Time-Varying Financial Spillovers from the US to Frontier Markets

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Abstract

We examine US stock index return and volatility spillovers on the mean and volatility of stock index returns of 21 Frontier markets. We entertain potential time-variation in spillovers in mean returns by considering a time-varying parameter (TVP) model. Spillovers in volatility are modeled by augmenting a standard GARCH(1,1) model with current and one-period lagged US conditional volatility effects. The resulting model can be cast in state space form. However, it is not time-invariant as the 'coefficient' multiplying the state variable (the TVP parameter) is current period US returns. The model is estimated by the Kalman Filter. Our TVP model detects statistically significant time-variation in return spillovers and statistically and quantitatively important volatility spillovers for most Frontier markets. Several important hypotheses of interest are tested using a variety of restricted versions of the general model. Perhaps not surprisingly, Frontier countries are characterized as neither completely segmented nor completely integrated. An important contribution of the paper is a detailed analysis of the relative contributions from US and own-country lagged effects on both the mean and volatility of returns in Frontier countries. Our results indicate possible orthogonality in the contribution of current US and lagged own-country returns on Frontier countries mean returns.

Key phrases: Frontier markets; stock index returns; return and volatility spillovers; time-varying parameters (TVP); time-varying volatility

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1. INTRODUCTION

The impact of a change in returns of one financial market on the returns of financial markets abroad (called return spillovers) depends on the financial openness of the foreign countries, as well as the nature of cross-country economic and financial linkages. As a result of such linkages, news released in one country may affect not only local market returns, but the returns of foreign markets as well. The newly arrived information may be reflected either instantly in the foreign market returns, or with a lag, depending on informational asymmetries, market liquidity, and other local market factors. The more financially open a stock market is, the more synchronized its returns are with the returns of foreign markets, and the greater the scope for return spillovers.

Conventional econometric models often assume a stable relationship between dependent and independent variables, embodied in fixed parameters. In the context of return spillovers, this assumption asserts constant sensitivity of local market returns to changes in returns of other stock markets. However, in a dynamically changing economic environment, such an assumption may not be realistic. For example, markets under study may be undergoing structural changes during the period of interest, or they may be experiencing macroeconomic reforms. Such an assumption could be particularly inappropriate when Frontier markets are in consideration, since as those markets evolve and mature, sensitivity of local returns to shocks coming from abroad may be evolving as well. Furthermore, the parameter stability assumption may not fully utilize all information embodied in the sequential nature of market returns and thus may not fully account for the dynamic evolution of the economic system. As a result, the estimated time-invariant sensitivity will be hardly useful in deriving any inferences or for any forward projections (Wells 1996).

Time-variation in return spillovers affect opportunities for international portfolio diversification and thus are of considerable interest for rational international investors. Hedging strategies depend on shocks to stock markets being relatively isolated, but if shocks travel quickly across international borders, the benefits of diversification may be undermined. Considering time-variable spillovers allows investors to better assess the speed and magnitude of shock transmission, and thus better utilize all available information. This may improve financial series forecasting, cost of capital calculation, and asset allocation. Knowledge about the evolution of spillovers could provide Frontier market policy makers with improved and more up-to-date information about the state of the economy, as well as about the nature and origin of any unrest in the local markets. It could enable them to better predict and assess the effects of shocks originating abroad, and thus facilitate adoption of more appropriate and better-timed monetary and fiscal policy decisions. Investigation of time-varying cross-market linkages may also be of interest to academics seeking to shed more light on the evolution of local economies and financial markets. It would enhance evaluation of the impact of local and global shocks on international financial markets, as well as improve understanding of shock transmission mechanisms. The scale of financial spillovers may provide important insights about the propagation of information across countries and enhance awareness of market co-movements.

In this study we investigate potential time-variability in the impact of US stock market returns on the returns of twenty-one Frontier markets during the period between December 1st, 2005 and January 15th, 2010. In addition to possible time-varying return spillovers, we also investigate the impact of the conditional volatility of US returns on the conditional volatilities of the Frontier markets (referred to as returns volatility spillovers). In our analysis, we only consider time-invariant volatility spillovers. Nonetheless, the transmission of volatility is an important subject of consideration. With volatility being a proxy for stock market uncertainty, volatility spillovers are the primary process by which financial unrest is transmitted internationally. Understanding volatility spillovers thus becomes important for international portfolio diversification and hedging strategies.

To investigate time-varying returns spillovers, we set up a a time-varying parameter (TVP) model. Spillover effects in volatility are modeled by augmenting a standard GARCH(1,1) model with volatility effects stemming from current period and one-period lagged US conditional volatility. The model can be cast into a state space form. However, it is not time-invariant as the 'coefficient' multiplying the state variable (the TVP parameter) is current period US returns. The model is estimated by the Kalman Filter. Several restricted versions of the general model are also estimated with Frontier country returns. Statistical tests on constancy of the mean spillovers parameter (i.e.

a test for constant parameter), tests for no spillover effects in mean returns and/or volatility, as well as other hypotheses of interest are performed. Relative contributions from the US and own-country lagged effects on both mean and volatility of Frontier countries' returns are explored.

The rest of the paper is organized as follows. Section 2 reviews relevant literature on TVP models that have been used to study financial market spillovers. Section 3 presents the data, the main empirical TVP model and estimation results. Section 4 considers some important hypotheses of interest, and reports statistical inferences that can be drawn on these hypotheses from the data. Section 5 provides a discussion of the results obtained. Section 6 offers concluding remarks and prospects for future research.

2. LITERATURE REVIEW

Time-variation in financial spillovers has long been recognized in international finance literature. Two approaches are commonly adopted to address non-constancy in parameters. The first approach is to divide the sample into turbulent and calm periods. To determine turbulent and non-turbulent periods, Dungey et al. (2005) suggest using post-sample rationalizations, Kaminsky and Schmukler (1999) uses news release data in studying the Asian crisis, and Aggarwal et al. (1999) divide their sample based on local and global events in studying the volatility of emerging markets.

The second approach is to use the sample data itself to distinguish turbulent from calm periods. Bialkowski et al. (2006) use a Markov switching framework to distinguish between turbulent and non-turbulent periods in studying spillovers among mature markets. Gebka and Serwa (2006) differentiate between calm and and turbulent periods using a threshold VAR in exploring spillovers between US and eight South-East Asian countries. Beirne et al. (2008) use dummy variables to capture parameter shifts when examining spillovers from mature to emerging markets. Diebold and Yilmaz (2009) incorporate parameter variability using rolling-sample regressions.

Although the literature cited above admits that spillover parameters are variable over time, it addresses this variability by distinguishing only between turbulent and calm periods. There is nothing, however, to guarantee that the spillovers are constant within either period. It could be that in turbulent times, as financial institutions re-balance portfolios, the liabilities of economies grow, and their exposure to cross-border shocks increases exponentially. It could be that the economies, as well as the financial institutions, evolve over time. It could be that major structural, political, and macroeconomic reforms are taking place on an ongoing basis. Or, it could be that the place of the country on the international trade scene is evolving over time.

In order to incorporate potential time-varying spillovers effects from such causes, we explore time-variability of return spillovers using time-varying parameter (TVP) models. These models can be cast in state space form and, hence, are amenable to estimation using the Kalman filter. The Kalman filter facilitates examination of return spillovers regardless of the state of the economy (whether turbulent or not). The picture of international return spillovers the filter portrays is more detailed and comprehensive, as the technique allows spillover parameters to be updated every period using all information available at the time. The incorporation of GARCH-like model of errors allows us to account for heteroscedasticity inherent in financial series, as well as to investigate volatility spillovers within the context of the TVP model.

The Kalman Filter has been used in an international setting to investigate evolving market efficiency and integration. For instance, Zalewska-Mitura and Hall (1999) use it in combination with GARCH errors to investigate efficiency of the Hungarian stock market. Rockinger and Urga (2001) use a similar model to investigate market efficiency of the Czech, Polish, Hungarian, and Russian stock markets. Brooks et al. (2002) compare the performance of GARCH and Kalman filter models in investigating time-varying country risk. Jochum (1998) uses it in combination with bivariate GARCH-M errors to investigate the behavior of the risk premium on the Swiss stock market. Choudhry and Wu (2009) find the Kalman filter to be overwhelmingly superior in forecasting weekly stock returns of twenty UK firms compared to GARCH models. Further review of applications of the Kalman filter in economics can be found in Pasricha (2006) and Bouye (2009).

3. EMPIRICAL MODELS OF MARKET RETURNS

We begin by discussing the data set used in section 3.1. The subsequent two sections 3.2 and 3.3 set up empirical TVP models for US and Frontier market returns, respectively. Estimation issues are discussed briefly in section 3.4. Empirical results are presented in section 3.5.

3.1. Data

To explore evolution of financial spillovers from the US, we use daily closing prices of the MSCI Barra Index for the United States and twenty-one Frontier markets. Our sample spans the period from December 1st, 2005 to January 15th, 2010 and contains 1077 observed closing prices.

We obtain percentage annualized returns for each country K as a log difference in daily closing prices:

$$R_{\mathrm{t}}^{\mathrm{K}} = 100 * (lnP_{\mathrm{t}}^{\mathrm{K}} - lnP_{\mathrm{(t\text{-}1)}}^{\mathrm{K}}) * 252 \tag{1}$$

where $P_{\mathrm{t}}^{\mathrm{K}}$ stands for closing price of each country's index at day t and 252 represents the average number of trading days in a calendar year.

Daily returns have been chosen for our investigation to better account for stock market dynamics. Market efficiency would suggest that news is quickly and efficiently incorporated into stock prices (Fama 1998). Therefore, while information generated yesterday may be significant in explaining prices today, it is less likely that information generated last week would have much impact today. Furthermore, changes in rates of return are news-driven. Announcements such as declarations of war, profit forecasts and changes in interest rates are factors that affect market sentiment and drive equity prices in the short run. Using daily stock data permits an analysis of how investor sentiment can be transmitted from one market to another.

The following Frontier markets are included in our sample: Argentina, Bahrain, Bulgaria, Croatia, Estonia, Jordan, Kazakhstan, Kenya, Kuwait, Lebanon, Mauritius, Nigeria, Oman, Pakistan, Qatar, Romania, Saudi Arabia, Slovenia, Sri Lanka, Tunisia, and United Arab Emirates. The markets and length of the sample have been chosen such that the longest time series are attainable for the greatest number of countries. Lithuania, Serbia, Ukraine, Bangladesh, Trinidad and Tobago, Jamaica, Botswana and Ghana are also classified as Frontier markets by the World Bank, but they are not analyzed in this study due to lack of a sufficiently long sample series. Since MSCI indexes are designed consistently across countries, they offer an adequate platform for investigation of cross-market spillovers. The MSCI indexes are value-weighted and compounded with dividends reinvested. To avoid double counting, stock prices of companies set up abroad are not included. All indexes are in US dollars, providing additional comparability across markets and implicitly taking care of currency market effects.

3.2 Model of US Market Returns

We begin with an investigation of US market returns. Our most general Model 1 describing US returns incorporates time-varying impact of one-period lagged US returns. It is specified as follows:

$$R_{\mathrm{t}}^{\mathrm{US}} = \theta^{\mathrm{US}} + a_{\mathrm{t}}^{\mathrm{US}} R_{\mathrm{t\text{-}1}}^{\mathrm{US}} + u_{\mathrm{t}}^{\mathrm{US}} \tag{2}$$

$$u_{\mathrm{t}}^{\mathrm{US}} \sim iidN(0, H_{\mathrm{t}}^{\mathrm{US}})$$

$$H_{\mathrm{t}}^{\mathrm{US}} = b_0 + b_1 H_{\mathrm{t\text{-}1}}^{\mathrm{US}} + b_2 u_{\mathrm{t\text{-}1}}^{2\ \mathrm{US}} \tag{3}$$

$$a_{\mathrm{t}}^{\mathrm{US}} = c(1-\rho) + \rho a_{\mathrm{t\text{-}1}}^{\mathrm{US}} + n_t^{\mathrm{US}} \tag{4}$$

$$n_{\mathrm{t}}^{\mathrm{US}} \sim N(0, Q^{\mathrm{US}})$$

$R_{\mathrm{t}}^{\mathrm{US}}$ is US index returns, and θ^{US} its unconditional mean. The time-varying impact of lagged US returns is captured by the parameter $a_{\mathrm{t}}^{\mathrm{US}}$. Using the terminology of state space models, Eq. (2) is the measurement equation. It relates the observed (explained) variable $R_{\mathrm{t}}^{\mathrm{US}}$ to the state variable (time-varying parameter) $a_{\mathrm{t}}^{\mathrm{US}}$. The 'coefficient' multiplying the state variable is current period US returns. Eq. (4) is the state equation describing the evolution of $a_{\mathrm{t}}^{\mathrm{US}}$ as an AR(1) process. Detailed exposition of such state space models, along with their estimation via the Kalman filter, can be found in Harvey (1989) and Hamilton (1994).

u_t^{US} is the unexplained portion of US returns and H_t^{US} its conditional variance, a proxy for US financial market uncertainty. Eq. (3) is a standard GARCH(1,1) model for the conditional variance of the observation equation error u_t^{US}. The GARCH parameters b_1 and b_2 capture the impact of previous period US conditional volatility (uncertainty) and unexpected news about mean returns on current volatility, respectively. In what follows, we estimate the above model as well as several restricted versions of it using US returns data.

