Time-Varying Risk and Return in Global Portfolio Management

ANDREAS C. CHRISTOFI, PANAYIOTIS THEODOSSIOU, AND ANDREAS PERICLI

ANDREAS CHRISTOFI is an associate professor and chair of the Department of Economics and Finance at the School of Business Administration at Monmouth University in West Long Branch, New Jersey.

PANAYIOTIS THEODOSSIOU is professor of finance at the School of Business at Rutgers University-Camden in New Jersey.

ANDREAS PERICLI is a principal economist at the Federal Home Loan Mortgage Corporation in McLean, Virginia.

A class of econometric techniques known as ARCH (autoregressive conditional heteroscedasticity) allows researchers to explicitly model the dynamic nature of uncertainty surrounding security prices. These methods are popular because they are capable of exploiting predictable components of the volatility of security returns. A natural application of these models is in the stock markets of the industrialized countries.

It has been documented that the stock market innovations and volatility shocks in the U.S. are rapidly transmitted to the rest of the world. As world economies become increasingly interdependent, it is reasonable to assume that capital markets will become more susceptible to common shocks, especially in periods of high volatility.[1]

The literature on the subject is divided. Odier and Solnik [1993] and Lin, Engle, and Ito [1994] raise concerns about whether international diversification can protect investors in periods of extreme fluctuations in the U.S. market. At such times, the benefit of holding an international portfolio may be reduced when investors need it the most. More recent studies such as Cavaglia et al. [1997] and De Santis and Gerard [1997], however, show that gains from international diversification for a U.S. long-term investor remain economically attractive, regardless of the volatility.

Little attempt has been made to evaluate the relevance of time-varying volatility for practitioners. Such an inquiry is critical for portfolio managers who may be interested in implementing these techniques and who ultimately bear the underlying risk. Unless there is clear evidence that one set of states is more informative than another, we would not expect investors to expend the required resources to shift from a traditional buy-and-hold portfolio strategy to a more costly one with more frequent revisions.

PURPOSE OF STUDY

The purpose of this study is to assess the potential benefits of the presumed additional information implied by the modeling of volatility feedback. In particular, it evaluates the performance of a portfolio that is based on mean and volatility spillovers between the U.S. stock market and those of Japan and the U.K., using an autoregressive process known as generalized autoregressive conditional heteroscedasticity (GARCH), as described in the appendix.

Our investigation is comprehensive, and we consider the results informative and useful to investors and portfolio managers. It is comprehensive in that it considers transaction costs and risk aversion. It is informative because it reveals additional gains for international investors beyond a conventional buy-and-hold portfolio strategy.

The results indicate that during periods of high volatility (like the October 1987 stock market crash) mean reversion is more profound, and volatility feedback becomes more informative; that is it incorporates more predictable components. During periods of low volatility, the states are less informative, so the portfolio revision horizon becomes less critical. In this case, a conventional buy-and-hold portfolio strategy would be more appropriate.[2]

In brief, our results demonstrate that time-varying portfolio inputs are informative, but costly. Only if investors hold a synthetic index fund may they be able to beat a conventional buy-and-hold portfolio strategy. As pointed out by Bruce and Eisenberg [1992], synthetic index funds avoid high transaction costs and offer higher liquidity. In addition, such funds offer agility and maneuverability and permit quick turnover, which enables investors to weather financial storms during unstable times.

DATA

The standard portfolio optimization problem requires as inputs means, variances, and covariances. In principle, these measures should be forward-looking, reflecting investor expectations. In practice, however, they are estimated from historical data using various modeling frameworks. The objective in forming expectations from historical data is that a model encompass as much information as possible.

The data used to estimate the GARCH model include weekly stock market returns for the U.S., Japan, and the U.K., and span the period from May 14, 1984, through October 3, 1994. We select these stock markets because of their integration, liquidity, and capitalization. In addition, collectively they represent almost continuous trading, since they trade sequentially, and have been the subject of many recent empirical studies of mean and volatility spillovers.[3]

The data are split into two subperiods: one covering May 14, 1984-August 9, 1993, and the other August 16, 1993-October 3, 1994. The first data set is used to estimate the inputs to the portfolio optimization problem. The out-of-sample data set (August 16, 1993-October 13, 1994) is used to assess the reliability of the GARCH-based portfolio, assuming no revision throughout the entire period.

