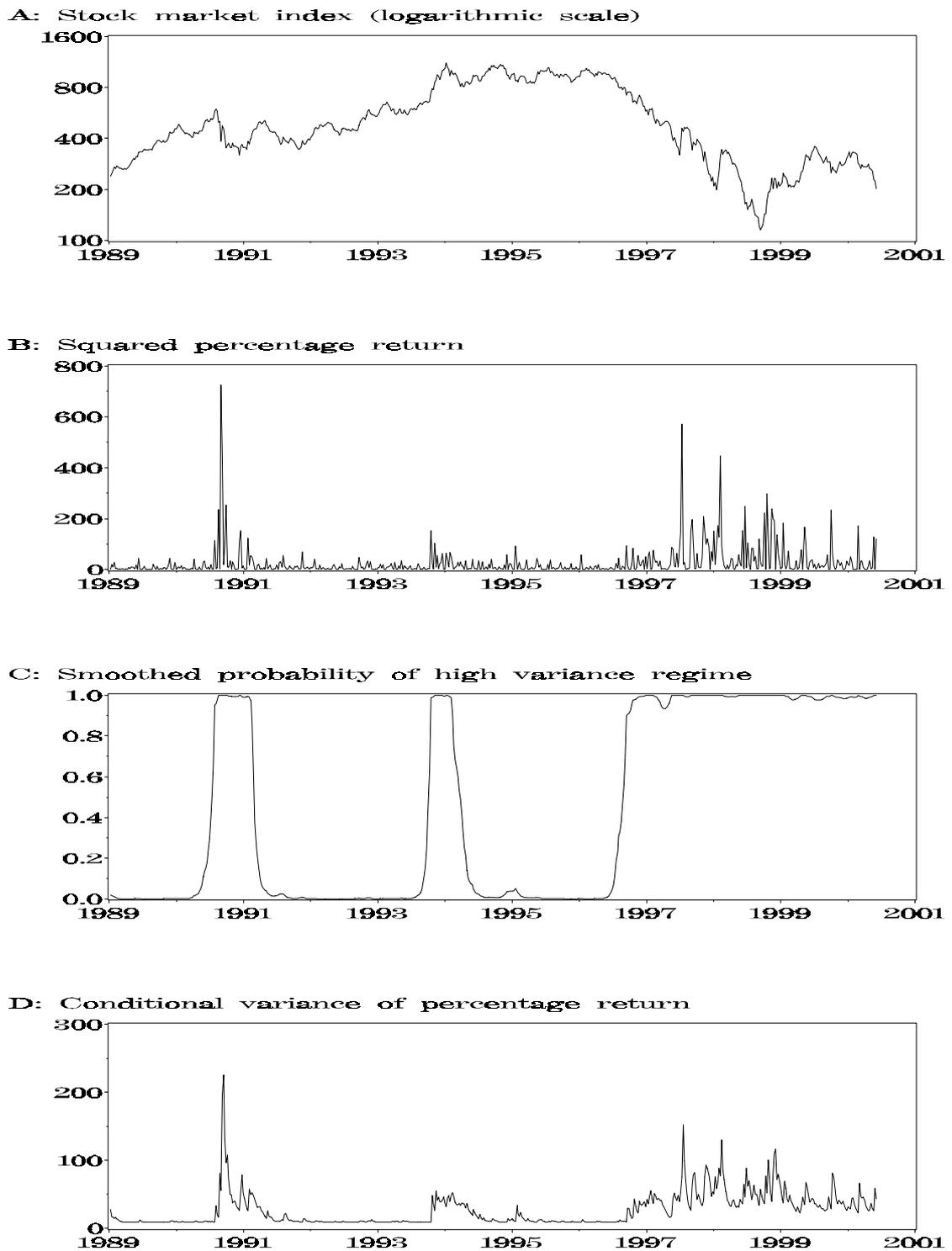
Figure 5: Thai stock market over the sample period January 1989 to June 2000.