3.3 Model of Frontier Market Returns

Model 1 for Frontier country market returns is specified as follows:

$$R_t^K = \theta^K + a_t^{US} R_t^{US} + a^K R_{t-1}^K + u_t^K \tag{5}$$

$$u_t^K \sim N(0, H_t^K)$$

$$H_t^K = b_0 + b_1 H_{t-1}^K + b_2 u_{t-1}^{2\,K} + b_3 H_t^{US} + b_4 H_{t-1}^{US} \tag{6}$$

$$a_t^{US} = c(1-\rho) + \rho a_{t-1}^{US} + n_t^{US} \tag{7}$$

$$n_t^{US} \sim N(0, Q^{US})$$

$$E(u_t^K n_t^{US}) = 0$$

R_t^K is index returns of Frontier country K, and θ^K its unconditional mean. The effect of contemporaneous US returns on Frontier country mean returns is captured by the parameter a_t^{US}. It accounts for time-varying spillovers in mean returns from the US to the Frontier country. The impact of one-period lagged own-country returns is captured by the parameter a^K, assumed to be fixed rather than time-varying for simplicity. This does not interfere with our main object of study here, which is an investigation of time-variation in return spillovers from US to Frontier markets. The volatility specification in eq. (6) is a standard GARCH(1,1) model, augmented with current and past US volatility terms. Accordingly, the parameters b_3 and b_4 represent volatility spillovers from US to the individual country. The conditional variance of the unexplained portion of Frontier market returns H_t^K is a proxy for local market uncertainty.

In earlier analysis, for sixteen of the twenty-one Frontier markets, Bidarkota and Todorov (2010) determine the best-fitting model to incorporate only current period US returns in Eq. (5). For Bahrain, Kuwait, Oman, and Tunisia, they determine the best-fitting model to include not only current, but also one-period lagged, US returns. For Kenya, they determine the best-fitting model to incorporate 2-period own country lagged returns as well. For simplicity, we omit lagged US returns as well as 2-period own country lagged returns. Accordingly, we estimate Eq. (5) for all countries in our sample.

It is interesting to note that most Frontier markets open five or more hours before the US market opens, with the exception being Argentina (opening one hour ahead). One important implication is that return spillovers may not reflect the impact of actual realized US returns, but expected US returns. Any announcements made in the US after closing of the stock exchanges on day 1, and before opening on day 2, are reflected in the US market on day 2. Throughout the trading day on day 2 on local Frontier markets, investors observe those announcements, and incorporate them in their asset valuations immediately. To better describe such a situation, we could say that it is the US overnight returns that affect the local markets, rather than the actual daily returns, where the overnight returns are defined as the change in price between closing on day 1 and opening on day 2. The overnight returns form the expected returns, and are reflected in US daily returns on the next day. Those returns seem to affect local market returns despite the fact that local markets may close for the day before the US market opens. Similar discussion and more details on the international transmission of overnight returns can be found in Lin, Engle, and Ito (1994), Hamao, Masulis, and Ng (1994), and Baur and Jung (2006).

3.4 Estimation Issues

Model 1 for US returns and for Frontier market returns can be cast as linear conditionally Gaussian state space models. An important point worth noting about Model 1 is that the state space model is not time-invariant. The 'coefficient' multiplying the state variable (the TVP parameter) is current period US returns. Nonetheless, they can be easily estimated using the Kalman filter algorithm. The filter also enables estimation of the spillover parameter (the state variable) every period utilizing all available information to date. With linear Gaussian models, the Kalman filter provides the most efficient estimator. A somewhat similar model is estimated by Rockinger and Urga (2001). With non-linear and/or non-Gaussian models, the filter is no longer optimal. Modified versions of the filter such as the extended Kalman filter are available. Detailed description of the Kalman filter and the conditions for its optimality can be found in Harvey (1989) and Hamilton (1994).

The GARCH model of errors accounts for volatility clustering that has been well-documented in returns data. With volatility clustering, large changes tend to follow large changes, and small changes tend to follow small changes. The changes from one period to the next are typically of unpredictable sign. Large disturbances, positive or negative, influence the magnitude of the realization of next period's disturbance through the variance term. In this way, large shocks can persist for several periods.

The GARCH model of errors however has some limitations. Although explicitly designed to model time-varying conditional variances, it fails to capture wild market fluctuations (for example, crashes and bubbles) and other unanticipated events leading to structural changes. For instance, time-varying volatility spillovers depending on an underlying state variable that tracks the state of the economy have been considered (Baele 2005). Furthermore, GARCH errors often fail to fully capture fat tails observed in asset returns (Creal, Koopman, and Lucas 2010).

3.5 Empirical Results

3.5.1 Model 1 Estimates for US Returns

Maximum likelihood (ML) estimates of Model 1 for the US are presented in Table 1. The long-run unconditional mean of returns θ is estimated to be 12.044 percent per annum, although it is not statistically significantly different from zero. The unconditional mean of the time-varying coefficient on lagged returns C is estimated to be -0.098. The AR parameter ρ driving this time-varying coefficient is 0.948, but the standard deviation $\sqrt{Q^{\mathrm{US}}}$ of the signal shock n_{t} driving the AR process is essentially zero, suggesting no time-variation in this parameter. The GARCH parameter a_1 is estimated to be 0.911 and the ARCH parameter a_2 to be 0.08, in line with values reported in numerous earlier studies.

Table 1 also reports estimates of a restricted version of Model 1 for the US in column 3 with $a_{\mathrm{t}}^{\mathrm{US}}$ being constant (Model 2). Thus, the restricted specification in column 3 features no time-variation in the impact of lagged returns on current mean returns. The parameter estimates and their standard errors for Model 2 reported in column 3 are largely identical to those reported for Model 1.[1] We compare Model 1 (the unrestricted model) with its restricted version using a likelihood ratio (LR) test. The test statistic is reported in the bottom row of Table 1. Testing Model 2 against Model 1 (test for no time-variation in $a_{\mathrm{t}}^{\mathrm{US}}$) results in an LR statistic of only 0.118. Constancy of $a_{\mathrm{t}}^{\mathrm{US}}$ cannot be rejected even at large significance levels, using critical values from the χ^2 distribution with two degrees of freedom.[2] We proceed by testing Model 2 (the unrestricted model) for homoskedasticity. The resulting large test statistic of 728.437 (details not reported) overwhelmingly rejects in favor of time-varying volatility. Thus, results of the hypotheses tests indicate that the best-fitting model of US returns is the constant parameter restricted version of Model 1, referred to as Model 2 above (i.e. the GARCH model with constant $a_{\mathrm{t}}^{\mathrm{US}}$). In what follows, time-varying conditional variances of US returns estimated with this model are used to estimate Model 1 (and several restricted versions) using data on Frontier market returns.

[1] We also estimated homsoskedastic versions of both Models 1 and 2. Parameter estimates for the homoskedastic version of Model 1 suggest a time-varying parameter with no persistence. However, as noted above, a GARCH model (Model 1) suggests no time variation in this parameter.

[2] A test for homoskedasticity with Model 1 as the alternative hypothesis was easily rejected. Also, a joint test for time-invariance of all parameters in Model 1 (joint test for homoskedasticity and no time-variation in $a_{\mathrm{t}}^{\mathrm{US}}$) once again was overwhelmingly rejected.

Panel 1 in Figure 1 depicts observed returns for the US along with their one-step ahead predictions using the best-fitting Model 2. The figure clearly shows the unusually large fluctuations in returns observed during the global financial crisis around year 2009. The panels in Figure 2 plot US conditional volatility, as measured by the estimated standard deviation $\sqrt{H_t^{US}}$ in percent per annum, using Model 2 (along with the estimated conditional volatility for select Frontier countries to be discussed in Section 3.5.2). The conditional volatility ranges from a high of 1370 percent per annum in late 2008 to a low of 97 percent.

3.5.2 Model 1 Estimates for Frontier Market Returns

This subsection reports estimates of Model 1 for Frontier countries, applied to MSCI data ranging from December 1st, 2005 to January 15th, 2010. The parameter estimates and standard errors are reported in Table 2. The unconditional mean of returns θ^K for seven countries are estimated to be higher than the US value reported in Table 1, with the highest value for Kazakhstan at 31 percent annualized. For seven countries, the estimated mean returns are negative, with the lowest for Sri Lanka at -10 percent annualized. Estimates of the parameter on lagged own country returns a^K is positive for all Frontier markets, except Bulgaria (-0.067). The highest estimate is for Nigeria (0.443). These estimates are statistically significant for all but three countries.

Estimates of the mean US return spillovers parameter C are positive for 17 of the 21 countries. These estimates range from a high of 0.994 for Argentina to a low of -0.022 for Jordan. These estimates are however statistically significant for only 9 of the countries. Estimates of the AR parameter ρ governing time variation in spillovers from the US to Frontier countries are positive for 13 countries. These range from a high of 0.813 for Pakistan to a low of -0.974 for Oman. These estimates are statistically significant for 10 countries. Estimates of the standard deviation of the signal shock n_t^{US} driving the spillover process a_t^{US}, denoted by $\sqrt{Q^{US}}$ is zero for 7 countries. This essentially implies that, for these 7 countries, there is no time-variation in spillovers from the US. Except for Bulgaria, these are all countries in the Middle East (Bahrain, Jordan, Kuwait, Oman, Qatar, and S. Arabia).

Estimates of the GARCH parameter b_1 range from a high of 0.98 for Romania to a low of 0.55 for Bahrain. Estimates of the ARCH parameter b_2 range from a high of 0.21 for Mauritius to a low of 0.02 for Croatia. Estimates of the impact of current US volatility on Frontier markets volatility b_3 range from a high of 0.44 for Bahrain to a low of 0 for Slovenia, Nigeria, and Pakistan. Estimates of the impact of one-period lagged US volatility b_4 on all Frontier markets is essentially zero.

The various panels of Figure 1 plot observed returns for a few Frontier countries (selected in alphabetical order) along with their fitted values derived from Model 1.[3] The figures show that for almost all countries (except Argentina and Nigeria), Model 1 captures only a small portion of the daily return fluctuations.

The various panels of Figure 2 plot estimates of the standard deviations $\sqrt{H_t^K}$ from Model 1. Each panel drawn for a selected Frontier country also shows plot of the standard deviation $\sqrt{H_t^K}$ from the best-fitting Model 2 for the US. The figures show that these volatilities are consistently higher for 10 Frontier countries than the US. Volatility in the US peaks in late 2008 and early 2009 coinciding with the turmoil in global financial markets. This is replicated and/or magnified for 11 of the Frontier countries. For some countries such as Nigeria and Pakistan, the peak in volatility clearly lags that for the US. For many Frontier markets, the volatility plots show numerous episodes of volatility clusters (with smaller peaks than around late 2008-early 2009) than is evident for the US. For these countries, we expect a lower degree of comovement of conditional volatilities with the US.

The various panels of Figure 3 plot time-varying US return spillovers parameter a_t^{US}. As indicated earlier, for 7 of the countries for which $\sqrt{Q^{US}}$ is estimated to be zero, the plots show a_t^{US} converging to a constant value. Because the algebraic sign of the estimate of the AR parameter ρ is negative for these countries, the convergence is oscillatory. Except for Sri Lanka, for all the remaining countries, estimates of $\rho$are positive. For UAE, the estimates of a_t^{US} are essentially zero. Typically, the magnitude of spillovers a_t^{US} ranges between -0.5 and 0.75, with occasional spikes in both directions. Argentina is the only country with no estimated negative spillovers.

[3]Plots in all figures in the paper are shown only for these same selected Frontier countries for the sake of brevity. Complete details are available from the authors on request.