The dummy variables are used to test for differential behavior of the mean, volatility, and correlation structure of returns during the pre- and post-October 1987 stock market crash periods. For our purposes, the pre-crash period is May 14, 1984-October 13, 1987, and the post-crash period is October 26, 1987-August 9, 1993.

The stock market returns for each country are computed using the standard formula: $R_{i,t} = 100[\log(P_{i,t}/X_{i,t}) - \log(P_{i,t-1}/X_{i,t-1})]$, where $P_{i,t}$ is the level of the stock price index for country i based on Friday's closing prices, and $X_{i,t}$ is the corresponding exchange rate expressed as units of currency i per U.S. dollar, for i = U.S., JP, and U.K. The indexes are the S&P 500 for the U.S., the Topix for Japan, and the FT-SE 100 for the U.K.

The use of weekly rather than daily or intradaily data is more appropriate for this study mainly because of the transaction costs involved in rebalancing the portfolio. In addition, weekly data minimize the correlation bias caused by non-synchronous trading across the three markets.

TIME-VARYING PORTFOLIO STRATEGY

We want to assess the potential benefits to portfolio managers who may consider revising their portfolio according to the conditional inputs derived from the time-varying methodology. For this purpose, we obtain estimates of the portfolio inputs by fitting the GARCH model during the period of May 14, 1984-August 9, 1993. The resulting series of means, variances, and covariances of the returns of the three indexes change through time. This allows us to form mean-variance efficient portfolios on a weekly basis. We call this portfolio strategy *active*. The benchmark is a standard buy-and-hold portfolio strategy with fixed weights based on the unconditional means, variances, and covariances of the returns.

As a point of reference, we also consider a naive portfolio strategy based on equal weights. We contrast the performance of these strategies on a weekly basis by applying the current period's portfolio weights to the (actual) returns of the subsequent period, adjusting for transaction costs.

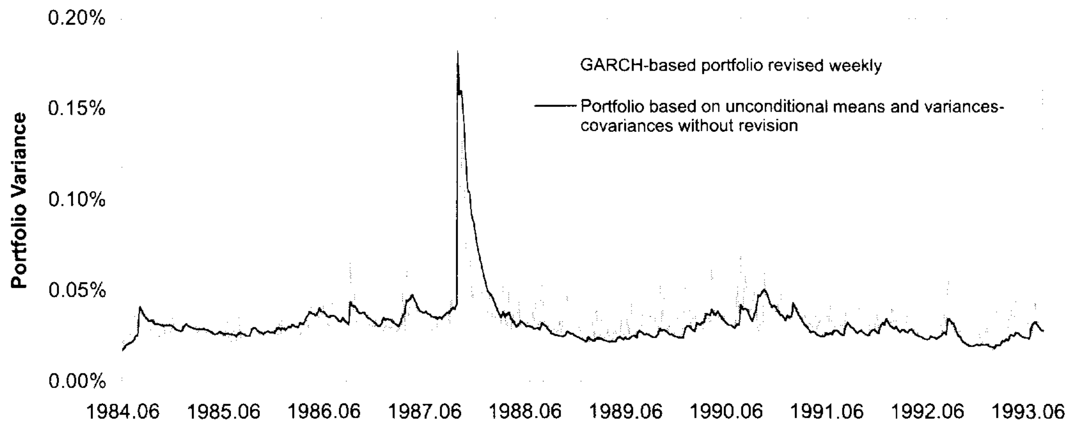
In order to make meaningful comparisons between the performance of the strategies, we control for equal risk aversion. This assumption ensures that we are dealing with the same individual investor or class of investors.

