"An Assessment of Equity Market Volatility Spillovers: Evidence from the USA & the Caribbean"

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Abstract

The study utilizes a GARCH-BEKK framework in investigating whether there are volatility spill-overs among regional stock markets, in particular Trinidad & Tobago, Barbados and Jamaica, as well as between Jamaica and the U.S. over the period 2005 to 2017. This is assessed using the daily returns of the Composite index of each stock market, with the findings of both assessments confirming the presence of spill-over effects across these jurisdictions, highlighting that shocks that emanate within one stock market can propagate to other equities markets. Of importance is that the NYSE exhibited the most volatility spillover effects to the Jamaican stock market relative to the spill-over from the regional markets to the Jamaican Stock Market. Further investigation of the volatility within these economies was also done using a VEC model, which incorporated various key macroeconomic variables. The findings suggesting that a deterioration in real GDP volatility for the U.S. contributes to increased stock market volatility across all the regional markets examined, while a deterioration in the spread between a short-term GOJ Global bond and the US Treasury bill rate can lead to increased volatility in the Jamaican stock market. The assessment is also important as timely recognition of the implications of adverse macroeconomic developments can aid policymakers to take relevant action in preserving economic and financial sector stability.

JEL Classification Numbers: G11, G14, E44

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1.0 Introduction

The global financial crisis has led to renewed impetus to examine the issue of volatility spillovers in financial markets, given that market price volatility transmission or volatility spillovers can have a destabilizing effect both within and across markets. Volatility spillovers across markets occur when historical price volatility in one market impacts current volatility in another market and can occur within markets when historical volatility in a particular market impacts the current volatility in the same market. Moreover, the crisis has also underscored that, given the substantial costs involved, it is important for economies to understand how shocks are propagated in their financial markets and the magnitude of these effects over time. Market efficiency proponents have argued that spillovers could reflect a failure of market efficiency. They posit that market participants should not be able to predict returns or volatility in one market using lagged information. It is further argued that the ability to do so reflects inefficiencies in market structures, particularly in the dissemination of relevant information to market participants. Nonetheless, opponents to this view have pointed out that spill overs may not reflect a failure of market efficiency if news about fundamentals were serially correlated, in which case news associated with a given time period is carried over into future time periods.

Substantial volatility transmission within and across markets may lead to erosion in investor confidence, reduced capital flows and ultimately undermine stability in these markets. This occurs because increased volatility is synonymous with higher risk and increased risk associated with a given economic activity usually leads to weakened participation in that activity. In the equities markets, an understanding of volatility transmission is important for determining the cost of capital and in assessing the impact of portfolio investment and leverage decisions. Furthermore, strong volatility spillovers can therefore have potential adverse implications for market capitalization, financial stability and economic growth.[3]

In addition, given the growing inter-linkages among economies, it is crucial that policymakers be able to gauge the potential for cross market and common market shocks in order to facilitate timely and effective implementation of monetary policy. At the same time, a deeper understanding of the market return volatility linkages by financial institutions enables these

[3] This has been a key reason for many academics to examine the implications of volatility spill overs. Market price volatility spill over, market price volatility transmission and volatility spill over are being used synonymously.

entities to better hedge against market risks from shocks that persist within and across markets and can play a role in the preservation of financial system stability. This relationship can be better understood through Kirby and Ostdiek's (1997) speculative trading model of financial asset futures. In this model, price volatility behavior is explained on the basis of traders conducting transactions based on future expectations as well as the need to transfer market risks through hedging. This model utilized the mean-variance portfolio optimization theory to derive a relationship between the demand for asset 'futures' and the return volatility or risk of the underlying asset. The theory assumes that the trader derives his demand for asset 'futures' by maximizing his expected profits subject to the variance or volatility in underlying asset returns. In a two market scenario, asset demand in each market will depend on the cross volatility between asset returns. In instances of negative correlation between markets, hedging can be derived in holding an asset to reduce overall risk in the portfolio. Therefore, cross market volatility, which can occur through a hedging channel, impacts demand and thus future volatility of the other assets in the portfolio.[4] Through hedging, news pertaining to an asset market will lead to an adjustment in the demand for that asset and also the demand for substitute assets in any other market. This is one way in which information in one market may spill over to another market. In addition, given that the demand for one asset is dependent on the variance of all the assets in the portfolio, spill overs also occur where information that alters expectations about returns in one market will influence demand and trading in another market.

Regarding studies on volatility transmission within the Caribbean, Hurditt (2004) applied the GARCH-BEKK procedure to returns from the Jamaican bond, foreign exchange and stock markets in order to estimate the magnitude of the common market and cross-market volatility spill-overs. The findings showed that of the three markets, the foreign exchange market exhibited the strongest common market volatility transmission, followed by the stock market. Nonehteless, the strongest cross market effects occur from the bond market to the foreign exchange and stock markets. Kim and Langrin examined the impact of foreign exchange market liberalization on stock market integration and volatility spill-overs for Jamaica and Trinidad and Tobago. The findings of the study showed that while the liberalization policy in Jamaica led to increased spill-overs from the U.S., a similar situation did not occur in the case of Trinidad and Tobago. In

[4] The model is meant to provide a general explanation of volatility spillovers.

addition, using more recent data for the period 2005 to 2010, Greenidge and Grosvenor (2012) also investigated the co-movement between stock markets in the developing countries of the Caribbean as well as from developed markets using a GARCH framework. The results of the framework confirm that significant spill-overs exist between each of the regional exchanges as well as from the NYSE. This study adds to the literature by exploring whether there are equity market price volatility spill-overs between Jamaica and the U.S. as well as across selected Caribbean economies including Jamaica and the extent to which a period of known financial market instability can impact these findings. The findings of the study are important in determining the scope for diversification and hedging benefits as well as the extent to which the equity market can potentially be a contagion channel across these economies. This study also supplements the previous literature by assessing whether selected key macroeconomic indicators can impact the degree of equity market price volatility across the economies which have been examined. The investigation can be useful for poilcymakers in taking proactive steps to preserve economic activity and safeguard financial sector stability.

2.0 Background on Major Stock Exchanges in the Caribbean Region

Concerning the equities markets in the Caribbean, the stock exchanges of Barbados (BSE), Trinidad and Tobago (TTSE) and Jamaica (JSE) are among the largest in the region.Furthermore, the equities markets represent a key source of inter-linkage between these economies. In 1991, these three stock exchanges entered into an arrangement to form the Regional Stock Exchange, which allows for the cross border listing and trading of securities. This agreement allowed securities on the exchange in each of these countries to be listed and traded in each other's markets in an effort to aid in stock market development. Moreover, in recent years, there has been an increasing listing of financial conglomerates across all three exchanges. These firms typically operate simultaneously in several Caribbean countries, possess extensive networks of branches and affiliates and are usually based entirely within the region.[5] While financial conglomerates can be beneficial to the development of the region, largely through gross capital formation and financial deepening, if these entities are in distress, this instability can spill-over to other countries, particularly through the equities markets.

[5] Cross-listed companies are among the largest in the region, accounting for roughly 40.0 percent of consolidated regional market capitalization as at end-2017.

Of the three major stock exchanges within the Caribbean region, the Jamaica Stock Exchange (JSE) has been in operation for the longest period. Its trading activities officially commenced in 1969, with the exchange initially known as the "Kingston Stock Exchange" and was originally restricted to brokers who traded both as agents and as principals. Of importance is that the JSE uses three major indices: the All Jamaican Composite Index which comprises Jamaican companies only, the JSE Select Index that comprises the JSE's 15 most liquid Securities and the JSE Cross Listed Index which is comprised of foreign companies only.

In 1989, the JSE opened a subsidiary, the Jamaica Central Securities Depository, to facilitate electronic transfer and settlement of securities. In addition, more recently in January 2000, the JSE established a fully automated trading platform, with a further launch of a new online trading platform in 2015 in an effort to attract greater investor interest both locally and abroad. This is in a context where previously online trading was a function limited to stockbrokers as a result of various restrictions as well as highly priced transaction fees.

Regarding the arrangement of the JSE, the Regular market is the main market of the JSE, while the Junior market caters to smaller and newer public companies which may not satisfy the requirements for listing on the Regular market. Also, listed on the JSE Main Market are ordinary and preference shares, which represent various business sectors such as banking and finance, manufacturing, retail and communications. As at end-2017, there were 26 securities being traded on the Main Market, with the composite index registering market capitalization of approximately US$8.4 billion.

The BSE is Barbados' main stock exchange. It was formerly known as the Securities Exchange of Barbados, which was established in 1987, under the Securities Exchange Act of 1982, in order to start a market to promote trading in financial securities and support investment by the public in business enterprises. As is the case for Jamaica, the Regular market is the main market of the BSE, while the Junior market caters to smaller and newer public companies, which may not meet the requirements necessary for listing on the Regular market. The Barbados Stock Exchange also uses three major indices: the Local Index, the Cross Listed Index and the Composite Index. The Local Index is representative of local companies listed on the regular market, the Cross listed Index is comprised of companies which are listed in Barbados but domiciled in another jurisdiction and the Composite Index captures all of the companies listed on the Exchange. In 2001, the Barbados Stock Exchange switched from the manual, open auction outcry method of trading to electronic trading. This was partly in effort to decrease transactions costs as well as enable greater market access for investors. Of note, the BSE is the smallest of the regional exchanges and company listings reflect a wide cross-section of stocks largely from the manufacturing and distribution sectors.