The various panels of Figure 4 plot the decomposition of Frontier country fitted returns into US and local market components. Quantitatively significant impact of US returns is found for 13 of the 21 markets. For 2 markets, Argentina and Kazakhstan, the effect of US returns is larger relative to that of lagged local returns. This implies that the evolution of returns in these countries is primarily governed by US market performance. For another set of countries, Bulgaria, Croatia, Estonia, Romania, Saudi Arabia, and Tunisia, the US component is about as important as local market component. On the other hand, returns for Jordan, Mauritius, Pakistan, Qatar, Slovenia, and Sri Lanka are dominated by the local market component. However, the impact of US returns remains strong. The remaining markets, Kenya, Kuwait, Lebanon, Nigeria, Oman, UAE, and Bahrain, are overwhelmingly dominated by the local component and the influence from US is minimal.

The various panels of Figure 5 plot the decomposition of Frontier country estimated conditional volatility into US and local market components.[4] Quantitatively significant impact of US volatility is found for 18 of the 21 markets, the exceptions being Kenya, Pakistan, and Sri Lanka. This effect is strongest for Romania, for which the US volatility spillover component is about as strong as the local market volatility component. For 4 markets, Bahrain, Mauritius, Romania, and Slovenia, the US volatility component is relatively large, implying that conditional volatility in these countries is strongly influenced by US current and one-period lagged US volatility.

In summary, Model 1 estimated for Frontier countries captures only a small portion of their daily return fluctuations. Most Frontier markets display volatility that is greater both in magnitude and variability relative to the US. This is expected as developing markets are considered more risky and hence are expected to exhibit greater uncertainty. Time-varying spillovers are important in 13 of the 21 Frontier countries. Quantitatively significant impact of US returns is found for 13 of the 21 markets. Quantitatively significant impact of US conditional volatility is found for 18 of the 21 markets.

In the next section, we formally test various restrictions on Model 1 that shed light on the economic importance of information flows emanating from the US market relative to local market feedback effects.

4. HYPOTHESES TESTS

This section performs several statistical tests of hypotheses of interest. Of central concern to this paper is whether the impact of spillovers from US on mean returns of Frontier markets is constant or time-varying. Accordingly, this is tested in subsection 4.1. A second interesting hypothesis, tested in sub-section 4.2, is whether there are any spillovers in volatility. Subsection 4.3 performs a joint test of the preceding two hypotheses, which is tantamount to a hypothesis of no influence of US on Frontier markets (complete segmentation). Subsection 4.4 examines the possibility of no impact of own country variables on its mean returns and volatility. This is interpreted as a test of the hypothesis of 'complete integration' between US and Frontier markets. A summary and brief interpretation of all the results from hypothesis tests is provided in subsection 4.5.

All tests are carried out by constructing the likelihood ratio (LR) test statistics. Model 1 estimated in section 3 is the most general (unrestricted) model in all the tests. The restricted model for each hypothesis is described in the subsections below. Each restricted model is obtained by imposing suitable restrictions on the parameters of Model 1. The LR test statistic is constructed as the difference $\Lambda = LnL_{\mathrm{u}} - LnL_{\mathrm{r}}$, where LnL_{u} is the maximized log-likelihood value for the unrestricted model and LnL_{r} is the corresponding value under the restrictions imposed by the null hypothesis. The resulting test statistic Λ has a χ^2 distribution with degrees of freedom equal to the number of restrictions imposed. The null hypothesis is rejected if the value exceeds the appropriate critical value.

Test results are reported in Table 3. Values of LR test statistics are reported for each Frontier country for each hypothesis. All statistical inferences drawn below assume a five percent significance level. A summary of statistical inferences drawn is provided in Table 4. Appendix A provides parameter estimates for each of the restricted models in Tables A.1-A.4. Appendix B plots figures for selected countries in Figures B1-B8. These figures provide a comparison of own-country lagged effects versus the effects from contemporaneous and lagged US shocks on both the mean and

[4] Formal variance decompositions are made in studies such as Rockinger and Urga (2001) and Baele (2005).

volatility of Frontier country returns.

4.1 Test for no time-variation in spillovers in mean returns

In this subsection we examine the significance of time-variability of US return spillovers. Because return spillovers transmit economic shocks, this clarifies whether the exposure of Frontier markets to economic shocks in the US fluctuates over time. The issue is studied by comparing a model restricting $a_{\mathrm{t}}^{\mathrm{US}} = constant$ with the general Model 1 estimated in Section 3 above. The specification under the null is denoted as Model 2 and can be written as follows:

$$R^{\mathrm{K}} = \theta^{\mathrm{K}} + a^{\mathrm{US}} R_{\mathrm{t}}^{\mathrm{US}} + a^{\mathrm{K}} R_{\mathrm{t\text{-}1}}^{\mathrm{K}} + u_{\mathrm{t}}^{\mathrm{K}} \tag{8}$$

$$u_{\mathrm{t}}^{\mathrm{K}} \sim N(0, H_{\mathrm{t}}^{\mathrm{K}})$$

$$H_{\mathrm{t}}^{\mathrm{K}} = b_0 + b_1 H_{\mathrm{t\text{-}1}}^{\mathrm{K}} + b_2 u_{\mathrm{t\text{-}1}}^{2\ \mathrm{K}} + b_3 H_{\mathrm{t}}^{\mathrm{US}} + b_4 H_{\mathrm{t\text{-}1}}^{\mathrm{US}} \tag{9}$$

Estimates of Model 2 are presented in Table A.1 in Appendix A. Estimates of the constant spillover parameter a^{US} are reported to be similar to the values of the unconditional expectation of return spillovers c from Model 1 for Frontier countries reported earlier in Table 2. The estimated current and lagged volatility spillover parameters b_3 and b_4 are also similar to those obtained from Model 1. Thus, information flows transmitted through volatility spillovers are not significantly affected by the absence of time-variation in return spillovers.

LR test statistics for the null hypothesis are reported in the second column of Table 3. Time-variability of $a_{\mathrm{t}}^{\mathrm{US}}$ is statistically significant (null hypothesis is rejected) for 13 countries. This indicates that time-variability of $a_{\mathrm{t}}^{\mathrm{US}}$ conveys economically important information that is not captured by the restricted model. Thus, changing sensitivity to US economic shocks is important. The null hypothesis of constant spillovers is not rejected for all the 7 Middle-Eastern countries in our sample as well as for Pakistan. For these countries, exposure of their returns to economic shocks originating in US is constant. This might be because some of the information transmitted through return spillovers is not relevant for these countries or is already captured by volatility spillovers and GARCH effects.

The various panels of Figure B.1 in Appendix B plot the US components of Frontier country returns estimated by Models 1 and 2. The contribution of US returns estimated from Model 1 is stronger for 5 countries, namely, Bahrain, Kuwait, Nigeria, Pakistan, and UAE. Thus, for this set of countries, time-variation in mean spillovers amplifies the estimated contribution of US effects on their mean returns. On the other hand, for Lebanon, Mauritius, and Slovenia, the US contribution to their mean returns is estimated to be larger from Model 2. For all other countries the US return components estimated by Models 1 and 2 are similar.

The contribution of US volatility to local market conditional volatility, estimated by Model 2 (Figure B.2 in Appendix B) increases for 8 of the 21 markets. For the remaining 12 markets, shutting down time-variability in return spillovers results in no substantive change in the estimated impact of current and one-period lagged US volatility.

4.2 Test for no spillovers in volatility

Here we investigate the significance of US volatility spillovers to Frontier countries. As volatility is a measure of market uncertainty, this sheds light on whether economic unrest in US is transmitted to Frontier countries through spillovers in volatility. We compare Model 1 with a version restricting $b_3 = b_4 = 0$. Rejecting the null hypothesis highlights the importance of information flows through volatility spillovers (Baele 2005, Bekaert and Harvey 1997) and the dissemination of economic disturbances across countries through this channel. The specification under the null, denoted as Model 3 in what follows, can be written as:

$$R_{\mathrm{t}}^{\mathrm{K}} = \theta^{\mathrm{K}} + a_{\mathrm{t}}^{\mathrm{US}} R_{\mathrm{t}}^{\mathrm{US}} + a^{\mathrm{K}} R_{\mathrm{t\text{-}1}}^{\mathrm{K}} + u_{\mathrm{t}}^{\mathrm{K}} \tag{10}$$

$$u_{\mathrm{t}}^{\mathrm{K}} \sim N(0, H_{\mathrm{t}}^{\mathrm{K}})$$

$$H_t^K = b_0 + b_1 H_{t-1}^K + b_2 u_{t-1}^{2\ K} \tag{11}$$

$$a_t^K = c(1-\rho) + \rho a_{t-1}^{US} + n_t^{US} \tag{12}$$

$$n_t^{US} \sim N(0, Q^{US})$$

$$E(u_t^K n_t^{US}) = 0$$

Estimates of Model 3 are presented in Table A.2 in Appendix A. Results indicate that the parameters c, ρ and $\sqrt{Q^{US}}$ remain largely unchanged for Slovenia. But, shutting down volatility spillovers causes the unconditional expectation of US return spillovers c to increase for all Frontier countries, except Argentina, Kazakhstan, and Mauritius. The AR parameter ρ correspondingly increases for 11 countries. Only for Mauritius, c decreases while ρ increases. Estimates of the standard deviation $\sqrt{Q^{US}}$ of the signal shock n_t^{US} increases for all Frontier countries, except Croatia and Romania.

LR test statistics for this hypothesis are presented in the third column of Table 3. The null hypothesis can be rejected for 14 of the 21 Frontier countries. For the 14 countries for which volatility spillovers are found to be important, information emanating from the US and transmitted through this channel may result in increased susceptibility of these Frontier country returns to US market disturbances. For the remaining 7 countries, volatility spillovers do not represent an important channel of information flows. This could be because information transmitted through volatility spillovers is already captured by return spillovers and GARCH effects. Absence of volatility spillovers could potentially make these countries less vulnerable to turbulence originating in the US market.

The various panels of Figure B.3 in Appendix B plot the US components of Frontier country returns estimated by Models 1 and 3. The contribution of US returns estimated from Model 3 is stronger for 4 countries, namely, Kuwait, Oman, Pakistan, and Qatar. Thus, for this set of countries, shutting down volatility spillover effects from the US amplifies the estimated contribution of US effects on their mean returns. This shows that information flows transmitted through mean returns now capture some of the spillovers earlier transmitted through the volatility channel. On the other hand, for Mauritius and Nigeria, the US contribution to mean returns is estimated to be actually larger from Model 1. This means that for these two countries, shutting down volatility spillovers weakens mean returns spillovers as well. For all other countries, the US components estimated by both Models 1 and 3 are similar. This means that for the bulk of the Frontier countries, information flows being transmitted from the US through mean returns and their volatility are largely orthogonal.

The contribution of lagged own country effects to local market conditional volatility, estimated by Model 3 (Figure B.4 in Appendix B), remains largely unchanged for all of the 21 markets.

4.3 Joint test for no spillovers in mean returns and no spillovers in volatility, or Test for Complete Segmentation of US and Frontier Markets

Here, we investigate the possibility of complete segmentation of Frontier and US markets. This clarifies the significance of US economic shocks and related disturbances for local markets. The analysis is done by comparing the general Model 1 estimated in Section 3 above with a model featuring no impact from US returns. Rejecting the null hypothesis confirms the importance of information flows emanating from US and refutes the hypothesis of complete segmentation. The model under the null is denoted as Model 4 and can be written as:

$$R^K = \theta^K + a^K R_{t-1}^K + u_t^K \tag{13}$$

$$u_t^K \sim N(0, H_t^K)$$

$$H_t^K = b_0 + b_1 H_{t-1}^K + b_2 u_{t-1}^{2\ K} \tag{14}$$

Model 4 estimates are reported in Table A.3 in Appendix A. Estimates of θ^{K} increase for 14 countries. The AR parameter a^{K} on own country lagged returns increases for 5 of these countries, as well as for 3 others. Estimates of the constant parameter in the volatility process b_0 increases for 7 countries, GARCH parameter b_1 increases for 12 countries, and the ARCH parameter b_2 increases for 14 countries.

The LR test statistics test are reported in Table 3, under the column heading 'Model 4'. The null hypothesis is strongly rejected for all Frontier countries. This confirms the importance of information flows from US and thus the impact of economic conditions there on Frontier country financial markets. This finding is in line with literature suggesting the importance of inter-market linkages. Inter-dependencies among countries is a factor of great importance for portfolio diversification. It is also important for determining the origin of economic crises and for designing relevant macroeconomic policies.