ANALYSIS OF RESULTS

Time-Varying Volatility

Exhibit 1 provides an insight into the mean reversion of the conditional volatility of the time-varying portfolio. The graph compares the volatility of an active GARCH-based portfolio, which is revised weekly, and the

Exhibit 1
Revised versus Unrevised Portfolio Variance



The dark line represents the conditional variance of a portfolio with fixed weights (without revision). The weights of this portfolio are derived from the unconditional means and variances-covariances. The light line is the conditional variance of a portfolio that is revised weekly according to the conditional means and variances-covariances with inputs obtained from the GARCH methodology.

volatility of a fixed-weight portfolio (without revision) implied by the unconditional structure of returns. That is, although both strategies use the same conditional variances and covariances of the U.S., U.K., and Japanese stock market returns as risk inputs, the former assumes weekly revisions, while the latter maintains the same weights.

As can be seen in the graph, the conditional series of the portfolio volatility reverts to its long-run average, which is represented by the unconditional series. The GARCH methodology exploits the information contained in the transitory departure of volatility from its long-run average. Its success depends to a great extent on its ability to identify and model the predictable components of the volatility.

How Informative is Time-Varying Volatility?

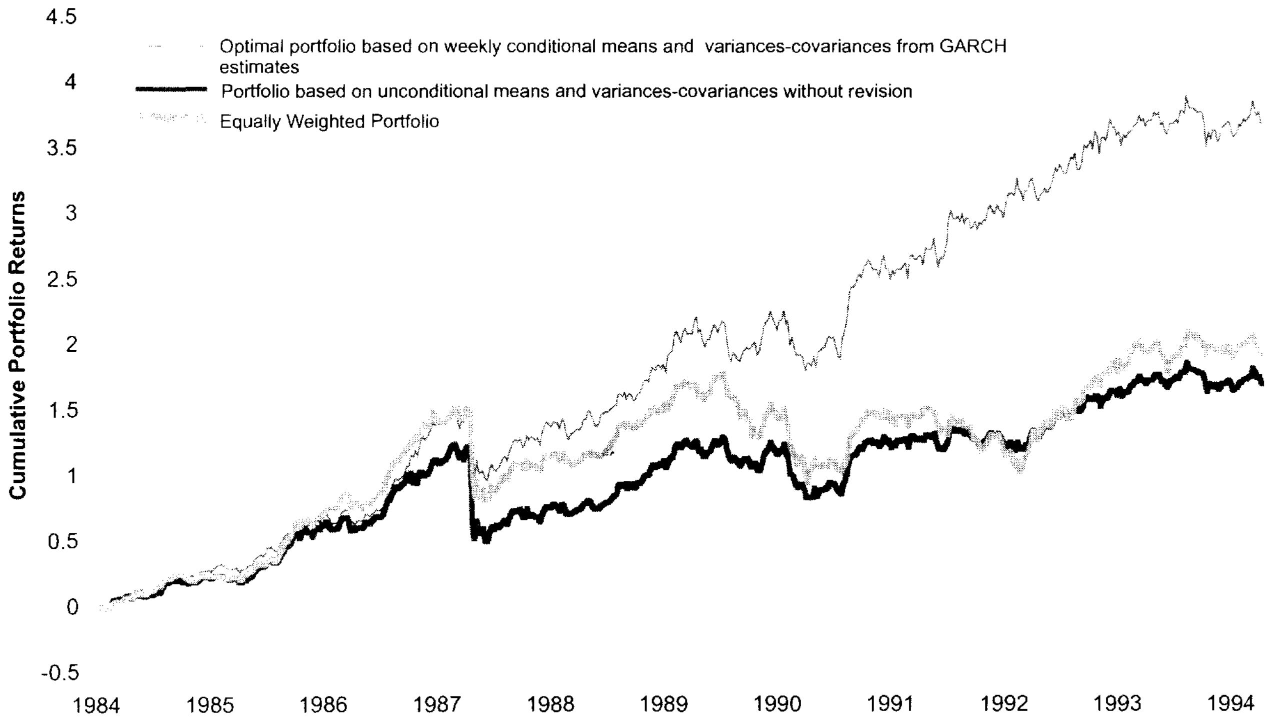
Since the portfolio strategies considered are constrained to yield equal long-run variances, as seen in Exhibit 1, a strategy with higher cumulative portfolio returns would be considered superior to the remaining strategies. Exhibit 2 depicts such a situation. This graph compares the cumulative rates of return of the three portfolios: an equally weighted portfolio; a portfolio constructed from the unconditional structure of returns without revision; and a GARCH-based portfolio implied by the weekly estimates of means, variances, and covariances of the returns of the three country indexes. The first two portfolio strategies are based on fixed weights, while the GARCH-based portfolio allows for weekly revisions.

