FORECASTING PAKISTANI STOCK MARKET VOLATILITY WITH MACROECONOMIC VARIABLES: EVIDENCE FROM THE MULTIVARIATE GARCH MODEL

ZOHAIB AZIZ
LECTURER
DEPARTMENT OF STATISTICS, FEDERAL URDU UNIVERSITY OF ARTS, SCIENCES & TECHNOLOGY

AND

Dr. JAVED IQBAL
ASSOCIATE PROFESSOR
INSTITUTE OF BUSINESS ADMINISTRATION

Introduction and Motivation

- Stock market volatility plays a vital role in economic and financial decision making.

Stock Market Volatility Forecast

- Stock market volatility forecasts are needed for several economic and financial decisions. For instance, in calculation of value-at-risk (VaR), conditional asset pricing and option pricing etc.

Dynamic Linkages of Stock Markets

- Market liberalization, gradual technological change, international trading and financing between the economies etc. have increased the stock market integration.

Relationship between Stock Market and Macroeconomic Variables

- Empirical finance literature explores that the macroeconomic variables help in explaining stock market volatility.

Contd.

- For instance, Cutler et al. (1989) indentifies that macroeconomic news can explain only between one-fifth and one-third of the movements of a stock market index.

- Liljeblom et al. (1997) states that interval of one-sixth to above two-thirds of changes in aggregate stock volatility might be related to macroeconomic volatility.

- In spite of strong theoretical motivation, the empirical studies on stock market volatility and macroeconomic variables are not usually seen especially for emerging markets.

Financial crisis and Stock Market Volatility

- Volatility may be affected by the financial crisis due to the increase in the correlation between the stock markets.

- Jang and Sul (2002) give the empirical evidences that correlation between the stock market is increased during financial crisis.

Contd.

- The above motivation raises the question here that how we can improve the stock market volatility forecast of emerging market Pakistan.

Dynamic Linkages with Global Market US

- Li (2007) explains that according to the 'global center hypothesis' US market as a global center plays a major role in the transmission of shocks.

- **Do the dynamic linkages of Pakistani stock market with the US market improve the volatility forecast of Pakistani stock market?**

- **Do the local and global macroeconomic variables improve the volatility forecast of Pakistani stock market?**

- **Do the financial crises have significant impact on the volatility forecast of Pakistani Stock market?**
- This paper attempts to investigate whether the local and global macroeconomic variables improves the volatility forecast of the Pakistani stock market.

Literature Review

- Against the strong theoretical motivation of impact of macroeconomic indicators on stock markets, there are very limited empirical studies on it some of which are reported here.

Paper	Market	Variables	Model	Results
Abugri (2006)	Latin American Stock Markets	Stock Returns, Local macroeconomic variables (Exchange rate, interest rates, industrial production and money supply), Global variables (MSCI world Index, US 3-moth T-bill)	VAR Model	Both global and local factors have significant influence in explaining returns in all the markets
Morelli (2002)	UK	Stock return, Local macroeconomic variables (Industrial production, real retail sales, money supply, inflation and exchange variables)	GARCH Model	Finds the significant impact of macroeconomic variables in terms of volatility on the stock market volatility
Liljeblom et al. (1997)	Finland	Stock return, some combine index of macroeconomic variables	Simple weighted moving averages model and GARCH model	Revealed the significant impact of local macroeconomic variable on the stock market volatility
Iqbal (2012)	Pakistan	KSE-100 and S&P-500 Indexes, Local and global macroeconomic variables(Industrial Production, CPI, interest rate, oil prices, gold prices etc.)	EGARCH Model	Finds that local macro variables as compared to global add to the explanatory power of Pakistani stock market volatility

Methodology: THE MGARCH Model

- Bivariate asymmetric VARMA(1,1)-GARCH(1,1) models with the BEKK specification of Engle and Kroner (1995) with exogenous variables:

$$R_t = \Lambda + \Psi R_{t-1} + \Omega u_{t-1} + u_t \qquad u_t | I_{t-1} \sim N(0, \Sigma_t)$$

$$H_t = \Gamma'\Gamma + \Theta' u_{t-1} u'_{t-1} \Theta + \Phi' H_{t-1} \Phi + A' \xi_{t-1} \xi'_{t-1} A + T' X_{t-1} T$$