The various panels of Figure B.5 in Appendix B plot one-period lagged own market components of Frontier country returns estimated by Models 1 and 4. The contribution of own-country returns estimated from Model 4 is stronger only for Kazakhstan. On the other hand, for Argentina and Romania, own-country returns contribution surprisingly declines once US effects are shut down. For all other countries, own country lagged returns components estimated by Models 1 and 4 are similar, indicating orthogonality of US and lagged own-country effects on mean returns.

The contribution of local market conditional volatility, estimated by Model 4 remains largely unchanged for 19 of the 21 markets (Figure B.6 in Appendix B). For Croatia and Romania, complete segmentation results in increased estimated impact of local markets volatility factors.

4.4 Joint test for no impact of own market lagged information, or
Test for 'Complete Integration' of US and Frontier Markets

Here we investigate whether local economic shocks remain significant, once disturbances from US are taken into account. The analysis is done by comparing the general Model 1 with a model featuring no impact of own market variables on either the mean or volatility of returns. Rejecting the null hypothesis confirms the importance of own market information flows and refutes the possibility of 'complete market integration'.[5] The model under the null is denoted as Model 5 and can be written as:

$$R_{\mathrm{t}}^{\mathrm{K}} = \theta^{\mathrm{K}} + a_{\mathrm{t}}^{\mathrm{US}} R_{\mathrm{t}}^{\mathrm{US}} + u_{\mathrm{t}}^{\mathrm{K}} \tag{15}$$

$$u_{\mathrm{t}}^{\mathrm{K}} \sim N(0, H_{\mathrm{t}}^{\mathrm{K}})$$

$$H_{\mathrm{t}}^{\mathrm{K}} = b_0 + b_3 H_{\mathrm{t}}^{\mathrm{US}} + b_4 H_{\mathrm{t\text{-}1}}^{\mathrm{US}} \tag{16}$$

$$a_{\mathrm{t}}^{\mathrm{US}} = c(1-\rho) + \rho a_{\mathrm{t\text{-}1}}^{\mathrm{US}} + n_{\mathrm{t}}^{\mathrm{US}} \tag{17}$$

$$n_t^{\mathrm{US}} \sim N(0, Q^{\mathrm{US}})$$

$$E(u_{\mathrm{t}}^{K} n_{\mathrm{t}}^{\mathrm{US}}) = 0$$

Estimates of Model 5 are reported in Table A.4 in Appendix A. Relative to Model 1, the unconditional expectation of US return spillovers c increases for 5 countries. The AR parameter estimate ρ increases for 11 countries. Estimates of the standard deviation $\sqrt{Q^{\mathrm{US}}}$ of the signal shock $n_{\mathrm{t}}^{\mathrm{US}}$ driving the spillover process $a_{\mathrm{t}}^{\mathrm{US}}$ increase for all countries except Romania.

LR test statistics are reported in Table 3, under the column heading 'Model 5'. The null hypothesis is overwhelmingly rejected for all Frontier countries. This confirms the importance

[5]Here, we are using the phrase 'complete market integration' in a different sense than commonly used in the literature, as in Bekaert and Harvey (1995). In the latter studies, complete market integration would be tantamount to replacing $R_{\mathrm{t}}^{\mathrm{US}}$ on the rhs of the first equation in the main text immediately following this footnote with the returns on a world market portfolio consisting of stocks traded in the US and all the Frontier countries.

of local market feedback effects. The LR test results here, in conjunction with those reported in subsection 4.3 above, clarify that Frontier markets are neither completely integrated nor completely segmented from the US. Such a finding is relevant for investment decisions because less than fully integrated markets lower the importance of financial markets as a path for transmitting economic shocks across countries.

The various panels of Figure B.7 in Appendix B plot the US components of Frontier country returns estimated by Models 1 and 5. The contribution of US returns estimated from Model 5 is now stronger for 3 countries, namely, Oman, Qatar, and UAE. On the other hand, for Pakistan, US returns contribution declines once own-country lagged effects are shut down. For all other countries, US contributions estimated from Models 1 and 5 are similar. This follows from the evidence on orthogonality of US and lagged own-country effects on mean returns of Frontier countries.

Shutting down local market effects results in significantly increased estimated impact of US current and one-period lagged volatility for all Frontier countries (Figure B.8 in Appendix B). US volatility effects seem to be amplified in the absence of local market effects.

4.5. Summary of hypotheses tests

In the preceding sections, we investigated several statistical hypotheses of interest. First, we tested for no time-variability of US return spillovers to Frontier markets. Next, we tested for no spillovers in US volatility. This was followed by a test for complete market segmentation and, subsequently, for complete market integration. The statistical inferences from our tests for these hypotheses are summarized in Table 4.

Statistically significant time-variability of US return spillovers are found for 13 of the 21 frontier markets. However, the presence of time-variability amplifies the quantitative impact of US returns for only 5 countries as compared to a model with constant spillovers. But, it does not affect the quantitative impact of US returns for 13 countries. Introduction of constant return spillovers does not affect the estimated contribution of US market volatility in accounting for Frontier market returns volatility for 13 markets, but increases it for the remaining.

Exploring the assumption of no US volatility effects indicates statistically significant volatility spillovers to 14 Frontier markets. It follows that these countries are exposed to economic unrest in the US, while the remaining 7 are not as vulnerable. Shutting down volatility spillovers does not affect the contribution of US returns in accounting for Frontier country mean returns for 15 markets, but increases it for 4. The contribution of local components to Frontier market volatility remains largely unaffected.

Our results strongly reject the polar null hypotheses of complete market segmentation or complete market integration. This indicates that Frontier markets are characterized as neither completely segmented from US nor completely integrated with it. Shutting down US return and volatility spillover effects completely does not change the contribution of one-period lagged local returns in accounting for Frontier country mean returns for 18 countries, and increases it for only 1 country. The contribution of local volatility effects remains largely the same for 19 countries but increases for 2. In testing for complete market integration, when all the effects from own-country returns are shut off, the contribution of US market returns in the estimated Frontier country mean returns remains largely unaffected for 17 of the 21 countries, but increases slightly for 3 countries. The absence of local market effects, however, results in a quantitatively important increase in the weight of US current and one-period lagged volatility in explaining the conditional volatilities of all markets. These results from the polar null hypotheses of complete market segmentation or complete market integration indicate possible orthogonality in the contributions of current US and lagged own-country returns on Frontier countries mean returns.

We also conducted separate hypotheses tests of homoskedasticity and of time-invariance of all estimated parameters in Model 1 (not reported for brevity). Both hypotheses are overwhelmingly rejected for all Frontier countries.

5. DISCUSSION

The finding of statistically significant financial market integration between the US and Frontier countries implies influence of US market returns and volatility on the mean and volatility of returns in Frontier countries. The greater the degree of integration, the greater the spillovers from US to Frontier markets, both in returns and volatility. Greater integration implies less country specific risk. However, this makes these countries vulnerable to recessions in the US.

Cross-border transmission of US economic shocks depends largely on the depth of economic and financial linkages between the US and Frontier countries. Establishing deeper and more liquid capital markets with diverse institutional investors may improve the ability of local economies to withstand shocks from abroad. Literature suggests several major ways of fostering robust financial markets (Kose 2003, Calvo, Izquierdo, and Mejia 2008, Reinhart 2009). Sound securities market infrastructure and institutions such as securities exchange and clearing systems, as well as implementation of regulatory reforms and international accounting standards, are also likely to be beneficial for developing healthy capital markets.

Structural features and country-specific fragility are also key factors affecting market vulnerability to shocks from abroad. For example, macroeconomic or financial weakness may increase susceptibility to shocks. Countries with both strong international financial and economic linkages, and high vulnerabilities are potentially more susceptible to spillovers. Domestic macroeconomic policies such as fiscal, monetary and exchange rate policies can additionally influence the impact of transmitted shocks. Higher current account and fiscal imbalances do little to insulate economies from transmission of turbulence. However, they may help dampen the impact on real economy. Last but not least, timely executed prudent economic policies may soften the impact of, and partly neutralize the effect of, US economic shocks.

6. CONCLUSIONS

In this study, we investigate whether financial stock index returns from the US have spillover effects on the stock index returns in 21 Frontier countries, using data from December 1st, 2005 through January 15th, 2010. We investigate spillovers from the US on both the mean and time-varying volatility of Frontier country returns. We entertain the possibility of time-variation in spillover effects in mean returns by considering a time-varying parameter (TVP) model. Spillover effects in volatility are modeled by augmenting a standard GARCH(1,1) model with volatility effects stemming from current period and one-period lagged US conditional volatility.

The model can be cast into a state space form. However, it is not time-invariant as the 'coefficient' multiplying the state variable (the TVP parameter) is current period US returns. The model is estimated by Kalman Filter. Several restricted versions of the general model are also estimated. Statistical tests on constancy of the mean spillovers parameter (i.e. a test for parameter constancy), tests for no spillover effects in mean returns and/or volatility, as well as other hypotheses of interest are performed. Relative contributions from US and own-country lagged effects on both mean returns and volatility of Frontier countries are explored.

Our analysis suggests that time-varying spillovers are statistically significant for a majority of the Frontier countries studied here. This implies time-varying exposure of these countries to US economic shocks. The presence of time-variability does not, however, affect the quantitative impact of US returns for most of these countries when compared with a model with constant spillover parameter. Most Frontier markets are found to display volatility that is greater both in magnitude and variability relative to the US. This is expected as developing markets are considered more risky and hence are expected to exhibit greater uncertainty. Our TVP model detects statistically significant volatility spillovers as well as quantitatively important impact of US conditional volatility for most of the Frontier markets. This indicates that Frontier countries are vulnerable to economic unrest in the US. However, we find the weight of US volatility factors in the conditional volatilities of most of the Frontier markets unaffected by forcing return spillovers to be constant.

Our results strongly reject the null hypotheses of complete market segmentation and complete market integration. This indicates that Frontier markets are characterized as neither completely segmented from the US nor completely integrated with it. In testing for complete market integration, when all the effects from own-country returns are shut off, the contribution of US market returns in the mean returns of most markets remains largely unaffected. However, the share of US current and one-period lagged volatility in the conditional volatilities of all markets increases. The results from the polar null hypotheses of complete market segmentation or complete market integration indicate possible orthogonality in the contribution of current US and lagged own-country returns on Frontier countries mean returns.

The hypotheses of homoskedasticity and time-invariance of all estimated parameters are both overwhelmingly rejected.

One line of extension of research presented in this article may be an explicit modeling of nonlinearities in the conditional mean and/or volatility relationship between US and Frontier market returns. For instance, there is literature suggesting increased spillovers during times of increased volatility (Ramchand and Susmel 1998). Also, the GARCH model could be modified to incorporate the leverage hypothesis. A second line of extension could be a multivariate investigation of time-varying spillovers and volatility. See, for example, Creal, Koopman, and Lucas (2010), for a recent illustration of this approach using the Student's t distribution that accounts for fat tails as well. Information contained in trading volume may also be useful in characterizing spillover effects. Geographic integration among groups of Frontier countries, such as the Middle Eastern countries, may be worth understanding (Baele 2005). An arguably more fruitful extension could be a theoretical exploration of the empirical relationships suggested by this study.

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Table 1. Parameter Estimates - US

The most general Model 1 given by: $R_t^{US} = \theta^{US} + a_t^{US} R_{t-1}^{US} + u_t^{US}$, $u_t^{US} \sim iidN(0, H_t^{US})$, $H_t^{US} = b_0 + b_1 H_{t-1}^{US} + b_2 u_{t-1}^{2\ US}$, $a_t^{US} = c(1-\rho) + \rho a_{t-1}^{US} + n_t^{US}$, $n_t^{US} \sim N(0, Q^{US})$. Model 2 is obtained by imposing $a_t^{US} = constant$ on Model 1. The sample spans from Nov. 15th 2005 to Jan 15th 2010. Standard errors are reported in parentheses below the parameter estimates. LR gives the value of the likelihood ratio test statistic.

Parameters	Model 1	Model 2
θ	12.044	12.041
	(7.069)	(6.946)
c	-0.098	-0.097
	(0.033)	(0.0329)
ρ	0.948	
	(0.23)	
$\sqrt{Q^{US}}$	0.000	
	(0.000)	
b_0	884.449	883.868
	(264.64)	(264.26)
b_1	0.911	0.911
	(0.012)	(0.012)
b_2	0.08	0.08
	(0.012)	(0.012)
$LogL$	-7587.715	-7587.775
$LR(a_t^{US} = const.)$		0.118

Note:

1. $LR(a_t^{US} = const.)$ is a test for no time-variation in the AR(1) parameter. The 5% χ_2^2 p-value equals 5.99.