The TTSE is the main stock exchange in the Republic of Trinidad and Tobago as well as the largest stock exchange in the Caribbean region based on market capitalization. In the early 1970's, the Government decided to localise the foreign-owned commercial banking and manufacturing sectors of the economy. This policy was expected to allow these types of companies to divest and sell a majority of their shares to nationals.

Furthermore, the establishment of the stock exchange in 1981 under the provisions of the Securities Industry Act 1981 formed a part of the efforts to formalise the Securities market in Trinidad and Tobago. This Act was subsequently replaced with the Securities Industry Act of 1995, to deal with the inefficiencies of the former and facilitated the establishment of a Securities and Exchange Commission, which is the sole regulator of the securities industry in the Republic of Trinidad and Tobago. The Commission was largely established to promote the orderly development of the securities market. Of note is that stock market deepening was also fostered by the TTSE's implementation of an Electronic Trading System on March 18th 2005, which replaced the pre-existing manual open outcry system which was utilized since its inception.

However, since the early 2000s, the TTSE has experienced some slowdown, both in terms of activity and listings and partly related to legislation restricting institutions from having more than 10.0 per cent of their portfolio in the shares of one company. This was further compounded by the slowdown in the Trinidad and Tobago economy partly stemming from depressed commodity (oil and gas) prices since 2014. Despite this, there have been a number of large capitalization listings, including the listings of First Citizen's Bank and the Trinidad and Tobago Natural Gas Company Limited. Recent figures on the capitalization of the Exchange's Main Index showed that as at end-2017 the composite index registered market capitalization of approximately US$18.1 billion.

3.0 Background on the New York Stock Exchange (NYSE)

As it relates to the NYSE, it is one of the world's largest market places for securities and other exchange traded investments. As such, the performance of the exchange can have far reaching implications for many economies, including Jamaica, which has strong economic and political linkages to the U.S. The United States is Jamaica's most important trading partner and therefore shocks impacting the U.S. and more specifically the equities markets can have implications for the Jamaican financial markets. Against this background, the key ties between Jamaica and the U.S. make it important to monitor the developments as it relates to the U.S. securities market.

The Exchange was formally constituted as the New York Stock and Exchange Board in 1817, later simplified to the NYSE. Of note is that New York City has three organized stock exchanges—the New York Stock Exchange (NYSE), NYSE Amex Equities, and NASDAQ—which together account for the bulk of all stock sales in the United States. The NYSE is an American stock exchange on Wall Street in New York City, had a market capitalization of US$21.3 trillion as of June 2017, with the majority of its listings respresenting U.S. companies. Some of the industries represented on the NYSE are from the financial sector, oil and gas industry, the consumer goods and services industry, healthcare, technology and the telecommunications sector.

In addition, the NYSE lists medium and large companies and investors can trade several major asset classes such as equities, options, exchange-traded funds and bonds. The NYSE houses several stock market indices, namely the Dow Jones Industrial Average, the S&P 500, the NYSE Composite, NYSE US 100 Index, the NASDAQ Composite and others. Of note, is that the NYSE Composite represents one of the larger indices and has been utilized for the purpose of this study.

4.0 Review of Literature on Stock Return Volatility Spillovers

Following the international stock market crisis in October 1987, research into volatility spill overs in financial markets gained momentum. Eun and Shim (1989) identified that about 26 per cent of international stock markets variability may be explained by variability in return in other stock markets. In addition, King and Wadhwani (1990) investigated a number of US markets after the crash and found evidence that there is transmission of price information across markets through volatility innovations, even when the information is market specific. Many studies have focused on volatility transmission within developed markets, but an increasing number of researchers have begun to focus on spill overs between markets in developed economies and those in emerging & developing nations.

Regarding stock market volatility transmission within developed markets, Hamao, Masulis and Ng (1990) found that spillovers exist from New York to Tokyo, London to Tokyo and New York to London. Bae and Karolyi (1994) showed that the magnitude of the spillover between US and Japan markets is affected by the type of shock originating in either market. Further work in this area by Ito and Lin showed that when trading volume is included in the analysis, the transmission of shocks between Tokyo and New York is as a result of volatility surges rather than trading volume surges. This evidence suggests that the transmission of shocks between markets is due to an efficient reaction to new information, rather than a contagion effect. Theodossiou and Lee (1993) investigated the transmission of stock market returns and volatility across the U.S., Japan, the U.K., Canada and Germany using weekly data. They reported volatility spillovers from the USA to Canada, Germany and the UK, and from the stock markets of Japan to Germany. Kaltenhaeuser (2003), in a study involving a combination of developed financial markets, found evidence of stock market volatility spillovers between the markets in the Euro area, US and Japan.

Regarding studies on inter-linkages between developed and less developed markets, Ng, Chang and Chou (1991) investigated volatility spillovers between US and various Asian stock markets. They find that volatility spillovers exist across Asian markets only in periods when international investment restrictions have been relaxed. Wei et al. (1995) found that volatility in the US market exhibits a significant influence over volatility in the Hong Kong and Taiwanese stock markets. In a study by Cheung and Ng (1996), they showed that variability of stock returns of Asian-Pacific markets is closely associated with the variability of stock returns in major US stock markets. Kim & Yoon et al. examined volatility transmission across selected stock markets during the Asian financial crisis periods of 1997 and 1998. It was found that reciprocal volatility transmission existed between Hong Kong and Korea, and unidirectional volatility transmission from Korea to Thailand. This suggests that Hong Kong played a significant role in volatility transmission to the other Asian markets. Lee (2001) provided new evidence on the price and volatility spillovers from the developed markets to emerging markets in the MENA region.[6] It was found that markets in this region are integrated globally with major developed markets such as the U.S., Japan and Germany. The basic finding is that price as well as volatility spillover effects exist from the developed stock markets to the MENA counterparts, but not vice versa. Al-Deehani (2005) investigated volatility spillover among the stock markets of the six member countries of the Gulf Cooperation Council (GCC). The results showed strong evidence of bi-directional contemporaneous volatility spillover between most of the markets. The author posited that this may be due to the increased economic and financial ties and the fast moving attempts of deregulation and integration initiated by the GCC. However, based on the findings, there is weak evidence of lagged volatility spillover among the markets.

Most studies in the literature on asset price volatility spillover utilize the autoregressive conditional heteroskedasticity model (ARCH) of Engle (1982) and the generalized extension of this model (GARCH) by Bollerslev (1986) to model volatility transmission. These models are popular when dealing with asset price volatility given that financial time series tend to exhibit volatility clusters.[7] These methods model volatility in financial series by modeling the variance in the return series as function of past variances and past errors derived from the mean equation. However, Univariate GARCH models are more useful in measuring the extent of volatility spillover from one financial asset return series to another while multivariate GARCH models are able to accommodate estimating volatility spillover among stock markets, as well as volatility persistence within each market. The model that will be employed in this study is the GARCH-BEKK model proposed by Engle and Kroner (1995) and named after Baba, Engle, Kraft and Kroner (1991). This model was chosen because of its more realistic assumptions relative to other multivariate GARCH models.

[6] The MENA region includes Middle Eastern and North African Countries.

[7] Volatility clustering occurs when large changes in the price of an asset are followed by other large changes and, similarly, small changes are often followed by small changes.

5.0 Empirical Methodologies Employed

5.1 The GARCH-BEKK Framework

The **GARCH-BEKK** framework is utilized to examine pairwise returns volatility linkages within some of the major stock markets in the Caribbean region as well as between Jamaica and the U.S. The mean equation of the model is outlined in equation 1.

$$R_t = \alpha + \beta' R_{t-1} + \varepsilon_t \qquad (1)$$

where:

$$R_t = \begin{bmatrix} r_{1,t} \\ r_{2,t} \end{bmatrix}; \quad \alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}; \quad \beta = \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}; \quad \varepsilon_t = \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$$

Equation 1 gives the conditional expected return equation and accommodates each market's own returns and the returns of other markets lagged one period where the vector R_t represents returns at time t of the relevant equity markets being considered. The α_t vector and the β_t matrix represent the coefficients in the mean equation, while the $\varepsilon_t$vector represents the errors in the mean equation.

The related variance-covariance equation is represented in equation 2:

$$\Sigma_t = C'C + A' \varepsilon_{t-1} \varepsilon'_{t-1} A + B' \Sigma_{t-1} B \qquad (2)$$

where:

$$\Sigma_t = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{bmatrix}; \quad C = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}; \quad A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}; \quad B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \qquad (3)$$

From expanding equation 2, the coefficients from the A and B matrices will give the extent of volatility spill overs within and between markets. As it relates to equation 2, Σ_t represents the variance-covariance matrix of the GARCH methodology. In estimating the bivariate GARCH-BEKK model, the software that will be used is EVIEWS version 6.