With global financial crisis dummy 'D'

$$H_t = \Gamma'\Gamma + \Theta' u_{t-1} u'_{t-1} \Theta + \Phi' H_{t-1} \Phi + A' \xi_{t-1} \xi'_{t-1} A + T' X_{t-1} T + G' D G$$

- Estimation is performed by multivariate conditional log-likelihood function maximixzed by Berndt, Hall, Hall, and Hausman (BHHH) numerical maximization algorithm

$$L_t(\Omega) = -log 2\pi - \frac{1}{2} \log |H_t| - \frac{1}{2} u'_t(\Omega) H_t^{-1}(\Omega) u_t(\Omega)$$

$$L(\Omega) = \sum_{t=1}^{T} L_t(\Omega)$$

Model Diagnostics & Hypotheses Tests

- **Multivariate Portmanteau Test:**

--The Hosking's test statistic for testing no auto and cross correlations in the residual vector series is given as:

$$Q_{k(m)} = T^2 \sum_{l=1}^{m} \frac{1}{T-l} tr\left(\hat{\Xi}_l' \hat{\Xi}_0^{-1} \hat{\Xi}_l \hat{\Xi}_0^{-1}\right) \quad \sim \chi^2(k^2 m)$$

- **Wald Test:**

-- The following Wald test is used to test the exogenous variables.

$$W = [S\hat{\beta}]' [S\hat{V}ar(\hat{\beta})S']' [S\hat{\beta}] \sim \chi^2(q)$$

Evaluation of Volatility Forecast

Realized Volatility Proxy

- Volatility is not directly observable. To avoid this issue the sum of square of daily returns of current month is considered as the realized proxy of volatility.

Recursive Estimation Method

- We use a recursive window estimation to compute the time varying volatility forecasts. For monthly data, we estimate the volatility models using the first 162 observations and obtain one day ahead forecasts conditional standard deviation to be compared with absolute return observation of the month 163. Keeping the first observation and including observation for month 163 in the sample we estimate the volatility model and make forecast for the month 163. We repeat this process for the entire available data sample. This process yields a series of one period ahead forecast for 60 months which corresponds roughly to month of trading.

Contd.

Out of Sample Forecast Evaluation

- ***Mean Absolute Percentage Error (MAPE)***

$$\text{MAPE} = \text{Meanof}\left|\frac{\sigma_t - \sqrt{\hat{h}_t}}{\sigma_t}\right| \times 100$$

- ***Median Absolute Percentage Error (MdAPE)***

$$\text{MdAPE} = \text{Medianof}\left|\frac{\sigma_t - \sqrt{\hat{h}_t}}{\sigma_t}\right| \times 100$$

The Data

Stock Price Index and Macroeconomic Variables

- We take the daily and monthlyKSE-100 (Karachi Stock Exchange) and monthly S&P-500 adjusted for dividends and splits from Datastream.
- Monthly Consumer Price Index (CPI), Money Stock (M2), Exchange Rate and Interest Rate (Call Money Rate) are used as local macroeconomic variables.
- US Industrial Production, Consumer price Index, Treasury Bill rate, world gold and oil prices (West Texas Intermediate spot price) as global.
- All local and global macroeconomic variables are obtained from International financial statistics (IFS) except gold and oil prices that were downloaded from the website http://www.gold.org and https://fred.stlouisfed.org respectively.

Contd.

- The data consist of 222 monthly observations from July, 1997 to December, 2015.

- All variables are employed in percent change except stock prices which are considered in percentage log returns. Moreover lagged macro variables are incorporated to see the their impact on current volatility.

Global Financial Crisis Period

- In case of GFC, we code 1 to crisis dummy “D” form February, 2007 to March, 2009 (total 26 observations) while 0 is coded for pre and post crisis period i.e. July, 1997 to January 2007(total 115) and April 2009 to December, 2015(total 81 observations) respectively.

Results and Discussion

- Bivariate asymmetric VARMA (1,1)-GARCH(1,1) models are fitted under BEKK specification for Pakistan-US stock market pair when local and global lagged macroeconomic variables and GFC crisis dummy are employed.

- Estimation is performed using multivariate student *t* distribution of errors.