Table 2. Parameter Estimates for Model 1

Model 1 for Frontier countries:

$$R^{K}_{t} = \theta^{K} + a^{US}_{t} R^{US}_{t} + a^{K} R^{K}_{t-1} + u^{K}_{t},\ u^{K}_{t} \sim N(0, H^{K}_{t}),\ H^{K}_{t} = b_0 + b_1 H^{K}_{t-1} + b_2 u^{2\ K}_{t-1} + b_3 H^{US}_{t} + b_4 H^{US}_{t-1}$$

$$a^{US}_{t} = c(1-\rho) + \rho a^{US}_{t-1} + n^{US}_{t},\ n^{US}_{t} \sim N(0, Q^{US}),\ E(u^{K}_{t} n^{US}_{t}) = 0.$$

Standard errors are reported in parentheses below the parameter estimates.

Country	θ^{K}	c	ρ	$\sqrt{Q^{US}}$	a^{K}	b_0	b_1	b_2	b_3	b_4
Argentina	10.504	0.994	0.672	0.216	0.109	0.684	0.809	0.144	0.113	0.000
	(10.501)	(0.047)	(0.129)	(0.069)	(0.03)	(0.000)	(0.042)	(0.035)	(0.054)	(0.000)
Bahrain	-6.01	0.001	-0.965	0.000	0.09	0.649	0.551	0.167	0.444	0.000
	(7.814)	(0.018)	(0.000)	(0.000)	(0.044)	(0.000)	(0.085)	(0.033)	(0.106)	(0.000)
Bulgaria	22.168	0.075	-0.931	0.000	-0.067	5.000	0.862	0.101	0.102	0.000
	(10.893)	(0.045)	(0.000)	(0.000)	(0.034)	(0.002)	(0.024)	(0.019)	(0.033)	(0.000)
Croatia	14.488	0.144	0.305	0.507	0.125	1.495	0.967	0.019	0.008	0.000
	(11.481)	(0.035)	(0.216)	(0.087)	(0.038)	(7.071)	(0.007)	(0.005)	(0.004)	(0.000)
Estonia	-1.381	0.125	0.01	0.419	0.124	0.563	0.894	0.07	0.052	0.000
	(0.000)	(0.041)	(0.206)	(0.068)	(0.037)	(0.000)	(0.019)	(0.016)	(0.018)	(0.000)
Jordan	-5.613	-0.022	-0.782	0.000	0.043	0.716	0.934	0.063	0.008	0.000
	(7.836)	(0.028)	(0.000)	(0.000)	(0.032)	(0.000)	(0.011)	(0.011)	(0.003)	(0.000)
Kazakhstan	30.973	0.256	0.073	0.36	0.004	0.745	0.943	0.046	0.018	0.000
	(16.627)	(0.059)	(0.411)	(0.067)	(0.036)	(7.122)	(0.011)	(0.012)	(0.011)	(0.000)
Kenya	3.673	0.019	0.218	0.381	0.348	0.844	0.932	0.061	0.002	0.000
	(8.203)	(0.027)	(0.158)	(0.059)	(0.037)	(0.000)	(0.008)	(0.011)	(0.003)	(0.001)
Kuwait	10.067	0.001	-0.92	0.000	0.075	0.816	0.936	0.054	0.021	0.000
	(9.904)	(0.034)	(0.000)	(0.000)	(0.035)	(3.674)	(0.009)	(0.009)	(0.007)	(0.000)
Lebanon	5.739	-0.02	0.069	0.281	0.131	0.655	0.736	0.25	0.139	0.000
	(26.155)	(0.035)	(1.287)	(0.12)	(0.041)	(2.072)	(0.04)	(0.057)	(0.032)	(0.000)
Mauritius	29.289	0.061	0.089	0.634	0.236	0.645	0.574	0.211	0.245	0.000
	(8.676)	(0.032)	(0.197)	(0.063)	(0.045)	(3.218)	(0.076)	(0.066)	(0.051)	(0.000)
Nigeria	9.585	-0.011	-0.64	0.243	0.443	0.764	0.899	0.088	0.000	0.008
	(7.673)	(0.021)	(0.121)	(0.058)	(0.032)	(0.000)	(0.016)	(0.019)	(0.001)	(0.003)
Oman	9.104	0.007	-0.974	0.000	0.106	0.66	0.844	0.111	0.072	0.000
	(8.843)	(0.031)	(0.072)	(0.000)	(0.037)	(0.000)	(0.022)	(0.019)	(0.018)	(0.002)
Pakistan	1.071	0.023	0.813	0.155	0.105	0.572	0.895	0.107	0.000	0.004
	(3.886)	(0.027)	(0.196)	(0.113)	(0.034)	(1.698)	(0.021)	(0.029)	(0.001)	(0.001)
Qatar	-9.35	-0.011	-0.958	0.000	0.091	0.838	0.877	0.093	0.096	0.000
	(12.367)	(0.042)	(0.395)	(0.000)	(0.036)	(0.000)	(0.019)	(0.017)	(0.022)	(0.000)
Romania	13.728	0.295	0.165	0.452	0.077	2.17	0.976	0.009	0.04	0.000
	(15.421)	(0.06)	(1.001)	(0.083)	(0.037)	(14.336)	(0.005)	(0.003)	(0.013)	(0.000)
S.Arabia	-0.456	0.129	-0.924	0.000	0.04	0.615	0.936	0.063	0.017	0.000
	(0.000)	(0.041)	(0.335)	(0.000)	(0.034)	(0.000)	(0.006)	(0.008)	(0.007)	(0.000)
Slovenia	19.693	0.159	0.495	0.285	0.179	1.118	0.941	0.059	0.000	0.000
	(9.492)	(0.036)	(0.347)	(0.112)	(0.035)	(0.000)	(0.011)	(0.014)	(0.000)	(0.000)
Sri Lanka	-9.719	0.064	-0.319	0.491	0.247	0.778	0.945	0.046	0.001	0.000
	(7.006)	(0.023)	(0.113)	(0.051)	(0.039)	(0.000)	(0.007)	(0.008)	(0.006)	(0.007)
Tunisia	17.188	0.059	0.114	0.395	0.088	0.666	0.923	0.062	0.007	0.001
	(7.144)	(0.023)	(0.183)	(0.065)	(0.038)	(3.827)	(0.023)	(0.023)	(0.016)	(0.016)
UAE	-0.563	-0.002	0.502	0.001	0.131	0.483	0.912	0.078	0.056	0.000
	(1.915)	(0.047)	(0.975)	(0.04)	(0.035)	(1.262)	(0.014)	(0.013)	(0.019)	(0.000)

Table 3. Hypothesis Tests

The table presents values of the test statistics derived from LR tests performed to examine restricted versions of Model 1 for Frontier market returns. The LR-statistic is approximately chi-squared. It has 2 degrees of freedom for Models 2 & 3, 5 for Model 4, and 3 for Model 5. All tests are performed at the 5% significance level. Respective critical values are as follows: 5.99 with 2 d.f.; 7.82 with 3 d.f.; 9.49 with 4 d.f.; and 11.07 with 5 d.f.

	Model under H_0			
Country	Model 2	Model 3	Model 4	Model 5
Argentina	9.572	5.09	343.551	131.576
Bahrain	0.021	152.778	475.823	26.8611
Bulgaria	12.697	58.501	60.97	51.632
Croatia	35.169	4.647	23.116	226.451
Estonia	11.073	13.343	38.209	128.63
Jordan	0.006	3.862	13.702	476.146
Kazakhstan	9.816	4.045	19.216	556.142
Kenya	16.128	3.234	17.901	351.252
Kuwait	0.001	18.421	18.568	440.989
Lebanon	2.928	51.504	76.22	467.694
Mauritius	18.814	27.678	60.366	106.388
Nigeria	13.227	21.108	42.086	374.232
Oman	0.007	5.515	19.402	205.541
Pakistan	3.226	16.877	72.413	315.625
Qatar	0.007	61.008	71.592	162.438
Romania	45.93	54.212	124.653	35.837
S.Arabia	0.007	8.895	30.472	839.083
Slovenia	6.371	52.75	76.391	114.68
Sri Lanka	52.489	0.997	77.202	350.446
Tunisia	36.571	31.739	52.207	226.96
UAE	0.000	22.839	23.083	494.803

Table 4. Summary of Hypothesis Tests

The table presents a summary of the statistical inferences reached on hypotheses tests reported in Table 3. The model under the null hypothesis in each of the columns 2-5 below corresponds to that in the corresponding columns of Table 3. The restriction being tested under each null hypothesis is noted in the header for columns 2-5. In all cases, the alternative hypothesis is Model 1.

Country	Presence of time-variable return spillovers	Presence of volatility spillovers	Complete Segmentation	Complete Integration
Argentina	yes	no	no	no
Bahrain	no	yes	no	no
Bulgaria	yes	yes	no	no
Croatia	yes	no	no	no
Estonia	yes	yes	no	no
Jordan	no	no	no	no
Kazakhstan	yes	no	no	no
Kenya	yes	no	no	no
Kuwait	no	yes	no	no
Lebanon	no	yes	no	no
Mauritius	yes	yes	no	no
Nigeria	yes	yes	no	no
Oman	no	no	no	no
Pakistan	yes	yes	no	no
Qatar	no	yes	no	no
Romania	yes	yes	no	no
S.Arabia	no	yes	no	no
Slovenia	yes	yes	no	no
Sri Lanka	yes	no	no	no
Tunisia	yes	yes	no	no
UAE	no	yes	no	no

Figure 1
Estimated Returns from Model 1

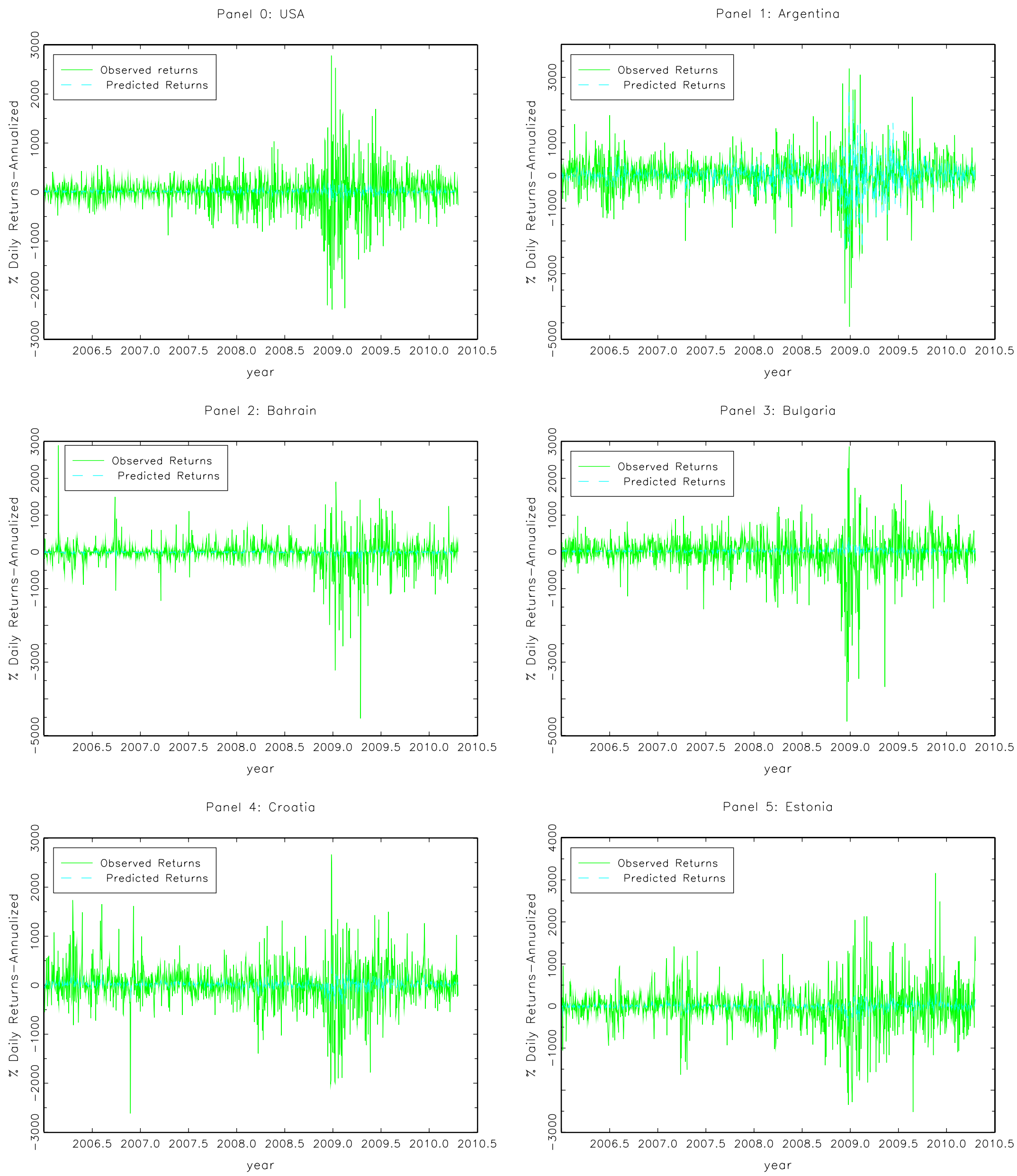


Figure 2
Plots of Time-Variable Volatility

Estimates of volatility for Frontier markets are derived from Model 1 and from best-fitting Model 2 for the US.