Exhibit 2 shows that, assuming only commission fees, an active portfolio strategy based on the GARCH estimates outperforms the other two strategies. Interestingly, this strategy maintains its superior performance even during the out-of-sample holding period of August 16, 1993-October 3, 1994. Since we consider the portfolio of an "average" investor, the typical commission rates on equities are roughly estimated to be 0.1% for the U.S., and 0.8% for Japan and the U.K. We assume that higher costs could be offset by less frequent portfolio revisions.

It is worth noting that the overall average holdings of the dynamic strategy with weekly revisions are similar to those of the fixed-weight strategy, derived from the unconditional estimates. Specifically, with transaction costs of 0.1% for the U.S. and 0.8% for the other two markets, the average portfolio holdings are: U.S. 78%, Japan 13%, and U.K. 9%. The standard portfolio based on the unconditional estimates consists of 68% U.S. stocks, 14% Japanese stocks, and 18% British stocks. Obviously, the U.S. market is favored due to its low transaction costs and risk-return trade-off.

As we would expect, the greatest part of the GARCH excess return originates during the October 1987 turmoil. During that period, the Dow Jones Industrial Average suffered a total of an 810-point correction (31.8%) in a series of large declines, including the 508-point drop on October 19, 1987 (22.6%).[4] Unlike the two

EXHIBIT 2
Portfolio Performance Assuming Only Commission Fees



The top line represents the cumulative rates of return of a portfolio based on conditional means and variances-covariances with weekly revisions derived from the GARCH model. The middle line is the performance of the conventional portfolio based on unconditional means and variances-covariances. The line showing the poorest performance corresponds to an equally weighted portfolio of the unconditional means and variances-covariances. In all cases the portfolio returns are net of commission fees: U.S. = 0.1%, JP = 0.8%, U.K. = 0.8%.

other portfolio strategies, which follow a passive approach, the GARCH-based strategy capitalizes on the information incorporated in the spillovers of the world capital markets and earns sufficient returns to more than compensate for the losses suffered during the October 19, 1987, plunge.

A similar, although weaker, exploitation of information by the GARCH-based formulation occurs during the period following October 13, 1989, when the Dow dropped 190.58 points (6.91%); the period following October 21, 1987, when it rose 186 points; the period following August 6, 1990, with a 93.31 point drop (3.32%) in the Dow; and the period following November 15, 1991, when the Dow declined 120.31 points (3.93%).

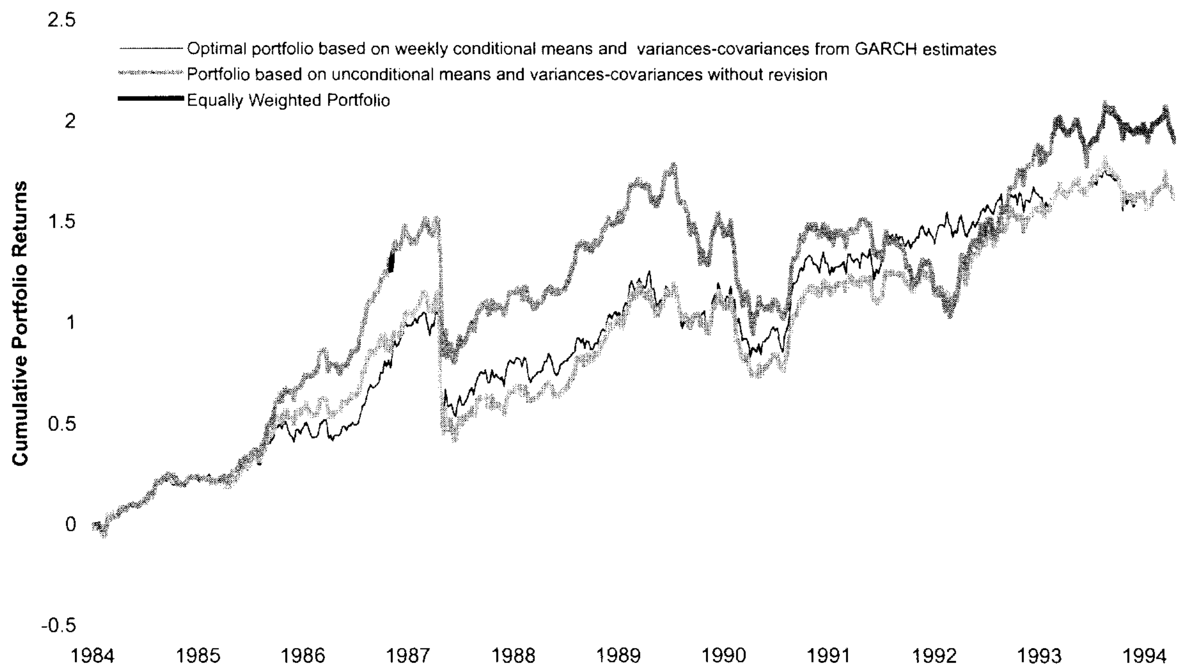
Do Transaction Costs Matter?