TABLE 1
ESTIMATED COEFFICIENTS FOR BIVARIATE ASYMMETRIC GARCH MODEL WITH LOCAL MACROEOCOMIC IMPACT AND ITS DIAGNOSITICS

Parameters	Bivariate Asymmetric VARMA(1,1)-BEKK(1,1)				
	No Macro Variable	Local (Pakistani) Macroeconomic Variables			
		Consumer Price Index	Money Stock (M2)	Exchange Rate	Interest rate
Panel A: Estimated Coefficients of Mean Equations					
λ_1	1.881 (0.144)	1.976 (0.007)	1.949 (0.004)	1.425 (0.044)	2.383 (0.000)
ψ_{11}	0.499 (0.144)	0.694 (0.124)	0.468 (0.155)	0.590 (0.152)	0.220 (0.552)
ψ_{12}	-3.613 (0.007)	-4.143 (0.015)	-3.501 (0.009)	-3.766 (0.008)	-2.779 (0.082)
ω_{11}	-0.004 (0.943)	-0.717 (0.106)	-0.506 (0.128)	-0.571 (0.169)	-0.132 (0.726)
ω_{12}	0.476 (0.102)	4.845 (0.003)	4.292 (0.001)	4.362 (0.002)	2.828 (0.082)
Panel B: Estimated Coefficients of Variance and Covariance Equations					
γ_{11}	3.122 (0.000)	4.023 (0.000)	2.043 (0.505)	3.831 (0.000)	3.177 (0.000)
θ_{11}	-0.251 (0.018)	-0.241 (0.033)	0.278 (0.035)	-0.024 (0.896)	-0.066 (0.603)
θ_{12}	-0.015 (0.541)	-0.0250 (0.318)	0.007 (0.794)	-0.010 (0.681)	0.005 (0.861)
ϕ_{11}	0.737 (0.000)	0.680 (0.000)	0.737 (0.000)	0.659 (0.000)	0.697169592 (0.000)
ϕ_{12}	-0.027 (0.438)	0.006 (0.917)	-0.014 (0.708)	-0.020 (0.360)	-0.032 (0.086)
a_{11}	-0.1484 (0.259)	-0.203 (0.106)	-0.170 (0.207)	-0.242 (0.019)	-0.234 (0.034)
a_{12}	0.054 (0.020)	0.062 (0.011)	0.0541 (0.0215)	0.034 (0.103)	0.042 (0.067)
τ_{12}	-	-0.961 (0.302)	0.637 (0.669)	-1.439 (0.004)	0.052 (0.004)

Panel C: Diagnostics					
LB(12)	47.208 (0.505)	47.769 (0.482)	48.336 (0.459)	38.793 (0.825)	52.026 (0.320)
LB(24)	95.468 (0.496)	101.193 (0.338)	97.507 (0.437)	83.250 (0.820)	110.610 (0.146)
LB^2(12)	34.363 (0.930)	46.417 (0.537)	30.342 (0.978)	44.178 (0.630)	39.906 (0.790)
LB^2(24)	102.508 (0.305)	102.257 (0.312)	108.634 (0.178)	100.856 (0.347)	110.267 (0.151)
Log-Likelihood	-1192.299	-1185.603	-1190.208	-1186.902	-1189.947
AIC	2436.599	2429.207	2438.417	2431.805	2437.895
BIC	2524.951	2527.753	2536.964	2530.351	2536.442

Value presented in the parentheses of Panel A, B and C is the P-value.

LB and LB^2 explain the multivariate Ljung-Box (portmanteau test) statistics for standardized and squarestandardized residuals respectively.

TABLE 2
ESTIMATED COEFFICIENTS FOR BIVARIATE ASYMMETRIC GARCH MODEL WITH GLOBAL MACROEOCOMIC AND GLOBAL FINANCIAL CRISIS IMPACT AND ITS DIAGNOSITICS