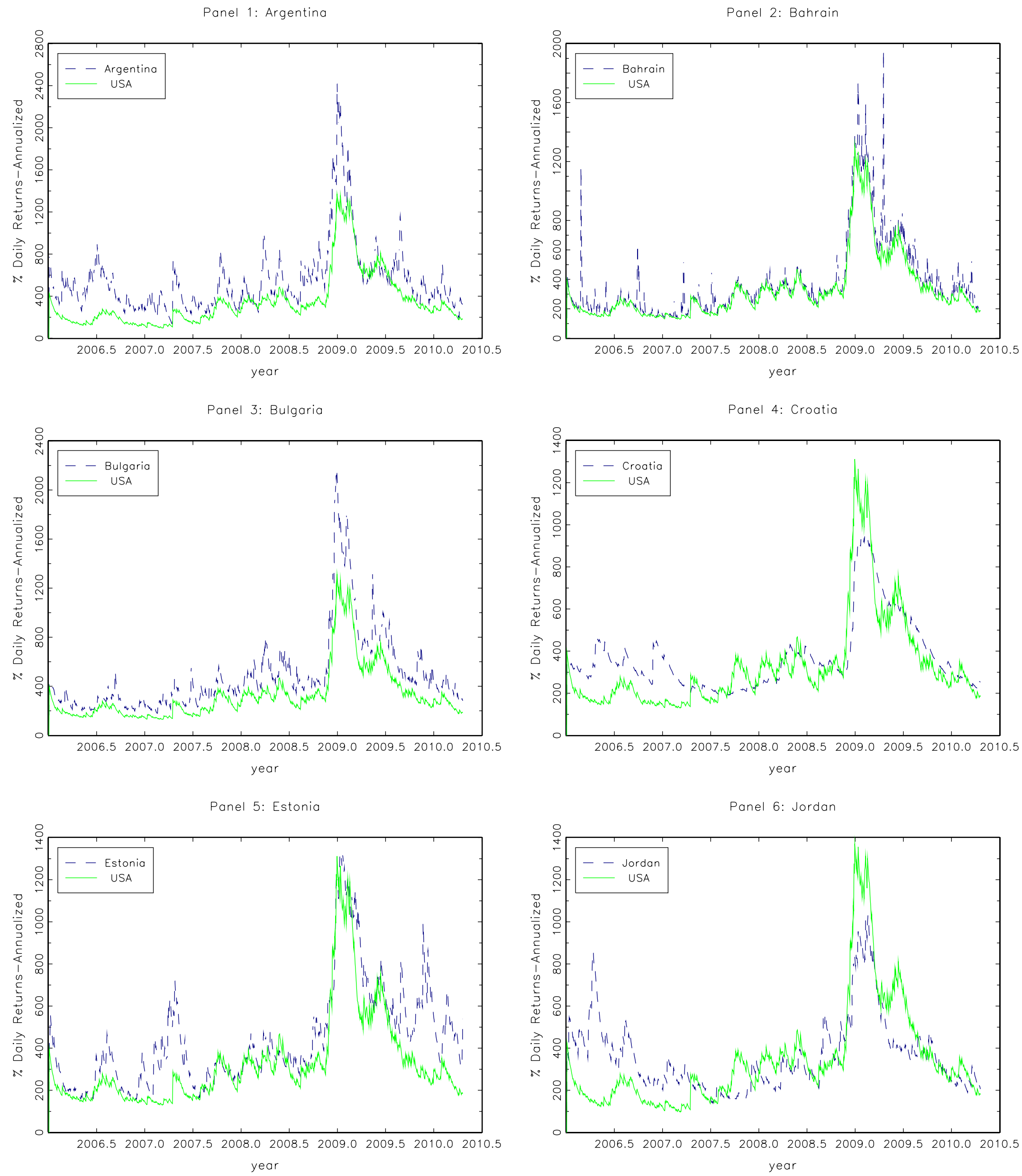


Figure 3
Time-Variable Return Spillover Parameter Estimated by Model 1 for Frontier Countries