As it is shown in Exhibit 3, when transaction costs include commission fees and bid-ask spreads, the three portfolios yield similar results. The bid-ask spreads range from 0.5% in the U.S. to 1.5% in the other two countries. Thus, unless investors are successful in avoiding the bid-ask spread by obtaining better executions during the last trading day of the week, they will not be able to beat a naive strategy.

Of course, costs could be managed by combining levered positions in the portfolio of equities, such as stock index futures contracts. Levered positions require a relatively small amount of investment, hence providing an extremely cost-effective means of accessing the world equity markets. The round-trip commission rates for these contracts range from 0.01% to 0.04% and the bid-ask spreads from 0.04% to 0.08%.

Exhibit 4 shows the performance of the three strategies with limited transaction costs of 0.05%, such as those associated with futures positions. As pointed out by Bruce and Eisenberg [1992], international investors will prefer a synthetic index fund (one that incorporates futures

EXHIBIT 3
Conventional Portfolio Performance Assuming Commission Fees and Bid-Ask Spreads



Trend lines are as described in Exhibit 2. Portfolio returns are net of commission fees and bid-ask spread on futures contracts: U.S. = 0.5%, JP = 1.5%, U.K. = 1.0%.

indexes) because of its low transaction costs and higher liquidity, all other things equal.

According to Exhibit 4, the GARCH-based strategy yields even better results than the results in Exhibit 2. Thus, our findings corroborate those of Cavaglia et al. [1997], and suggest that an active portfolio strategy with frequent revisions outperforms standard buy-and-hold benchmarks. This is especially true for synthetic index funds, which by definition involve lower transaction costs.

Comparison in a Nutshell

Unlike traditional historical volatility, time-varying (conditional) volatility produces superior portfolio inputs. Exhibit 2 shows that an active strategy based on conditional portfolio inputs, derived from a GARCH model, outperforms the buy-and-hold benchmarks, even when transaction costs are considered. Exhibit 3 implies that bid-ask spread-related transaction costs are highly penalizing for an active strategy. In this case, investors may not have an incentive to revise their portfolios as frequently as they would like. Alternatively, investors may resort to synthetic index portfolios that involve limited transaction costs. As shown in Exhibit 4, this is by far the most promising strategy.