As illustrated in equation 2, C is a 2x2 lower triangular matrix of constants, which is decomposed into a product of two triangular matrices to guarantee the positive semi-definiteness of matrix Σ_t The elements of the covariance matrix Σ_t, relies on only the past values of itself as well as past values of $\varepsilon_t{}'\varepsilon_t$. In addition, matrix A is a 2x2 square matrix which shows how the conditional variances are correlated with past squared errors. The elements of matrix A measures the effects of shocks or "news" on the conditional variances. This matrix captures the ARCH effects, where elements a_{ij} measure the degree of innovation or a shock from market *i* to market *j*. Concerning matrix B, the elements of this matrix shows how past conditional variances affect the current levels of conditional variances, or in other words, the degree of volatility persistence among the markets. The elements of this matrix capture GARCH effects, in particular the coefficient b_{ij} in matrix B represents the persistence in conditional volatility between market *i* and market *j*. Of note is that the diagonal parameters in matrix A measure the effects of own past shocks of market *i* on its conditional variance. While the diagonal elements of matrix B capture the effects of past volatility of market *i* on its conditional variance. The off-diagonal parameters in matrix A, which are a_{ij} a_{ji} , measure the effects of shocks, while parameter b_{ij} and b_{ji} capture the cross-market effects of volatility spillovers.

5.2 VEC Modelling Framework:

In investigating whether there is a long run relationship between volatility in returns in the different stock markets, a VECM will be employed. This model involves an estimation procedure for VAR models containing non-stationary variables, where the variables are integrated of the same order and are co integrated in the long run. In this instance, the variables are possibly driven by a common stochastic trend and as such are co integrated.

Equation (4) outlines a p-dimensional vector autoregressive model with Gaussian errors, where Y_t is a k-vector of I (1) variables, X_t is a d-vector of deterministic variables and A_i is a matrix of coefficients to be estimated. Additionally, the matrix B contains exogenous variables that are excluded from the co-integration space and ε_t is a k-vector of Gaussian errors.

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + BX_t + \varepsilon_t, \qquad (4)$$

Following Johansen (1991, 1995), equation (4) can be reformulated into a vector error-correction form as:

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 Y_{t-2} ..... + \Gamma_p \Delta Y_{t-p+1} + BX_t + \varepsilon_t \quad (5)$$

OR

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \varepsilon_t \quad (6)$$

where:

Y_t is the vector of endogenous variables and the parameter matrices α and β are contained in the π matrix. Furthermore, α and β specify the long run component of the model with β containing the co-integrating relation while α represents the speed of adjustment coefficients.

6.0 Summary Statistics: Stocks Indices of Selected Caribbean Economies & the U.S.

The data employed in the GARCH-BEKK Model captures returns based on the composite equity market indices for Jamaica, Trinidad, Barbados and the United States. Daily returns were computed for the period January 2005 to December 2017 and represent the continuously compounded return (or log return) of the equity index for each country and was calculated using equation 7, where:

$$r_t = 100 * \ ln\left(\frac{p_t}{p_{t-1}}\right) \quad (7)$$

and p_t is the stock index at date *t*.

Figure 1 shows returns based on the value weighted equity market indices of Jamaica, Trinidad, Barbados and the U.S. over the period January 2005 to December 2017, while table 1 reports summary statistics for each returns series. During the period under study, each index reflected large differences between their maximum and minimum returns, with this observation being most pronounced for the NYSE Composite Index. Moreover, the standard deviations observed in all markets indicates a high level of fluctuation in daily returns. During the period under study, the NYSE Composite Index displayed the highest degree of volatility, with a standard deviation of 124.0 per cent, while the TTSE index was the least volatile with a standard deviation of 28.0 per cent.

Figure 1. Daily Returns of the Composite Indices of Selected Caribbean Economies & the U.S.

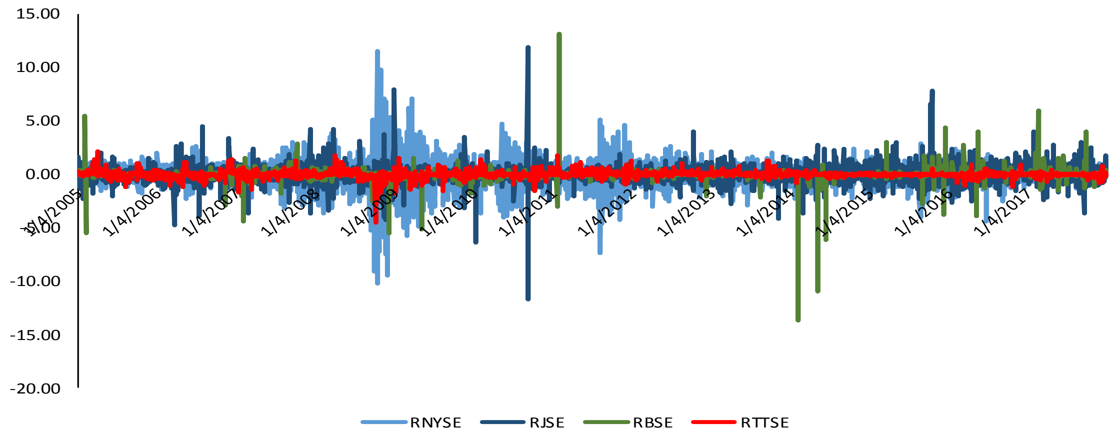


Table 1. Sample Statistic of stock market returns

	RBSE	RJSE	RNYSE	RTTSE
Mean	-0.005251	0.028411	0.018124	0.009015
Median	0	0.006763	0.06491	0.001815
Maximum	13.18099	11.89462	11.52575	2.134443
Minimum	-13.66352	-11.64464	-10.23206	-4.490539
Std. Dev.	0.556006	0.845298	1.242668	0.281493
Skewness	-3.381046	0.549269	-0.424717	-1.173187
Kurtosis	281.7034	35.25126	14.80042	32.68985
Jarque-Bera	1056.686	14.15802	1.903027	12.0594
Observations	3263	3263	3263	3263

7.0 BEKK GARCH results

7.1 GARCH BEKK Estimation (Model 1- JSE returns and NYSE returns)

Table 2 below presents the estimated coefficients in the variance-covariance matrix of the bivariate GARCH-BEKK model employed for analyzing the volatility relationship between the NYSE Composite Index (NYSE) and the JSE Main Index (JSE) over two periods.

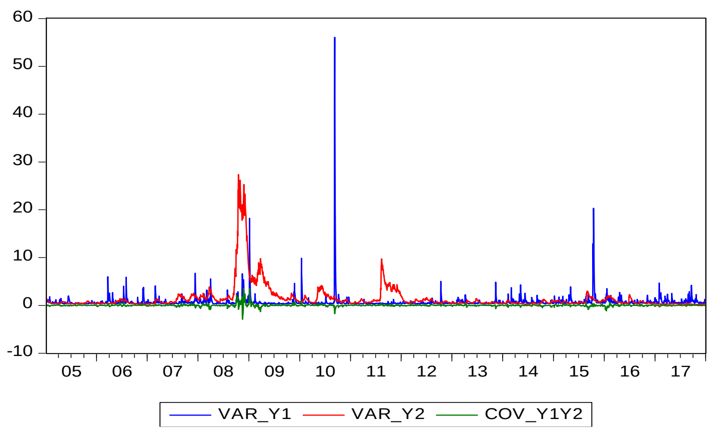
Table 2: Estimated coefficients for variance covariance equations

	Full Sample Period 2015-2017				Volatile period 2007-2011			
	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
MU(1)	-7.52E-05	0.010902	-0.006901	0.9945	-0.017885	0.016314	-1.096291	0.2730
MU(2)	0.04397	0.013293	3.307671	0.0009	0.034404	0.034943	0.984576	0.3248
OMEGA(1) (c11)	0.351391	0.007878	44.60127	0.0000	0.328582	0.008198	40.08065	0.0000
BETA(1) (b11)	0.785443	0.009154	85.80141	0.0000	0.748869	0.011849	63.2031	0.0000
ALPHA(1) (a11)	0.491203	0.010183	48.23722	0.0000	0.678764	0.017993	37.72467	0.0000
OMEGA(3) (c22)	0.102195	0.007533	13.56555	0.0000	0.18695	0.022861	8.177599	0.0000
OMEGA(2) (c21)	0.00056	0.00655	0.085464	0.9319	0.021093	0.024364	0.865749	0.3866
BETA(2) (b12)	0.95831	0.002866	334.3813	0.0000	0.947933	0.006218	152.4535	0.0000
ALPHA(2) (a12)	0.270874	0.008695	31.15148	0.0000	0.299568	0.015803	18.95647	0.0000

Log likelihood	-8342.334	Akaike info criterion	4.931405	-3710.992	Akaike info criterion	5.727470
Avg. log likelihood	-2.463045	Schwarz criterion	4.947687	-2.856807	Schwarz criterion	5.763286
Number of Coefs.	9	Hannan-Quinn criter.	4.937225	9	Hannan-Quinn criter.	5.740909