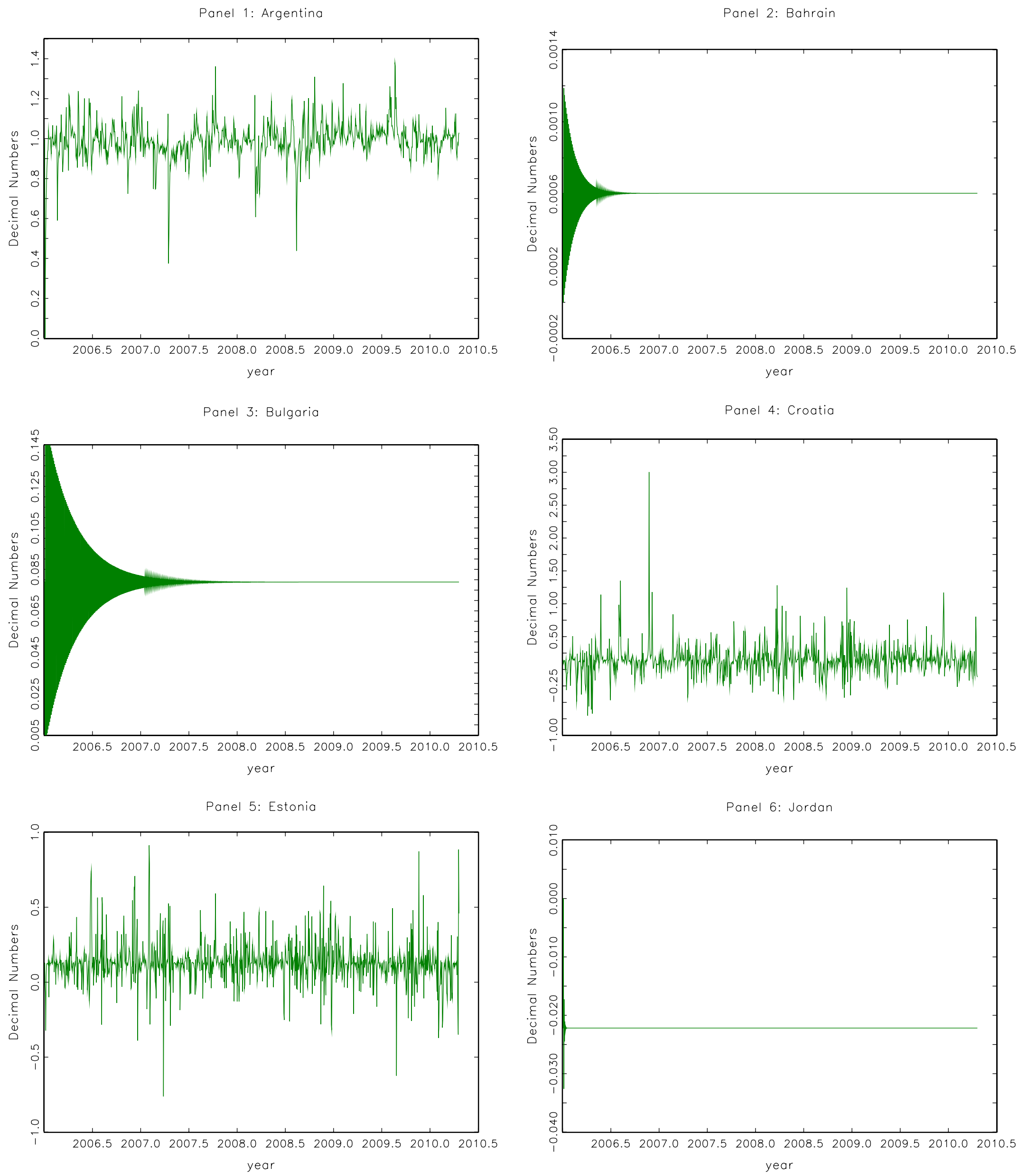


Figure 4
US and Own-Country Lagged Components of Returns Estimated by Model 1

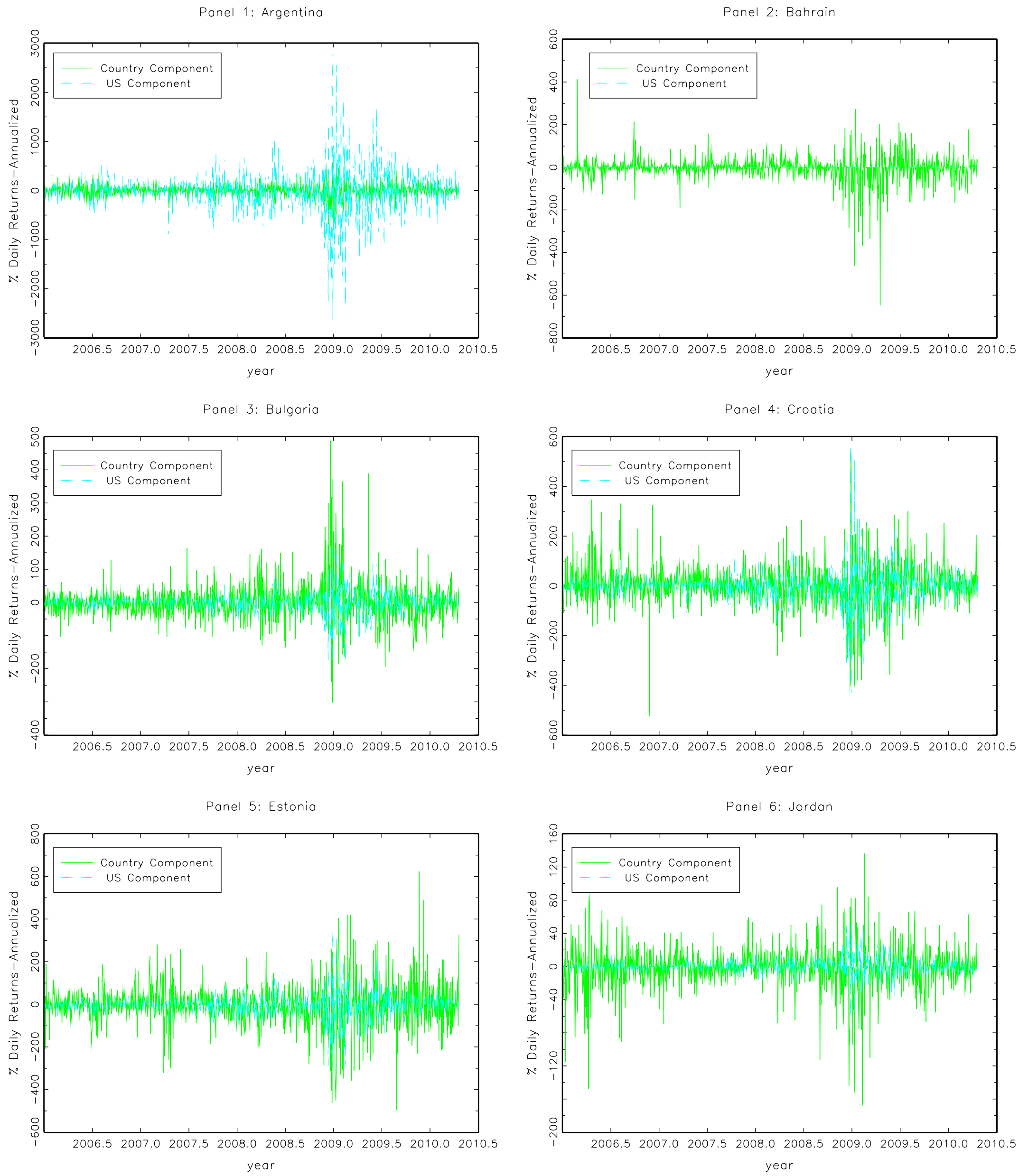
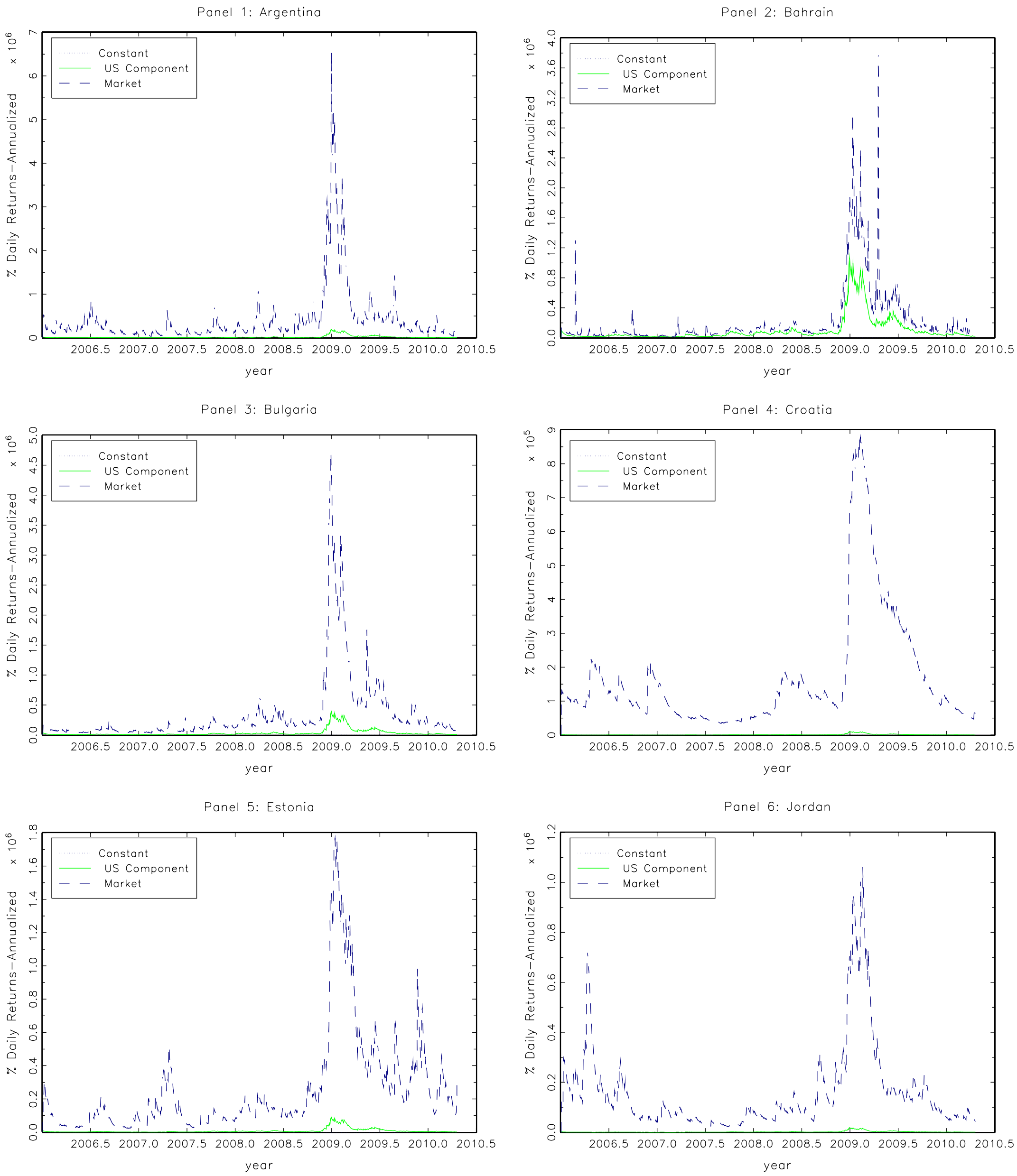


Figure 5
Conditional Volatility Components from Model 1



Appendix A
Parameter Estimates of Models 2-5 in Tables A.1-A.4

This Appendix contains parameter estimates of each of Models 2-5 for Frontier countries discussed in Section 4 in the text.

Table A.1 Parameter Estimates for Model 2

$$R^{\mathrm{K}} = \theta^{\mathrm{K}} + a^{\mathrm{US}} R_{\mathrm{t}}^{\mathrm{US}} + a^{\mathrm{K}} R_{\mathrm{t-1}}^{\mathrm{K}} + u_{\mathrm{t}}^{\mathrm{K}},\ u_{\mathrm{t}}^{\mathrm{K}} \sim N(0, H_{\mathrm{t}}^{\mathrm{K}}),\ H_{\mathrm{t}}^{\mathrm{K}} = b_0 + b_1 H_{\mathrm{t-1}}^{\mathrm{K}} + b_2 u_{\mathrm{t-1}}^{2\ \mathrm{K}} + b_3 H_{\mathrm{t}}^{\mathrm{US}} + b_4 H_{\mathrm{t-1}}^{\mathrm{US}}$$

Standard errors are reported in parentheses below the parameter estimates.

Country	θ^{k}	a^{US}	a^{K}	b_0	b_1	b_2	b_3	b_4
Argentina	5.122	0.998	0.11	1.736	0.812	0.184	0.077	0.000
	(25.4)	(0.008)	(0.028)	(17.353)	(0.035)	(0.036)	(0.034)	(0.000)
Bahrain	-5.982	-0.006	0.091	0.632	0.552	0.167	0.444	0.000
	(7.642)	(0.036)	(0.045)	(0.000)	(0.083)	(0.033)	(0.103)	(0.000)
Bulgaria	22.325	0.077	-0.067	0.583	0.806	0.1	0.229	0.000
	(10.917)	(0.045)	(0.035)	(2.636)	(0.047)	(0.022)	(0.087)	(0.000)
Croatia	27.781	0.155	0.135	1.421	0.945	0.052	0.012	0.000
	(11.059)	(0.037)	(0.033)	(13.098)	(0.011)	(0.012)	(0.006)	(0.000)
Estonia	-2.055	0.112	0.124	0.555	0.858	0.125	0.067	0.000
	(10.633)	(0.04)	(0.033)	(1.663)	(0.021)	(0.019)	(0.023)	(0.000)
Jordan	-5.758	-0.022	0.043	0.714	0.934	0.063	0.008	0.000
	(10.341)	(0.028)	(0.032)	(0.000)	(0.011)	(0.012)	(0.003)	(0.000)
Kazakhstan	36.639	0.246	0.002	0.667	0.921	0.076	0.036	0.000
	(16.929)	(0.059)	(0.033)	(2.002)	(0.014)	(0.015)	(0.02)	(0.000)
Kenya	4.355	0.027	0.313	0.594	0.91	0.094	0.007	0.001
	(7.488)	(0.027)	(0.032)	(1.52)	(0.008)	(0.011)	(0.012)	(0.011)
Kuwait	10.085	0.000	0.075	0.81	0.936	0.054	0.021	0.001
	(10.199)	(0.034)	(0.035)	(17.477)	(0.009)	(0.009)	(0.051)	(0.051)
Lebanon	4.301	-0.025	0.134	0.803	0.733	0.3	0.113	0.000
	(11.166)	(0.034)	(0.038)	(0.000)	(0.03)	(0.045)	(0.024)	(0.000)
Mauritius	27.388	0.071	0.204	0.573	0.275	0.714	0.456	0.000
	(7.45)	(0.031)	(0.04)	(0.000)	(0.042)	(0.094)	(0.015)	(0.000)
Nigeria	6.074	-0.011	0.442	0.617	0.873	0.129	0.000	0.011
	(6.095)	(0.021)	(0.031)	(0.000)	(0.017)	(0.021)	(0.000)	(0.004)
Oman	9.101	0.008	0.106	0.646	0.844	0.112	0.072	0.000
	(8.222)	(0.031)	(0.036)	(0.000)	(0.022)	(0.019)	(0.018)	(0.002)
Pakistan	8.329	0.021	0.106	1.177	0.873	0.142	0.000	0.007
	(12.787)	(0.023)	(0.034)	(3.21)	(0.016)	(0.023)	(0.000)	(0.003)
Qatar	-9.394	-0.011	0.091	0.821	0.877	0.093	0.096	0.000
	(11.611)	(0.042)	(0.036)	(2.846)	(0.018)	(0.017)	(0.022)	(0.000)
Romania	16.395	0.344	0.042	2.261	0.968	0.023	0.031	0.000
	(15.722)	(0.059)	(0.031)	(0.000)	(0.006)	(0.005)	(0.011)	(0.000)
S.Arabia	-1.576	0.13	0.04	0.957	0.937	0.064	0.012	0.000
	(2.838)	(0.041)	(0.034)	(0.000)	(0.000)	(0.004)	(0.005)	(0.000)
Slovenia	20.797	0.136	0.189	0.526	0.854	0.111	0.000	0.032
	(9.296)	(0.036)	(0.033)	(3.167)	(0.046)	(0.033)	(0.008)	(0.018)
Sri Lanka	-10.784	0.063	0.237	0.946	0.801	0.183	0.061	0.000
	(9.021)	(0.026)	(0.036)	(3.426)	(0.048)	(0.043)	(0.026)	(0.002)
Tunisia	14.425	0.051	0.092	0.643	0.856	0.158	0.002	0.007
	(7.108)	(0.022)	(0.035)	(0.000)	(0.029)	(0.036)	(0.000)	(0.000)
UAE	-2.5	0.000	0.13	0.668	0.915	0.078	0.042	0.000
	(0.000)	(0.047)	(0.034)	(0.000)	(0.012)	(0.012)	(0.015)	(0.000)

Table A.2 Parameter Estimates for Model 3

$$R^{\mathrm{K}}_{\mathrm{t}} = \theta^{\mathrm{K}} + a^{\mathrm{US}}_{\mathrm{t}} R^{\mathrm{US}}_{\mathrm{t}} + a^{\mathrm{K}} R^{\mathrm{K}}_{\mathrm{t-1}} + u^{\mathrm{K}}_{\mathrm{t}}\ ,\ u^{\mathrm{K}}_{\mathrm{t}} \sim N(0, H^{\mathrm{K}}_{\mathrm{t}}),\ H^{\mathrm{K}}_{\mathrm{t}} = b_0 + b_1 H^{\mathrm{K}}_{\mathrm{t-1}} + b_2 u^{2\ \mathrm{K}}_{\mathrm{t-1}},\ a^{\mathrm{K}}_{\mathrm{t}} = c(1-\rho) + \rho a^{\mathrm{US}}_{\mathrm{t-1}} + n^{\mathrm{US}}_{\mathrm{t}},$$

$$n^{\mathrm{US}}_{t} \sim N(0, Q^{\mathrm{US}}),\ E(u^{K}_{\mathrm{t}} n^{\mathrm{US}}_{\mathrm{t}}) = 0$$

Standard errors are reported in parentheses below the parameter estimates.