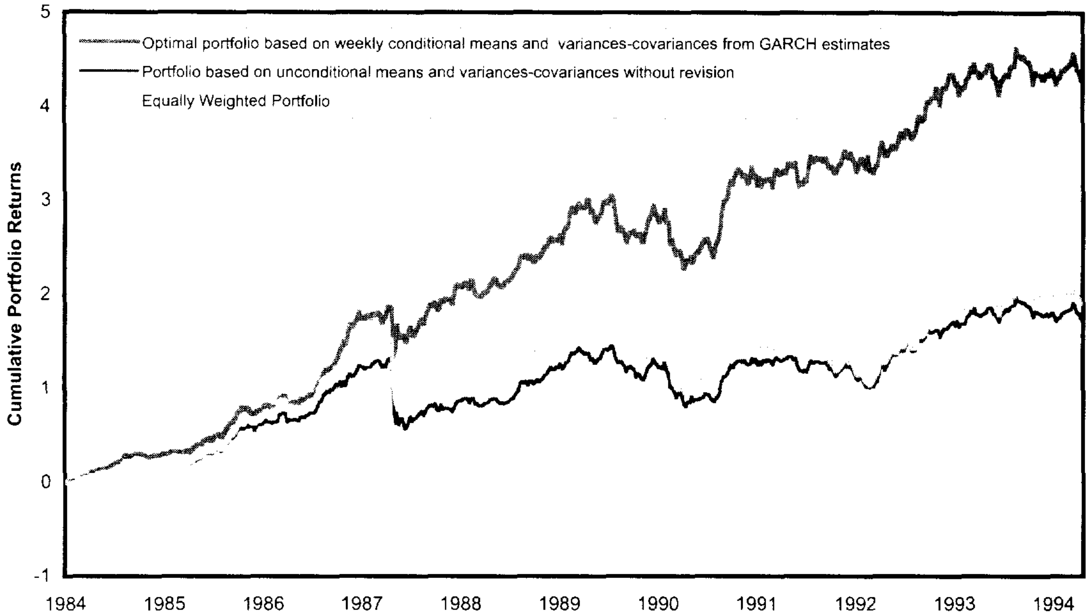
CONCLUSIONS AND IMPLICATIONS

We have analyzed an active portfolio strategy that uses time-varying parameters produced by a GARCH methodology. The results suggest that such a strategy outperforms alternative buy-and-hold strategies. When transaction costs are extended to include the bid-ask spread, investors can profit from adding low-cost levered positions, such as futures indexes, to their portfolios of equities. The additional information is attributable to the predictable systematic components embedded in the higher moments of the distribution of returns. These tidy elements reflect the nature of the information system of the capital markets.

For example, national and international policy coordinations and national monetary policies have seasonal

EXHIBIT 4

Portfolio Performance Assuming Commission Fees and Bid-Ask Spreads on Each Market of 0.05%



Trend lines are as described in Exhibit 2. Portfolio returns are net of commission fees and bid-ask spread (equivalent to those on futures contracts): U.S. = 0.05%, JP = 0.05%, U.K. = 0.05%.

and anticipatory attributes. Also, investor overreaction in the short term as well as the medium term, triggered by unexpected news, precipitates mean-reverting, although stochastic, volatility in security returns.

The implication of our work for portfolio managers, institutions, and individual investors is that active global diversification is more beneficial than ordinary buy-and-hold portfolio strategies. This claim holds even in periods of severe U.S. market declines. The gains (excess returns) from the additional information contained in the predictable components of the volatility more than offset the loss in diversification benefits occasioned by the increased correlation of returns.

APPENDIX

The General Autoregressive Conditional Heteroscedasticity Model

The multivariate general autoregressive conditional heteroscedasticity (GARCH) model used to obtain the required portfolio inputs is expressed as:

$$R_{i,t} = \mu_{i,t} + \varepsilon_{i,t} = m_i + m_{C,i}C_t + \beta_i R_{t-1} + \varepsilon_{i,t} \quad \text{(A-1)}$$

$$\sigma^2_{i,t} = v_i + v_{C,i}C_t + \alpha_i \eta_{t-1} + \gamma_i \sigma^2_{i,t-1} \quad \text{(A-2)}$$

$$\sigma_{i,j,t} = (\rho_{i,j} + \delta_{i,j}C_t)\sigma_{i,t}\sigma_{j,t} \quad \text{(A-3)}$$

for i, j = U.S., JP, and U.K.

where $R_{i,t}$ is the rate of return on security i at period t; $\mu_{i,t} \equiv E(R_{i,t} \mid \Phi_{t-1})$ and $\sigma^2_{i,t} \equiv Var(R_{i,t} \mid \Phi_{t-1})$ are the conditional mean and conditional variance of returns in market i based on past information, Φ_{t-1}; C_t is a dummy variable that takes a value of one for the pre-crash period and a value of zero for the post-crash period; $\sigma_{i,j,t} \equiv Cov(R_{i,t}, R_{j,t} \mid \Phi_{t-1})$ is the conditional covariance of returns in markets i and j; and $\rho_{i,j}$ is the contemporaneous correlation. The dummy variable is included in Equations (A-1)-(A-3) to test for differences in the conditional mean, conditional variance, and conditional covariance of returns during the pre- and post-crash periods.[6]