With reference to parameters which have been estimated, the diagonal values in matrix *A* indicates shocks to a specific market and diagonal values in the ***B*** matrix represent the persistence in own stock market conditional volatility. As shown in table 2, the own past shocks and past volatility of all markets are statistically significant based on the p-values and z-statistics of the relevant coefficients. Regarding the finding that $\boldsymbol{I\, a_{ii} I} < \boldsymbol{I\, b_{ii} I}$, this suggests that the behavior of current variance and covariance is not so much affected by the magnitude of past innovations as by the value of lagged variances and covariances. Furthermore, the statistical significance of GARCH parameters $\boldsymbol{b_{ii}}$ revealed that there is a strong degree of volatility clustering. The off-diagonal elements of matrices **A** and ***B*** capture the cross-market effects of shocks and volatility spillovers among the markets. In addition, there is a uni-directional link regarding transmission of shocks between the NYSE and the JSE as evidenced by the statistical significance of the off-diagonal parameter $\boldsymbol{a_{12}}$. This suggests volatility spillover from the NYSE to the JSE, since innovations (information of news between the two markets) initiating in one country affect volatility in the other market. Moreover, there is also strong evidence of uni-directional volatility persistence linkages between NYSE and JSE, the direction is from the NYSE to the JSE, as $\boldsymbol{b_{12}}$ is statistically significant. Thus, lagged volatility persistence in NYSE has a positive effect on current volatility in JSE overtime. Furthermore, the findings of the variance covariance equation (see **Table 2**) show that there is a statistical significance as it relates to the covariance of returns between both markets. Specifically, based on the log likelihood test, the covariance equation is significant at the 5 per cent level and confirms the suitability of the GARCH BEKK model in capturing spillover effects between the stock markets examined. The assessment was also examined for the period 2007 to 2011, which represents periods of known volatility, including the global crisis period. The results were similar to the findings based on the entire sample period, including the fact that the absolute value $\boldsymbol{a_{ii}}$ does not exceed the absolute value of $\boldsymbol{b_{ii}}$. Furthermore, an increase in the coefficient for parameter $\boldsymbol{a_{ii}}$ indicates that the impact of shocks or innovations is amplified during a volatile period.

Figure 2: Estimated conditional Variance-Covariance by Unrestricted GARCH BEKK



7.2 GARCH BEKK Estimation (Model 2- JSE returns and BSE returns)

The findings based on Model 2 confirm the presence of volatility spill-overs as results for the GARCH parameters are statistically significant (see **Table 3**). Furthermore, this means that current JSE stock market returns volatility may be influenced by the volatility in returns for the Barbadian stock market.

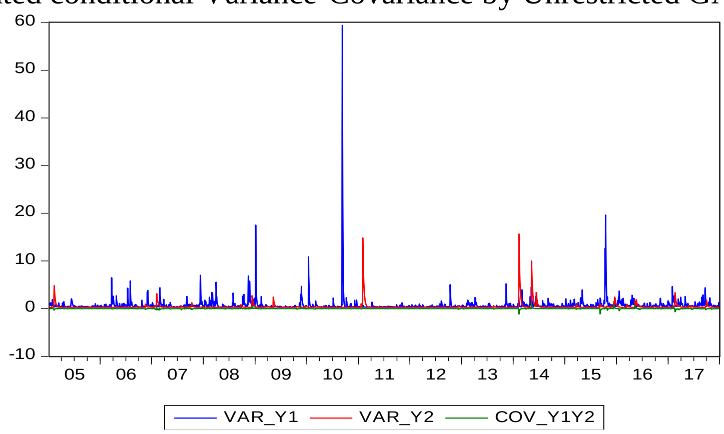
Table 3: Estimated coefficients for variance covariance equations

	Full Sample Period 2015-2017				Volatile period 2007-2011			
	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
MU(1)	-0.000592	0.010567	-0.056064	0.9553	-0.018488	0.016242	-1.138281	0.2550
MU(2)	-0.019662	0.013089	-1.502172	0.1331	-0.015766	0.012923	-1.219999	0.2225
OMEGA(1) (c11)	0.335898	0.0073	46.01486	0.0000	0.329473	0.007688	42.85826	0.0000
BETA(1) (b11)	0.785203	0.00892	88.02244	0.0000	0.745778	0.011579	64.40684	0.0000
ALPHA(1) (a11)	0.514414	0.010301	49.93656	0.0000	0.687211	0.018247	37.6611	0.0000
OMEGA(3) (c22)	0.216018	0.002229	96.90413	0.0000	0.143077	0.003546	40.35172	0.0000
OMEGA(2) (c21)	-0.004879	0.00827	-0.589877	0.5553	-0.004632	0.009587	-0.48312	0.6290
BETA(2) (b12)	0.90748	0.00204	444.9192	0.0000	0.883707	0.00467	189.2216	0.0000
ALPHA(2) (a12)	0.28757	0.006097	47.16749	0.0000	0.588185	0.019149	30.71621	0.0000
Log likelihood	-6509.97	Akaike info criterion		3.849407	-2195.432	Akaike info criterion		3.394044
Avg. log likelihood	-1.922046	Schwarz criterion		3.865689	-1.690094	Schwarz criterion		3.42986
Number of Coefs.	9	Hannan-Quinn criter.		3.855227	9	Hannan-Quinn criter.		3.407483

Similarly, the set of parameters which are the diagonal values in matrix *A* shows own market innovations while the diagonal parameter in *B* matrix reveal persistence in own stock market conditional volatility. As observed table 3, the own past shocks and past volatility between these two markets are statistically significant. Likewise, $\boldsymbol{I a_{ii} I} < \boldsymbol{I\, b_{ii} I}$, suggesting that current variance and covariance is impacted to a lesser extent by the magnitude of past shocks rather than by the value of lagged variances and covariances. The statistical significance of GARCH parameters $\boldsymbol{b_{ii}}$ reveals the extent of volatility clustering and the off-diagonal elements of matrices $\boldsymbol{A}$ and $\boldsymbol{B}$ capture the cross-market effects of shocks and volatility spillovers among the markets. Results also showed a uni-directional link regarding transmission of shocks between the BSE and the JSE, as the off-diagonal parameter a_{12} is statistically significant. Thus, there is volatility spillover from BSE to JSE, since shocks initiating from the BSE would affect volatility in the JSE. Furthermore, there is also strong evidence of uni-directional volatility persistence linkages between BSE and JSE, that is, from the BSE to JSE, as $\boldsymbol{b_{12}}$ is statistically significant. Therefore, lagged volatility persistence in BSE has a positive effect on current volatility in JSE over several periods. The covariance equation is also statistically significant as well as the parameters capturing spillover effects across markets and implies that both stock markets are influenced by common shocks. In particular, based on the log likelihood test, the covariance equation is significant at the 5 per cent level.

With reference to the period 2007 to 2011, the covariation equation is statistically significant. Furthermore, similar results were found for the entire sample period, where $\boldsymbol{Ia_{ii}I} < \ \boldsymbol{I\,b_{ii}I}$ and highlights the extent to which the magnitude of past shocks impacted the current variance and covariance. In addition to this, the large increase in a_{11} during the underscores the stronger impact of shocks or innovations on the equites market during a volatile time period (see Figure 3).

Figure 3: Estimated conditional Variance-Covariance by Unrestricted GARCH BEKK



7.3 GARCH BEKK Estimation (Model 3- JSE returns and TTSE returns)

The findings based on table 4 confirm the presence of volatility spill-over and volatility clustering for the sample periods examined, in particular the GARCH parameters were found to be statistically significant (see **Table 4**). More specifically, based on the results in Table 4, current JSE returns volatility may be influenced by volatility of returns in the Trinidad and Tobago Stock Market.