Parameters	Bivariate Asymmetric VARMA(1,1)-BEKK(1,1)						
	Global (US) variables						
	No Macro Variable	Industrial Production	Consumer Price Index	Treasury Bill Rate	Oil Prices	Gold Prices	Crisis Dummy
Panel A: Estimated Coefficients of Mean Equations							
λ_1	1.881 (0.144)	2.167 (0.002)	1.883 (0.001)	1.923 (0.004)	1.994 (0.004)	1.773 (0.013)	1.950 (0.003)
ψ_{11}	0.499 (0.144)	0.431 (0.201)	0.493 (0.094)	0.499 (0.141)	0.624 (0.104)	0.557 (0.137)	0.498 (0.132)
ψ_{12}	-3.613 (0.007)	-3.414 (0.014)	-3.664 (0.002)	-3.606 (0.008)	-4.043020541 (0.00966919)	-3.717 (0.008)	-3.630 (0.007)
ω_{11}	-0.004 (0.943)	-0.465 (0.166)	-0.556 (0.057)	-0.520 (0.128)	-0.647 (0.088)	-0.572 (0.119)	-0.524 (0.121)
ω_{12}	0.476 (0.102)	4.179 (0.002)	4.495 (0.000)	4.311 (0.001)	4.915 (0.001)	4.405 (0.001)	4.350 (0.001)
Panel B: Estimated Coefficients of Variance and Covariance Equations							
γ_{11}	3.122 (0.000)	3.153 (0.000)	2.288 (0.006)	3.258 (0.000)	3.301 (0.000)	3.44 (0.000)	3.187 (0.000)
θ_{11}	-0.251 (0.018)	-0.253 (0.041)	-0.256 (0.000)	0.233 (0.034)	-0.213 (0.037)	0.216 (0.083)	0.238 (0.032)
θ_{12}	-0.015 (0.541)	-0.014 (0.596)	0.003 (0.899)	0.024 (0.399)	-0.019 (0.534)	0.021 (0.411)	0.011 (0.620)
ϕ_{11}	0.737 (0.000)	0.721 (0.000)	0.794 (0.000)	0.726 (0.000)	0.700 (0.000)	0.686 (0.000)	0.733 (0.000)
ϕ_{12}	-0.027 (0.438)	-0.025 (0.549)	0.009 (0.627)	-0.038 (0.356)	0.095 (0.000)	-0.038 (0.293)	-0.026 (0.291)
α_{11}	-0.148 (0.259)	-0.169 (0.212)	-0.071 (0.606)	-0.162 (0.190)	0.310 (0.050)	-0.204 (0.132)	-0.169 (0.196)
α_{12}	0.054 (0.020)	0.053 (0.055)	0.066 (0.001)	0.058 (0.014)	-0.047 (0.078)	0.048 (0.042)	0.042 (0.052)
τ_{12} /Dummy Coeff.	----	-0.033 (0.972)	-9.831 (0.000)	-0.003 (0.530)	0.054 (0.382)	-0.036 (0.699)	-0.024 (0.987)

Panel C: Diagnostics							
LB(12)	47.208 (0.505)	45.820 (0.562)	54.275 (0.247)	46.153 (0.548)	48.783 (0.441)	46.621 (0.529)	47.465 (0.494)
LB(24)	95.468 (0.496)	94.003 (0.538)	104.596 (0.257)	95.778 (0.487)	97.909 (0.426)	97.359 (0.442)	94.830 (0.514)
$LB^2(12)$	34.363 (0.930)	37.874 (0.852)	29.027 (0.986)	35.488 (0.909)	56.326 (0.191)	34.953 (0.920)	43.775 (0.646)
$LB^2(24)$	102.508 (0.305)	99.501 (0.382)	102.353 (0.309)	109.006 (0.171)	117.106 (0.070)	107.597 (0.1968)	106.359 (0.220)
Log-Likelihood	-1192.299	-1190.485	-1189.261	-1191.272	-1190.120	-1191.406	-1191.156
AIC	2436.599	2438.971	2436.522	2440.544	2438.241	2440.812	2440.313
BIC	2524.951	2537.518	2535.069	2539.090	2536.787	2539.359	2538.860

Value presented in the parentheses of Panel A, B and C is the P-value.

LB and LB^2 explain the multivariate Ljung-Box (portmanteau test) statistics for standardized and squarestandardized residuals respectively.