The parameters $m_{C,i}$, $v_{C,i}$, and $\delta_{i,j}$ represent deviations from their respective post-crash values. Significant negative deviations would indicate that the respective measures were higher during the post-crash period, and vice versa. Thus, the intercepts of the conditional mean and conditional variance equations of returns in each market are $m_i + m_{C,i}$ and $v_i + v_{C,i}$ for the pre-crash period and m_i and v_i for the post-crash period. Similarly, the correlations of returns are $\rho_{i,j} + \delta_{i,j}$ for the pre-crash period and $\rho_{i,j}$ for the post-crash period.

The conditional means of returns in the three markets are specified as a VAR(1) process; that is, they are a function of past returns from all three markets, $R_{t-1} = [R_{US,t-1}, R_{JP,t-1}, R_{UK,t-1}]'$. The autoregressive coefficients $\beta_i = [\beta_{i,US}, \beta_{i,JP}, \beta_{i,UK}]$, for i = U.S., JP, and U.K., are indicative of mean spillovers from one market to the others. Specifically, statistically significant values for $\beta_{i,i}$ indicate that current returns in market i are influenced by their own past values. Statistically significant $\beta_{i,j}$ values, for $i \neq j$, indicate that current returns in market i are influenced by past returns in market j; i.e., there are mean spillovers from market j to market i. The error term $\varepsilon_{i,t}$ represents innovations (shocks) in market i during week t and is expressed as the difference between the observed and the expected rates of return, $R_{i,t} - \mu_{i,t}$.

The conditional variance of returns in each market is specified as a linear function of past volatility shocks from the three markets, represented by a vector of past squared innovations $\eta_{t-1} = [\varepsilon^2_{US,t-1}, \varepsilon^2_{JP,t-1}, \varepsilon^2_{UK,t-1}]'$ and their own past conditional variance $\sigma^2_{i,t-1}$. The conditional variance equation provides a means of exploring the transmission of volatility shocks from one market to the others (volatility spillovers). Letting $\alpha_i = [\alpha_{i,US}, \alpha_{i,JP}, \alpha_{i,UK}]$, statistically significant values for $\alpha_{i,i}$ indicate that volatility in market i is influenced by its own volatility shocks (own-volatility spillovers). Statistically significant $\alpha_{i,j}$ values for $i \neq j$ imply that current volatility in market i is influenced by past volatility shocks in market j; i.e., there are volatility spillovers from market j to market i.[7]

The parameter estimates for Equations (A-1)-(A-3) are obtained by minimizing a sample log-likelihood function that depends on conditional variances, covariances, and standardized residual variances (ε^2/σ^2). The robustness of the model is explored by applying several diagnostic tests, including stationarity or reversion in the conditional variances and stability in the correlation structure. Also, the variances in Equations (A-2) are constrained to have positive values.

ENDNOTES

[1]See Bollerslev, Chou, and Kroner [1992] for a survey of the extensive empirical literature concerned with temporal dependencies in asset returns. A more recent survey of ARCH modeling of time-varying conditional variances is in Bollerslev, Engle, and Nelson [1994]. For studies of correlations across markets, see Eun and Shim [1989], Hamao, Masulis, and Ng [1990], King and Wadhwani [1990], Koch and Koch [1991], Koutmos and Booth [1995], Theodossiou and Lee [1993, 1995], and Theodossiou et al. [1997].

[2]For a detailed exposition of the issue of portfolio revision horizon, see Arnott and Lovell [1990, 1993].

[3]Stocks traded on these markets make up approximately 70% of the world market capitalization.

[4]The weights suggested by the October 19, 1987, crash are not considered in the revision of the GARCH portfolio, since it would not have been possible to have anticipated the crash. Instead, the average of the past weights is used for that period.