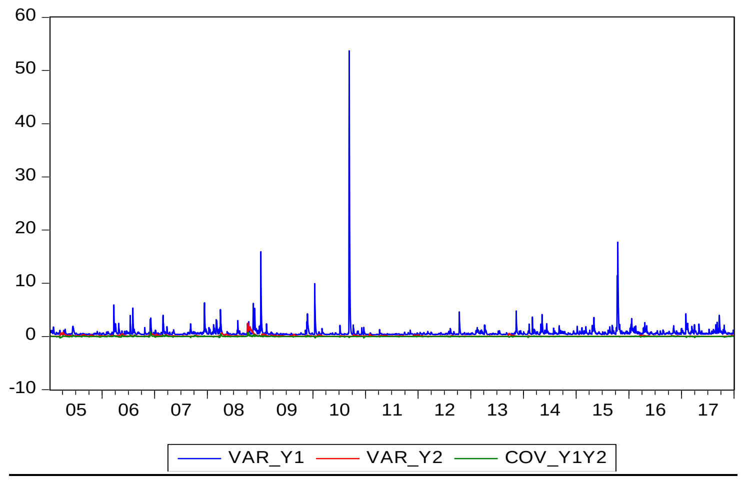
Table 4: Estimated coefficients for variance covariance equations

	Full Sample Period 2015-2017				Volatile period 2007-2011			
	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
MU(1)	0.004106	0.011719	0.350376	0.7261	-0.00943	0.018093	-0.521204	0.6022
MU(2)	0.004039	0.002302	1.754132	0.0794	0.028116	0.007016	4.007344	0.0001
OMEGA(1) (c11)	0.358998	0.008048	44.60772	0.0000	0.326171	0.007862	41.48831	0.0000
BETA(1) (b11)	0.780396	0.009869	79.07301	0.0000	0.756782	0.011381	66.49593	0.0000
ALPHA(1) (a11)	0.489777	0.010932	44.80114	0.0000	0.666342	0.0182	36.61147	0.0000
OMEGA(3) (c22)	0.02851	0.000704	40.48302	0.0000	0.099297	0.005104	19.45287	0.0000
OMEGA(2) (c21)	-0.002729	0.001592	-1.713818	0.0866	-0.009795	0.005721	-1.712105	0.0869
BETA(2) (b12)	0.946968	0.001298	729.2934	0.0000	0.876163	0.008866	98.82095	0.0000
ALPHA(2) (a12)	0.343175	0.004312	79.57721	0.0000	0.428494	0.012403	34.54729	0.0000
Log likelihood	-3692.969	Akaike info criterion		2.185987	-1766.87	ıike info criterion		2.73421
Avg. log likelihood	-1.090336	Schwarz criterion		2.20227	-1.360177	:hwarz criterion		2.770026
Number of Coefs.	9	Hannan-Quinn criter.		2.191808	9	Hannan-Quinn criter.		2.747649

The diagonal parameters in matrix ***A*** and matrix ***B*** highlight that the impact of own past shocks and past volatility on the variance covariance equation of all markets is statistically significant. It was also found that $\boldsymbol{Ia_{ii}I < Ib_{ii}I}$**,** indicating that the movement of the current variance and covariance is not largely impacted by the magnitude of past innovations but by the value of the lagged variances and covariances. Similarly, the statistical significance of GARCH parameters b_{ii} reveals the presence of volatility clustering. Furthermore, the off-diagonal elements of matrices ***A*** (a_{ij}, a_{ji}) and ***B*** $(b_{ij},\ b_{ji})$ capture the cross-market effects of shocks and volatility spillovers among the markets. There is a uni-directional link regarding transmission of shocks between the Trinidad and Tobago Stock Market (TTSE) and the JSE as the off-diagonal parameter a_{12} is statistically significant. This means that there are volatility spillovers from the TTSE to the JSE exist and shocks initiating from the TTSE would affect volatility in the JSE. Additionally, there is also strong evidence of uni-directional volatility persistence between the TTSE and the JSE, in particular the direction of this relationship is from the TTSE to the JSE, as $\boldsymbol{b_{12}}$ is statistically significant at the 5 per cent level. Similar to the other markets, the variance covariance equation is statistically significant as well as the coefficient on parameters which capture spillover effects. Also, regarding the period 2007 to

2011, the variance covariance equation was also found to be statistically significant, while additional results also showed that $Ia_{ii}I < \ Ib_{ii}I$ (see Table 4).

Figure 4: Estimated conditional Variance-Covariance by Unrestricted GARCH BEKK



7.4 GARCH BEKK Estimation (Model 4- BSE returns and TTSE returns)

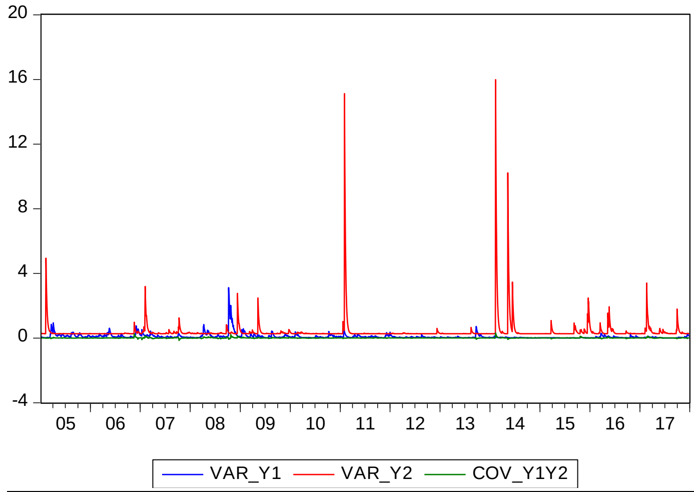
Findings from this model confirm the presence of volatility spill-overs and volatility clustering for the sample period, as relevant GARCH parameters were found to be statistically significant (see Table 5). Of importance is that, based on the results in Table 5, current BSE returns volatility is influenced by volatility of returns in the Trinidad and Tobago Stock Market.

Table 5: Estimated coefficients for variance covariance equations

	Full Sample Period 2015-2017				Volatile period 2007-2011			
	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
MU(1)	0.002849	0.002408	1.183349	0.2367	0.025469	0.00707	3.602498	0.0003
MU(2)	-0.014957	0.013461	-1.11111	0.2665	-0.006992	0.013181	-0.530454	0.5958
OMEGA(1) (c11)	0.031957	0.000692	46.20084	0.0000	0.118196	0.00503	23.49877	0.0000
BETA(1) (b11)	0.934259	0.001499	623.2003	0.0000	0.823315	0.011463	71.82367	0.0000
ALPHA(1) (a11)	0.384017	0.004846	79.24714	0.0000	0.514615	0.014814	34.73798	0.0000
OMEGA(3) (c22)	0.214603	0.002261	94.93438	0.0000	0.144772	0.001987	72.84442	0.0000
OMEGA(2) (c21)	0.006499	0.009108	0.713533	0.4755	0.007074	0.009406	0.752036	0.4520
BETA(2) (b12)	0.908029	0.002006	452.5851	0.0000	0.882234	0.003752	235.1183	0.0000
ALPHA(2) (a12)	0.290487	0.006055	47.97716	0.0000	0.589925	0.017046	34.60817	0.0000
Log likelihood	-2446.114	Akaike info criterion		1.449728	-1042.874	Akaike info criterion		1.619514
Avg. log likelihood	-0.722207	Schwarz criterion		1.46601	-0.802829	Schwarz criterion		1.655329
Number of Coefs.	9	Hannan-Quinn criter.		1.455548	9	Hannan-Quinn criter.		1.632953

Regarding the set of diagonal parameters, the values in matrix ***A*** and matrix ***B*** highlight that the own past shocks and past volatility of all markets are statistically significant. In particular, the statistical significance of GARCH parameter b_{ii} highlights the presence of volatility clustering. Nonetheless, the off-diagonal elements of matrices ***A*** (a_{ij}, a_{ji}) and ***B*** ($b_{ij,}\ \ b_{ji}$) capture the cross-market effects of shocks and volatility spillovers among the markets. Also, there is a unidirectional link regarding transmission of shocks between the Trinidad and Tobago Stock Market (TTSE) and the BSE as off-diagonal parameter a_{12} is statistically significant. Thus, volatility spillover from the TTSE to the BSE exists and shocks initiating from the TTSE would affect volatility in the BSE. Moreover, there is also strong evidence of uni-directional volatility persistence linkages between TTSE and BSE, the direction is from TTSE to BSE, as coefficient $\boldsymbol{b_{12}}$ is statistically significant at the 5 per cent level. Furthermore, lagged volatility persistence in TTSE has a positive effect on current volatility in BSE. Similar to the other markets, the covariance equation is statistically significant and both stock markets are influenced by common news. The log likelihood test of the covariance equation is also significant at the 5 per cent level and is also the case based on estimates for the period 2007 to 2011 (see Table 5).

Figure 5: Estimated conditional Variance-Covariance by Unrestricted GARCH BEKK



8.0 Estimation Results

VEC Models were also utilized to further investigate the relationship between equity market volatility for Jamaica and the U.S. as well as among selected Caribbean economies in the region. Additional variables were also included in the analysis to ascertain possible factors which can impact the degree of equity market volatility both within and across the economies which have been examined in each model.

8.1 Model 1 - VEC Results: Jamaica & the U.S.

More specifically, impulse response analysis is used to analyze the relationship between equity market volatility in both Jamaica and the U.S. Stock market volatility for Jamaica is measured using a rolling standard deviation of stock market returns using the JSE Main Index. While stock market volatility for the U.S. is measured using a rolling standard deviation of stock market returns using the NYSE Composite Index. Other variables included in the model were the spread between a short-term GOJ Global bond and the US Treasury bill rate as well as the volatility in real U.S. GDP growth rates. An exogenous dummy variable was also included in the model to capture the periods of the Jamaica Debt Exchange Programme (JDX) as well as the global financial crisis.[8]

Prior to estimating the model, all data series were tested for stationarity. Results of the Augmented Dickey Fuller Test showed that all variables are integrated of order one.[9] Following this assessment, the model was run in levels under a VAR framework in order to obtain the optimal lag length. This was to ensure the proper fitting of the model and ensure model parameters are efficiently estimated. The optimal lag length as suggested by the several tests is 1 lag (see **Table 6**).