TABLE 3
INCREMENTAL CONTRIBUTION/ INFORMATION CONTENTTS OF LOCAL, GLOBAL AND ALL MACRO VARIABLES

	All local variables		All global variables		Both local and global variables	
	No GFC*	GFC**	No GFC	GFC	No GFC	GFC
Wald Test	21.5222 (0.000)	11.564 (0.020)	19.605 (0.0015)	13.135 (0.022)	60.835 (0.000)	116.862 (0.000)
AIC	2426.840	2436.510	2444.747	2461.008	2441.479	2445.431
BIC	2555.970	2575.834	2584.072	2610.527	2621.581	2635.728
Log-Likelihood	-1175.420	-1177.255	-1181.373	-1186.504	-1167.739	-1166.715
LB (12)	34.368 (0.930)	51.122 (0.352)	46.743 (0.524)	43.223 (0.668)	41.647 (0.729)	38.864 (0.823)
LB(24)	81.443 (0.855)	110.914 (0.142)	102.127 (0.315)	92.271 (0.588)	78.829 (0.898)	89.128 (0.677)
LB (12) sq.	68.972 (0.025)	64.66 (0.0546)	58.032 (0.152)	74.170 (0.009)	55.473 (0.21371)	58.238 (0.147)
LB(24) sq.	130.262 (0.011)	114.006 (0.101)	95.513 (0.494)	128.623 (0.0147)	78.130 (0.90836)	132.089 (0.008)

* No GFC: No global financial crisis dummy incorporated

**GFC: Financial crisis dummy incorporated

values in parenthesis are the P-values

TABLE 4
FORECAST EVALUATION: FINDING THE BEST FORECAST MODEL

Cases	MAPE	MdAPE
Univariate	178.4211	162.1266
Multivariate	120.4034	100.3845
Multivariate with GFC	117.2948	106.5437

TABLE 5
FORECAST EVALUATION: MACRO VARIABLES IMPACT

Macroeconomic Variables	MAPE	MdAPE
No Macro	120.403	100.384
Local		
Consumer Price Index	132.986	114.686
Money Stock (M2)	125.003	115.875
Exchange Rate	107.284	89.082
Interest Rate	98.324	86.610
All Local Variables	114.030	94.616
All Local Var. with GFC	153.136	124.897
Global		
Industrial Production	104.760	96.784
Consumper Price Index	134.840	111.632
Treasury Bill Rate	120.225	101.702
Oil	112.482	97.216
Gold	114.236	101.185
All Global Variables	153.136	124.897
All Global Var. with GFC	146.872	123.631
All		
Both Local and Global	107.763	93.528
Both Local and Global with GFC(crisis dummy)	125.003	115.875

Conclusion

- This paper investigates whether local or global macroeconomic variable improves the volatility forecast of Pakistani stock market.
- Significantly impact of both local and global macro variables is seen on the Pakistani stock market volatility.
- The significant impact of global macro variables implies that Pakistani stock market is becoming increasingly integrated to the global economy.
- However, the contribution of the local macro variables is larger to improve the volatility forecast of Pakistani stock market than global.
- Exchange rate and interest rate in set of local macro variables and oil price and industrial production as global macro variables are found to be prominent contributor variables that affect Pakistan's stock market volatility.
- The results are not considerable sensitive to inclusion of the GFC dummy.

References

- Abugri, B. A., (2006), Empirical relationship between macroeconomic volatility and stock returns: Evidence from Latin American markets*. International Review of Financial Analysis*, 17: 396-410.

- Cutler, D. M., Poterba, J. M. and Summers, L. H., (1989), What moves stock prices? *Journal of Portfolio Management*, 15: 4-12.

- Engle R., Kroner F. K., (1995), Multivariate simultaneous generalized ARCH. *Econometric Theory*, 11: 122-150.

- Iqbal, J., (2012), Do local and global macroeconomic variables help forecast volatility of Pakistani stock market. Paper presented at 32nd International Symposium on Forecasting, Conference, Boston, USA.

- Liljeblom, E. and Stenius, M., (1997), Macroeconomic volatility and stock market volatility: empirical evidence on Finnish data. *Applied Financial Economics*, 7: 419-426.

- Li, H. (2007), International linkages of the Chinese stock exchanges: A mutivariate GARCH analysis. *Applied Financial Economics* 17: 285-297.

Contd.

- Morelli, D., (2002), The relationship between conditional stock market volatility and conditional macroeconomic volatility: empirical evidence based on UK data. *International Review of Financial Analysis*, 11, 101-110.

- Roll, R., (1988), . *Journal of Finance*, 43: 541-566.