[5]See Bruce and Eisenberg [1992] for a more detailed discussion. Generally speaking, futures prices differ from spot prices by a premium that represents the cost of carry.

[6]For a detailed description of the model, see Theodossiou et al. [1997].

[7]The unconditional means, variances, and covariances are calculated using the formulas:

$$\mu = (I - \beta)^{-1}(m + m_C C_t),\ \sigma^2 = (I - \alpha - \gamma)^{-1}(\nu + \nu_C C_t),$$

and $\sigma_{i,j} = (\rho_{i,j} + \delta_{i,j} C_t)\sigma_i\sigma_j$, respectively.

REFERENCES

Arnott, Robert D., and Robert M. Lovell, Jr. "Monitoring and Rebalancing the Portfolio." In John L. Maginn and Donald L. Tuttle, eds., *Managing Investment Portfolios.* Boston: Warren, Gorham & Lamont, Inc., 1990.

——. "Rebalancing: Why, When, How Often?" *Journal of Investing*, 2 (1993), pp. 5-10.

Bollerslev, Tim, Ray Y. Chou, and Kenneth F. Kroner. "ARCH Modeling in Finance: A Review of Theory and Empirical Evidence." *Journal of Econometrics*, 52 (1992), pp. 5-59.

Bollerslev, Tim, Robert F. Engle, and Daniel B. Nelson. "ARCH Models." In R.F. Engle and D.L. McFadden, eds., *Handbook of Econometrics*, Vol. IV, Chapter 49. Amsterdam: Elsevier Science, 1994.

Bruce, Brian R., and Anne Eisenberg. "Global Synthetic Index Funds." *Journal of Investing*, 1 (1992), pp. 45-47.

Cavaglia, Stefano M.F.G., Magnus Dahlquist, Campbell R. Harvey, Fred Nieuwland, Peter L. Rathjens, and Jarrod W. Wilcox. "Emerging/Developed Market Portfolio Mixes." *Emerging Markets Quarterly*, 1 (1997), pp. 47-61.

De Santis, Giorgio, and Bruno Gerard. "International Asset Pricing and Portfolio Diversification with Time-Varying Risk." *Journal of Finance*, 52 (1997), pp. 1881-1912.

Eun, Cheol S., and Sangdal Shim. " International Transmission of Stock Market Movements." *Journal of Financial and Quantitative Analysis*, 24 (1989), pp. 241-256.

Hamao, Yasushi, Ronald W. Masulis, and Victor Ng. "Correlation in Price Changes Across International Stock Markets." *Review of Financial Studies*, 3 (1990), pp. 281-307.

King, Mervyn, and Sushil Wadhwani. "Transmission of Volatility Between Stock Markets." *Review of Financial Studies*, 3 (1990), pp. 5-33.

Koch, Paul D., and Timothy W. Koch. "Evolution in Dynamic Linkage Across Daily National Stock Indexes." *Journal of International Money and Finance*, 10 (1991), pp. 231-251.

Koutmos, G., and G.G. Booth. "Asymmetric Volatility Transmission in International Stock Markets." *Journal of International Money and Finance*, 14 (1995), pp. 747-762.

Lin, Weng-Ling, Robert F. Engle, and Takatoshi Ito. "Do Bulls and Bears Move Across Borders? International Transmission of Stock Returns and Volatility." *Review of Financial Studies*, 7 (1994), pp. 507-538.

Odier, P., and Bruno Solnik. "Lessons for International Asset Allocation." *Financial Analysts Journal*, 49 (1993), pp. 63-77.

Theodossiou, Panayiotis, and Unro Lee. "Mean and Volatility Spillovers Across Major National Stock Markets: Further Empirical Evidence." *Journal of Financial Research*, 16 (1993), pp. 337-350.

——. "Relationship Between Volatility and Expected Returns Across International Stock Markets." *Journal of Business, Finance, and Accounting*, 21 (1995), pp. 289-300.

Theodossiou, Panayiotis, Emel Kehya, Gregory Koutmos, and Andreas Christofi. "Volatility Reversion and Correlation Structure of Returns in Major International Stock Markets." *The Financial Review*, 32 (1997), pp. 1-20.