Based on the findings of both the Trace test and the Max Eigen value test, one cointegrating equation was detected, highlighting that there is a long run relationship between the variables examined. The results have been normalized on the JSEVOL variable. Of note, the findings show that a 1 per cent increase in NYSEVOL leads to a decline in the JSEVOL variable by a factor of 3.8. This suggests that in the long run there is the presence of diversification benefits between both exchanges. However, a 1.0 per cent increase in the spread between the short-term GOJ global and the U.S. treasury would result in a 9.8 per cent increase in the JSEVOL variable. In addition, a 1 per cent increase in US GDP volatility would result in a 26.4 per cent increase in volatility in the JSE index.

Generalized impulse response function (GIRF) analysis was also used as it is invariant to the ordering of the variables in the VECM, allowing a unique solution to be achieved. Additionally, the accumulated responses of impulse response functions were estimated for 12 periods ahead. Prior to this though, an examination of the characteristic autoregressive polynomial of the VEC system showed that the system satisfied stationarity conditions as no root lay outside the unit circle. The results found were generally in line with a priori expectations.

The impulse response functions show that there is an initial worsening in the volatility of returns in the Jamaican equities market (JSEVol) in response to a shock in the volatility of returns of U.S. equities, as measured by the NYSE Composite index (NYSEVol) (see **Figure 7**). However, following the 4th quarter, there is sustained improvement which continues into the 12th quarter. This finding provides evidence that overtime increased volatility in the U.S. equities market may lead to

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[8] The JDX involved the extension of maturity and reduction of coupon rates on local currency denominated GOJ bonds.

[9] The first differences of the series are stationary.

lower uncertainty as it relates to the Jamaican equities markets, as investors may feel reduced need to switch from Jamaican equities investments.

Furthermore, a shock to the volatility in real GDP growth for the U.S. would cause a deterioration in the NYSEVol variable. This is not surprising in a context where increased volatility in real GDP in the U.S. may lead to increased uncertainty as it relates to the performance of listed entities, weak investor sentiment as well as reduced appetite for risk-taking by some investors. Increased volatility in real GDP growth for the U.S. is also associated with increased volatility in the Jamaican equities markets.

In terms of accumulated responses, the results show that after 12 periods, shocks to the spread between yields short-term GOJ Global bonds and US Treasury bill rates would result in a marginal deterioration in the NYSEvol variable while there was a stronger increase in the JSEVol variable. An increase in this spread variable may be indicative of a potential increase in macroeconomic fragility, which can contribute to increased investor uncertainty regarding the Jamaican equities market.

8.2 Model 2 VEC Results: Jamaica, Trinidad & Barbados

A VEC model was also used to estimate the relationship between equity market volatility for Jamaica, Barbados and Trinidad. In addition to the measure of volatility, which was computed using the 3-month rolling standard deviation of the monthly returns based on the Main Index in each economy, 2 exogenous dummy variables were included in the model.

Dummy variables were used to capture the global financial crisis period as well as periods of cross listing on all three exchanges. In addition, volatility in real U.S. GDP growth rates was also used in the model given that it represents a variable which can potentially impact equity market volatility spill-overs across all three economies. Prior to estimating the model, a preliminary assessment of the data was also carried out. Unit root tests were done to ascertain the degree of integration of the variables, which was found to be order 1. Against this background, the Johansen test was carried out to determine if the variables were also co-integrated. The Schwarz information criterion suggested an optimal lag length of 1 for this procedure (see **Table 10**). Further tests revealed one co-integrating equation at the 5 per cent level of significance (see **Table 11**).

Of note is that the results have been normalized on the Barbadosvol variable. In addition, the findings show that a 1.0 per cent increase in the Trinidadvol variable resulted in a 72.2 per cent increase in volatility in the Barbados stock index (see **Table 12**). The long run results for the US GDP volatility variable are insignificant. A 1.0 per cent increase in the JSEVOL variable resulted in a 50.4 per cent increase in the volatility of the Barbados stock index.

The impulse response functions show that overtime there is improvement in the volatility of returns in the Barbados equities market (BarbadosVol) in response to a shock in the volatility of returns of for the other two equities markets (JSEvol & Trinidadvol) (see **Figure 8**). In addition, there is also a general improvement in the JSEvol variable and the Trinidadvol variables in response to the increased volatility in the Barbados equities market. The lower uncertainty in these markets may reflect a reduced need by investors to switch from Jamaican and Trinidadian equity investments. As such, while increased volatility in U.S. real GDP growth rates may lead to increased volatility in the Barbados equities markets, this may not lead increased spill-over to other markets. The examination of the impulse response functions did reveal, however, that increased volatility in the Trinidadian stock market does lead to increased volatility in the equity market in Jamaica and vice versa. This may be due to Trinidad being one of Jamaica's largest trading partner.

9.0 Conclusion

In summary, the results of the models examined demonstrate that there is generally a high degree of own market volatility across the stock markets examined as well as cross market spillovers between all stock markets and the Jamaican stock exchange. More specifically, in uncertain periods the magnitude of volatility between markets is important. Of the markets examined, the NYSE exhibited the most cross market spillover effects to the Jamaican stock market relative to the spill-over from the regional markets to the Jamaican Stock Market. This reflects the extent to which volatility surprises in the NSYE would affect the JSE. Regarding the regional markets considered, the highest cross market volatility spill-over was evident from the BSE to the JSE. Against this backdrop, policymakers must consider the complex and intricate relationship between the selected markets and the Jamaican financial system. This is necessary as JSE capitalization has been increasing relative to GDP which increases the financial systems' vulnerablility to market risks. Moerover, an assessment of the impact of volatility surprises is relevant to effective portfolio management, the transmission of monetary policy and the preservation of financial system stability.

Further investigation of the volatility within these economies was also done using a VEC model, which incorporated various key macroeconomic variables. The results suggest that a deterioration in real GDP volatility for the U.S. contributes to increased stock market volatility across all the regional markets examined. This is not surprising in a context where increased volatility in real GDP in the U.S. may lead to increased uncertainty as it relates to the performance of listed entities, weak investor sentiment as well as reduced appetite for risk-taking by some investors. Furthermore, in the long run, a 1.0 per cent increase in the Trinidadvol variable resulted in a 72.2 per cent increase in volatility in the Barbados stock index. At the same time, a 1.0 per cent increase in the JSEVOL variable resulted in a 50.4 per cent increase in the volatility of the Barbados stock index.

Additionally, the findings showed that deterioration in the spread between short-term GOJ Global bonds and the US Treasury bill rate can lead to increased volatility in the Jamaican stock market. Of note is that an increase in this spread variable may be indicative of a potential increase in macroeconomic fragility, which can contribute to increased investor uncertainty regarding the Jamaican equities market. In particular, a 1.0 per cent increase in NYSEVOL leads to a decline in the JSEVOL variable by a factor of 3.8. This suggests that in the long run there is the presence of diversification benefits between both exchanges. However, a 1.0 per cent increase in the spread between the short-term GOJ global and the U.S. treasury bill rate would result in a 9.8 per cent increase in the JSEVOL variable. In addition, a 1 per cent increase in US real GDP volatility would result in a 26.4 per cent increase in volatility in the JSE index. Against this background, the assessment is also important as timely recognition of the implications of adverse developments macroeconomic developments can aid policymakers to take relevant action in preserving economic activity and ensuring financial sector stability.

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Appendix:

Figure 6: Time Plots of the Variables

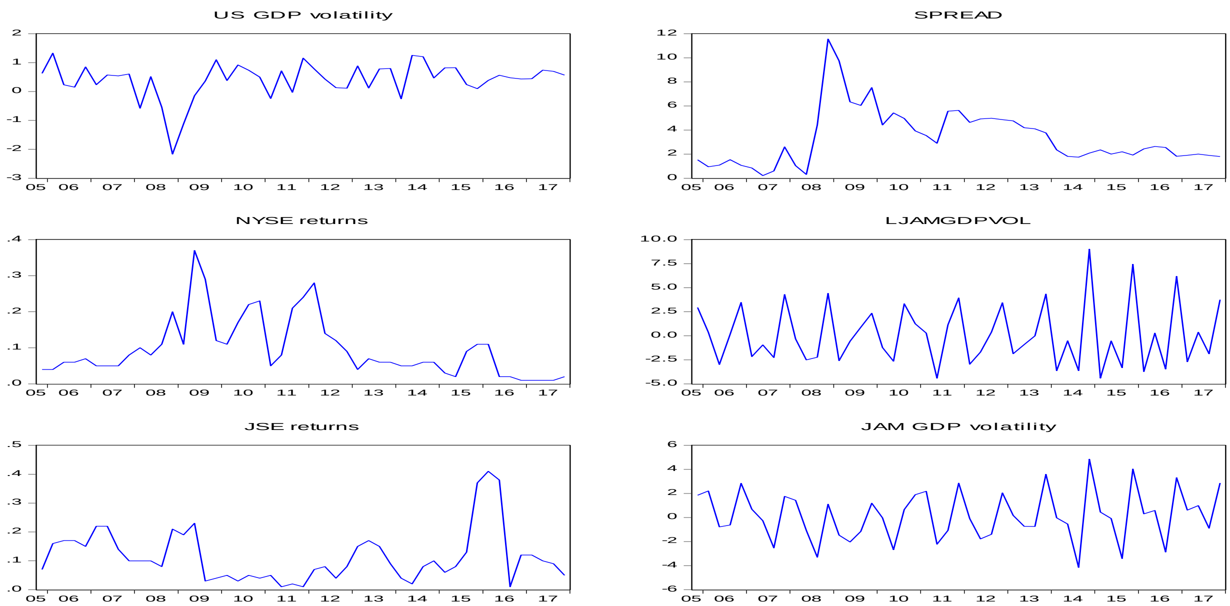

Table 6: VAR Lag Order Selection Criteria – Model 1

Endogenous variables: JSEVOL NYSEVOL SPREAD US_GDP_VOLATILITY
Exogenous variables: C D1
Date: 11/09/18 Time: 07:43
Sample: 2005Q4 2017Q4
Included observations: 45

Lag	LogL	LR	FPE	AIC	SC	HQ
0	8.394588	NA	1.16e-05	-0.017537	0.303647	0.102197
1	59.99184	89.43523*	2.39e-06*	-1.599637*	-0.636084*	-1.240434*
2	74.64217	22.78940	2.60e-06	-1.539652	0.066270	-0.940980
3	86.47063	16.29699	3.30e-06	-1.354250	0.894041	-0.516110
4	103.8864	20.89898	3.44e-06	-1.417175	1.473485	-0.339566

Note: * Indicates lag order selected by the criterion; LR - sequential modified LR test statistic (each test at 5% level);

FPE - Final prediction error; AIC - Akaike information criterion; SC - Schwarz information criterion; HQ - Hannan-Quinn

information criterion

Table 7: Trace Test for Cointegration (VEC Model 1)

Date: 05/24/19   Time: 17:27
Sample (adjusted): 2006Q2 2017Q4
Included observations: 47 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: JSEVOL NYSEVOL SPREAD US_GDP_VOLATILITY
Exogenous series: D1
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.594771	78.36622	63.87610	0.0019
At most 1	0.343704	35.91094	42.91525	0.2095
At most 2	0.236954	16.11718	25.87211	0.4832
At most 3	0.069917	3.406624	12.51798	0.8251

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 8: Maximum Eigenvalue Test for Cointegration (VEC Model 1)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.594771	42.45527	32.11832	0.0019
At most 1	0.343704	19.79377	25.82321	0.2551
At most 2	0.236954	12.71055	19.38704	0.3519
At most 3	0.069917	3.406624	12.51798	0.8251

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 7: Impulse Response Graphs – VEC Model 1

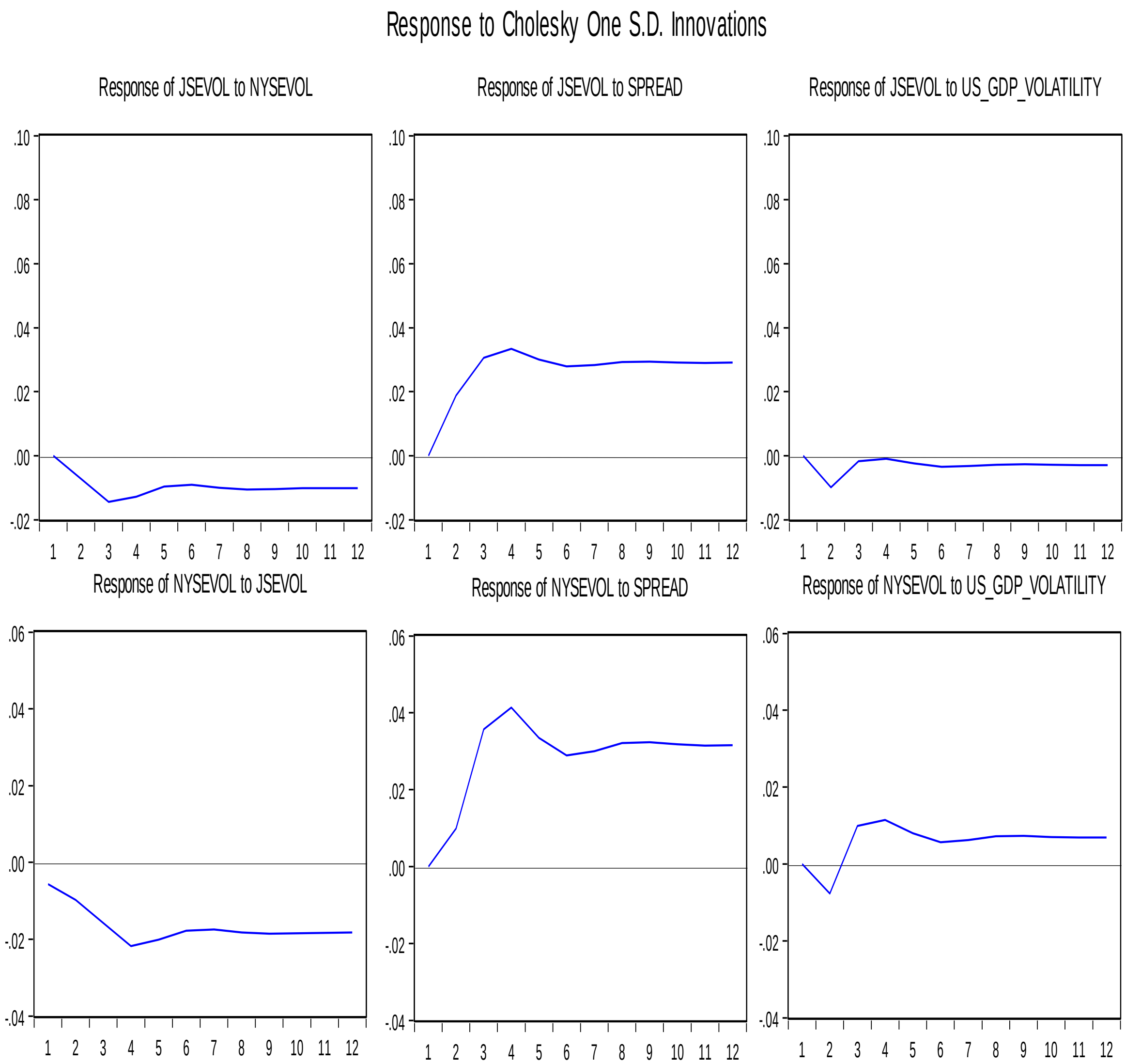

Table 9: VEC Results - Model 1

Vector Error Correction Estimates
Date: 01/04/19 Time: 08:41
Sample (adjusted): 2006Q2 2017Q4
Included observations: 47 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
JSEVOL(-1)	1.000000
NYSEVOL(-1)	3.833755
	(0.58654)
	[6.53619]
SPREAD(-1)	-0.097467
	(0.02190)
	[-4.45078]
US_GDP_VOLATILITY(-1)	-0.264364
	(0.15945)
	[-1.65799]
C	-0.049199

Error Correction:	D(JSEVOL)	D(NYSEVOL)	D(SPREAD)	D(US_GDP_VOLATILITY)
CointEq1	-0.103063	-0.216080	1.164262	-0.115020
	(0.05605)	(0.03511)	(1.05383)	(0.14826)
	[-1.83869]	[-6.15455]	[1.10479]	[-0.77579]
D(JSEVOL(-1))	-0.014256	0.138358	-2.247533	-0.336818
	(0.15214)	(0.09530)	(2.86044)	(0.40243)
	[-0.09370]	[1.45185]	[-0.78573]	[-0.83696]
D(NYSEVOL(-1))	0.232700	0.257810	0.978422	0.247255
	(0.20644)	(0.12930)	(3.88117)	(0.54603)
	[1.12723]	[1.99383]	[0.25209]	[0.45282]
D(SPREAD(-1))	0.003408	-0.013771	0.147588	0.004771
	(0.00835)	(0.00523)	(0.15700)	(0.02209)
	[0.40818]	[-2.63294]	[0.94007]	[0.21601]
D(US_GDP_VOLATILITY(-1))	-0.075343	-0.094373	-0.563018	-0.283799
	(0.06046)	(0.03787)	(1.13666)	(0.15991)
	[-1.24621]	[-2.49213]	[-0.49533]	[-1.77470]
C	-0.013769	-0.013361	-0.250976	-0.038368
	(0.01324)	(0.00829)	(0.24891)	(0.03502)
	[-1.04003]	[-1.61122]	[-1.00831]	[-1.09565]
D1	0.059887	0.068070	1.403959	0.170688
	(0.03146)	(0.01970)	(0.59139)	(0.08320)

	[1.90386]	[3.45486]	[2.37398]	[2.05148]
R-squared	0.167392	0.535084	0.215104	0.181643
Adj. R-squared	0.042500	0.465347	0.097369	0.058889
Sum sq. resids	0.261641	0.102649	92.48255	1.830516
S.E. equation	0.080877	0.050658	1.520547	0.213923
F-statistic	1.340298	7.672846	1.827025	1.479733
Log likelihood	55.29673	77.28459	-82.59661	9.580307
Akaike AIC	-2.055180	-2.990834	3.812622	-0.109800
Schwarz SC	-1.779626	-2.715280	4.088176	0.165754
Mean dependent	-0.002340	-0.000426	0.018085	-0.005611
S.D. dependent	0.082652	0.069281	1.600460	0.220514

Table 10: VAR Lag Order Selection Criteria (Model 2)

VAR Lag Order Selection Criteria
Endogenous variables: BARBADOSRETSVOL JSE_RETURNSVOL TRINIDADRETSVOL US_GDP_VOLATILITY
Exogenous variables: C D1 D2
Date: 11/09/18 Time: 11:04
Sample: 2005Q4 2017Q4
Included observations: 45

Lag	LogL	LR	FPE	AIC	SC	HQ
0	210.6585	NA	1.72e-09	-8.829265	-8.347488	-8.649663
1	255.6821	76.03990	4.78e-10*	-10.11920*	-8.995058*	-9.700133*
2	261.2649	8.436245	7.83e-10	-9.656217	-7.889703	-8.997679
3	280.6066	25.78888	7.21e-10	-9.804736	-7.395852	-8.906728
4	303.5674	26.53253*	5.96e-10	-10.11411	-7.062854	-8.976630

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 11: Trace Test for Cointegration (VEC Model 2)

Date: 05/30/19 Time: 14:31
Sample (adjusted): 2006Q2 2017Q4
Included observations: 47 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: BARBADOSVOL JSEVOL TRINIDADVOL US_GDP_VOLATILITY
Exogenous series: D1 D2
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.421622	66.25512	63.87610	0.0311
At most 1	0.374346	40.52129	42.91525	0.0851
At most 2	0.216076	18.48027	25.87211	0.3126
At most 3	0.139080	7.038448	12.51798	0.3405

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 8: Impulse Response Graphs – VEC Model 2

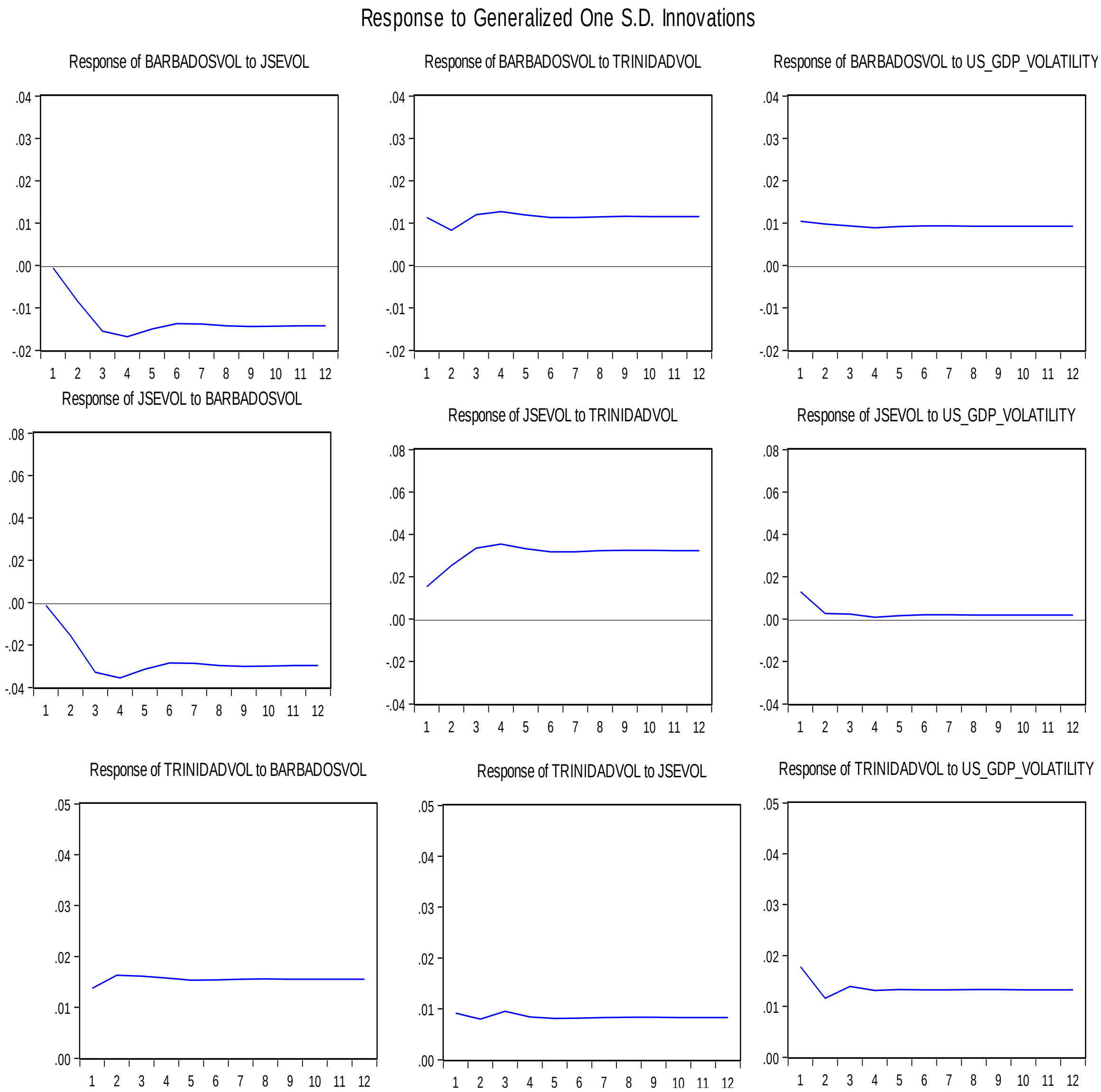

Table 12: VEC Results - Model 2

Vector Error Correction Estimates
Date: 01/03/19 Time: 09:22
Sample (adjusted): 2006Q2 2017Q4
Included observations: 47 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1			
BARBADOSVOL(-1)	1.000000			
JSEVOL(-1)	0.503805 (0.11764) [4.28259]			
TRINIDADVOL(-1)	-0.722612 (0.28860) [-2.50382]			
US_GDP_VOLATILITY(-1)	-0.003977 (0.05524) [-0.07200]			
@TREND(05Q4)	-0.002979 (0.00097) [-3.08408]			
C	0.009367			
Error Correction:	**D(BARBADOSVOL)**	**D(JSEVOL)**	**D(TRINIDADVOL)**	**D(US_GDP_VOLATILITY)**
CointEq1	-0.333318 (0.12485) [-2.66980]	-1.006597 (0.25236) [-3.98872]	0.055561 (0.15159) [0.36652]	-0.624066 (0.73992) [-0.84342]
D(BARBADOSVOL(-1))	0.191573 (0.17114) [1.11938]	0.466284 (0.34594) [1.34788]	0.113687 (0.20780) [0.54710]	1.176798 (1.01429) [1.16022]
D(JSEVOL(-1))	0.055416 (0.07399) [0.74898]	0.191787 (0.14956) [1.28236]	-0.011181 (0.08984) [-0.12445]	-0.298627 (0.43850) [-0.68101]
D(TRINIDADVOL(-1))	-0.257891 (0.14735) [-1.75017]	-0.147695 (0.29785) [-0.49587]	-0.095158 (0.17891) [-0.53186]	0.107201 (0.87330) [0.12275]
D(US_GDP_VOLATILITY(-1))	0.010902 (0.02835) [0.38449]	-0.055104 (0.05731) [-0.96148]	-0.026701 (0.03443) [-0.77561]	-0.312357 (0.16804) [-1.85886]
C	-0.004292	-0.056840	0.000111	-0.008794

	(0.01909)	(0.03859)	(0.02318)	(0.11315)
	[-0.22479]	[-1.47289]	[0.00481]	[-0.07772]
D1	0.027223	0.071196	0.034026	0.170617
	(0.01396)	(0.02821)	(0.01695)	(0.08271)
	[1.95064]	[2.52383]	[2.00800]	[2.06282]
D2	-0.000514	0.043799	-0.009184	-0.033392
	(0.02007)	(0.04057)	(0.02437)	(0.11896)
	[-0.02560]	[1.07948]	[-0.37681]	[-0.28069]
R-squared	0.222105	0.342089	0.148380	0.205435
Adj. R-squared	0.082483	0.224003	-0.004474	0.062820
Sum sq. resids	0.050600	0.206744	0.074598	1.777297
S.E. equation	0.036020	0.072809	0.043735	0.213475
F-statistic	1.590761	2.896935	0.970728	1.440492
Log likelihood	93.90795	60.83084	84.78586	10.27365
Akaike AIC	-3.655657	-2.248121	-3.267483	-0.096751
Schwarz SC	-3.340739	-1.933202	-2.952565	0.218167
Mean dependent	0.001064	-0.002340	-0.001489	-0.005611
S.D. dependent	0.037604	0.082652	0.043638	0.220514