Country	θ^{k}	c	ρ	$\sqrt{Q^{\mathrm{US}}}$	a^{K}	b_0	b_1	b_2
Argentina	0.241	0.966	0.661	0.252	0.101	0.501	0.931	0.062
	(5.22)	(0.047)	(0.125)	(0.058)	(0.031)	(3.006)	(0.016)	(0.018)
Bahrain	-13.236	0.284	0.824	0.433	0.04	0.109	0.749	0.377
	(5.272)	(0.038)	(0.031)	(0.056)	(0.047)	(0.000)	(0.019)	(0.048)
Bulgaria	22.042	0.079	-0.988	0.000	-0.078	0.052	0.919	0.094
	(11.917)	(0.048)	(0.02)	(0.000)	(0.034)	(0.366)	(0.017)	(0.023)
Croatia	14.795	0.153	0.397	0.458	0.126	1.177	0.972	0.022
	(15.71)	(0.035)	(0.183)	(0.097)	(0.037)	(15.331)	(0.005)	(0.006)
Estonia	0.533	0.138	-0.017	0.437	0.12	0.789	0.924	0.071
	(0.000)	(0.04)	(0.186)	(0.071)	(0.036)	(0.000)	(0.012)	(0.016)
Jordan	-5.514	-0.02	-0.802	0.000	0.044	0.556	0.944	0.061
	(15.749)	(0.029)	(0.000)	(0.000)	(0.032)	(5.131)	(0.008)	(0.011)
Kazakhstan	33.111	0.254	0.033	0.358	-0.001	1.198	0.947	0.049
	(17.472)	(0.059)	(0.309)	(0.068)	(0.035)	(0.000)	(0.009)	(0.011)
Kenya	0.236	0.021	0.204	0.388	0.353	0.672	0.934	0.063
	(0.000)	(0.026)	(0.152)	(0.058)	(0.036)	(0.000)	(0.008)	(0.011)
Kuwait	10.957	0.009	0.142	0.000	0.078	0.998	0.948	0.06
	(9.666)	(0.034)	(3.847)	(0.001)	(0.034)	(0.000)	(0.006)	(0.008)
Lebanon	0.208	0.023	0.192	0.542	0.119	0.501	0.935	0.065
	(0.000)	(0.034)	(0.083)	(0.061)	(0.041)	(1.959)	(0.007)	(0.012)
Mauritius	18.781	0.042	0.161	0.793	0.293	0.821	0.987	0.006
	(10.011)	(0.033)	(0.088)	(0.051)	(0.049)	(3.956)	(0.002)	(0.001)
Nigeria	8.784	-0.01	0.424	0.309	0.431	0.441	0.9	0.098
	(8.09)	(0.023)	(0.158)	(0.054)	(0.032)	(0.000)	(0.012)	(0.017)
Oman	12.445	0.025	-0.985	0.000	0.094	0.003	0.91	0.116
	(9.013)	(0.031)	(0.045)	(0.000)	(0.036)	(0.121)	(0.011)	(0.019)
Pakistan	0.296	0.048	-0.222	0.453	0.123	0.861	0.96	0.031
	(2.332)	(0.033)	(0.429)	(0.067)	(0.036)	(4.016)	(0.005)	(0.005)
Qatar	0.369	0.041	0.65	0.179	0.081	0.23	0.971	0.03
	(11.766)	(0.045)	(0.277)	(0.071)	(0.036)	(1.594)	(0.004)	(0.005)
Romania	0.422	0.3	0.543	0.422	0.075	0.473	0.982	0.014
	(0.000)	(0.066)	(0.135)	(0.059)	(0.039)	(0.076)	(0.002)	(0.002)
S.Arabia	0.115	0.14	-0.215	0.001	0.042	1.003	0.942	0.066
	(0.000)	(0.042)	(2.988)	(0.000)	(0.034)	(5.301)	(0.005)	(0.008)
Slovenia	19.753	0.159	0.495	0.285	0.179	1.802	0.941	0.059
	(9.409)	(0.035)	(0.21)	(0.079)	(0.034)	(0.000)	(0.009)	(0.012)
Sri Lanka	-10.107	0.068	-0.32	0.503	0.248	1.154	0.946	0.046
	(6.643)	(0.022)	(0.101)	(0.048)	(0.039)	(0.000)	(0.006)	(0.008)
Tunisia	16.362	0.064	0.102	0.402	0.087	0.418	0.941	0.056
	(6.543)	(0.022)	(0.167)	(0.064)	(0.037)	(0.000)	(0.015)	(0.017)
UAE	1.624	0.027	0.788	0.002	0.129	2.501	0.935	0.079
	(3.514)	(0.049)	(0.000)	(0.041)	(0.034)	(5.335)	(0.007)	(0.011)

Table A.3 Parameter Estimates for Model 4

$R^{\mathrm{K}} = \theta^{\mathrm{K}} + a^{\mathrm{K}} R^{\mathrm{K}}_{\text{t-1}} + u^{\mathrm{K}}_{\mathrm{t}},\ u^{\mathrm{K}}_{\mathrm{t}} \sim N(0, H^{\mathrm{K}}_{\mathrm{t}}),\ H^{\mathrm{K}}_{\mathrm{t}} = b_0 + b_1 H^{\mathrm{K}}_{\text{t-1}} + b_2 u^{2\ \mathrm{K}}_{\text{t-1}}$

Standard errors are reported in parentheses below the parameter estimates.

Country	θ^{k}	a^{K}	b_0	b_1	b_2
Argentina	18.43	-0.004	0.616	0.944	0.061
	(16.224)	(0.032)	(0.000)	(0.007)	(0.009)
Bahrain	8.602	0.102	0.007	0.972	0.033
	(8.798)	(0.034)	(0.000)	(0.003)	(0.004)
Bulgaria	21.468	-0.081	2.852	0.915	0.099
	(11.112)	(0.034)	(0.000)	(0.017)	(0.023)
Croatia	31.151	0.128	2.324	0.945	0.945
	(11.088)	(0.032)	(0.000)	(0.009)	(0.012)
Estonia	-6.304	0.115	0.335	0.898	0.121
	(11.593)	(0.033)	(1.264)	(0.011)	(0.017)
Jordan	0.161	0.045	0.966	0.944	0.061
	(0.000)	(0.033)	(0.000)	(0.008)	(0.011)
Kazakhstan	39.083	-0.018	0.005	0.933	0.074
	(16.794)	(0.033)	(0.000)	(0.009)	(0.012)
Kenya	4.457	0.315	0.009	0.914	0.101
	(6.565)	(0.032)	(0.126)	(0.007)	(0.011)
Kuwait	10.897	0.077	0.416	0.948	0.06
	(10.401)	(0.034)	(1.442)	(0.006)	(0.008)
Lebanon	-0.328	0.148	1.229	0.894	0.149
	(1.692)	(0.035)	(0.000)	(0.008)	(0.016)
Mauritius	28.788	0.162	0.000	0.944	0.069
	(12.472)	(0.033)	(0.000)	(0.005)	(0.008)
Nigeria	12.722	0.432	1.449	0.886	0.135
	(8.256)	(0.031)	(4.651)	(0.015)	(0.022)
Oman	21.477	-0.081	0.581	0.915	0.099
	(11.432)	(0.034)	(0.000)	(0.017)	(0.023)
Pakistan	0.725	0.111	0.001	0.949	0.055
	(1.664)	(0.031)	(0.006)	(0.004)	(0.005)
Qatar	0.225	0.079	0.148	0.962	0.043
	(0.000)	(0.034)	(1.174)	(0.006)	(0.008)
Romania	18.168	0.035	0.000	0.976	0.024
	(18.807)	(0.032)	(0.000)	(0.003)	(0.003)
S.Arabia	3.685	0.037	1.623	0.943	0.066
	(29.195)	(0.034)	(6.081)	(0.005)	(0.008)
Slovenia	24.909	0.174	0.491	0.926	0.085
	(9.664)	(0.032)	(2.264)	(0.009)	(0.013)
Sri Lanka	-5.257	0.23	0.000	0.92	0.102
	(7.427)	(0.034)	(0.000)	(0.01)	(0.016)
Tunisia	15.446	0.089	0.338	0.898	0.124
	(7.107)	(0.034)	(1.751)	(0.024)	(0.035)
UAE	-0.997	0.128	0.564	0.935	0.078
	(1.109)	(0.034)	(0.000)	(0.007)	(0.011)

Table A.4 Parameter Estimates for Model 5

$$R^{\mathrm{K}}_{\mathrm{t}} = \theta^{\mathrm{K}} + a^{\mathrm{US}}_{\mathrm{t}} R^{\mathrm{US}}_{\mathrm{t}} + u^{\mathrm{K}}_{\mathrm{t}},\ u^{\mathrm{K}}_{\mathrm{t}} \sim N(0, H^{\mathrm{K}}_{\mathrm{t}}),\ H^{\mathrm{K}}_{\mathrm{t}} = b_0 + b_3 H^{\mathrm{US}}_{\mathrm{t}} + b_4 H^{\mathrm{US}}_{\mathrm{t\text{-}1}},$$

$$a^{\mathrm{US}}_{\mathrm{t}} = c(1-\rho) + \rho a^{\mathrm{US}}_{\mathrm{t\text{-}1}} + n^{\mathrm{US}}_{t},\ n^{\mathrm{US}}_{t} \sim N(0, Q^{\mathrm{US}}),\ E(u^{K}_{\mathrm{t}} n^{\mathrm{US}}_{\mathrm{t}}) = 0$$

Standard errors are reported in parentheses below the parameter estimates.

Country	θ^{k}	c	ρ	$\sqrt{Q^{\mathrm{US}}}$	b_0	b_3	b_4
Argentina	21.819	1.059	0.379	0.432	0.546	2.252	0.000
	(11.94)	(0.051)	(0.204)	(0.058)	(0.000)	(0.135)	(0.000)
Bahrain	-8.409	0.001	-0.554	0.282	0.561	0.195	1.109
	(7.355)	(0.036)	(0.307)	(0.081)	(0.000)	(0.127)	(0.137)
Bulgaria	30.37	0.14	0.979	0.053	0.528	2.191	0.000
	(0.081)	(0.081)	(0.018)	(0.031)	(0.000)	(0.101)	(0.000)
Croatia	28.498	0.134	0.013	0.744	0.568	1.408	0.000
	(9.983)	(0.041)	(0.12)	(0.051)	(0.000)	(0.086)	(0.000)
Estonia	10.399	0.149	0.143	0.668	0.538	1.732	0.000
	(10.407)	(0.046)	(0.124)	(0.048)	(1.606)	(0.101)	(0.000)
Jordan	-14.362	-0.016	-0.291	0.319	0.567	0.563	1.147
	(9.971)	(0.041)	(0.333)	(0.043)	(1.204)	(0.404)	(0.407)
Kazakhstan	0.107	0.249	-0.057	0.648	0.5	0.381	6.132
	(7.556)	(0.087)	(0.229)	(0.051)	(2.816)	(1.355)	(1.37)
Kenya	17.223	-0.004	0.013	0.633	0.589	0.997	0.224
	(8.353)	(0.038)	(0.205)	(0.047)	(0.000)	(0.000)	(0.066)
Kuwait	-0.053	-0.009	0.227	0.241	0.503	0.972	0.983
	(0.529)	(0.044)	(0.311)	(0.043)	(0.000)	(0.000)	(0.000)
Lebanon	-10.213	-0.007	-0.033	0.995	0.581	0.026	1.865
	(11.621)	(0.048)	(0.133)	(0.081)	(1.51)	(0.069)	(0.147)
Mauritius	-10.213	-0.007	-0.033	0.995	0.581	0.026	1.865
	(11.621)	(0.048)	(0.133)	(0.081)	(1.51)	(0.069)	(0.147)
Nigeria	9.852	-0.012	0.308	0.662	0.607	0.000	1.147
	(8.112)	(0.042)	(0.175)	(0.049)	(0.000)	(0.000)	(0.066)
Oman	0.214	-0.011	-0.304	0.247	0.501	0.058	1.262
	(2.557)	(0.036)	(0.574)	(0.068)	(2.063)	(0.065)	(0.088)
Pakistan	21.018	0.098	-0.208	0.643	0.598	2.124	0.001
	(11.81)	(0.052)	(0.185)	(0.046)	(0.000)	(0.123)	(0.000)
Qatar	-16.963	-0.044	0.163	0.354	0.56	2.557	0.000
	(12.343)	(0.051)	(0.431)	(0.047)	(0.409)	(0.121)	(0.000)
Romania	25.161	0.289	0.621	0.323	0.535	3.33	0.513
	(15.104)	(0.063)	(0.153)	(0.067)	(1.168)	(0.866)	(0.831)
S.Arabia	-37.559	0.027	0.114	0.361	0.601	4.835	0.000
	(16.571)	(0.069)	(0.53)	(0.042)	(3.89)	(0.219)	(0.000)
Slovenia	41.454	0.079	-0.039	0.57	0.578	1.306	0.000
	(8.691)	(0.038)	(0.169)	(0.065)	(5.288)	(0.085)	(0.000)
Sri Lanka	0.256	0.034	0.135	0.691	0.501	0.226	0.848
	(1.865)	(0.035)	(0.13)	(0.063)	(0.000)	(0.361)	(0.343)
Tunisia	27.861	0.022	-0.142	0.578	0.66	0.344	0.505
	(7.172)	(0.031)	(0.162)	(0.051)	(0.000)	(0.311)	(0.307)
UAE	-19.252	0.016	-0.057	0.271	0.553	4.343	0.000
	(15.134)	(0.065)	(0.495)	(0.041)	(0.000)	(0.198)	(0.000)

Appendix B
Plots from Models 2-5 in Figures B.1-B.8

This Appendix contains figures from Model 1 and each of Models 2-5 for Frontier countries discussed in Section 4 in the text. The figures provide a comparison of own-country lagged effects versus the effects from contemporaneous and lagged US shocks on both the mean and volatility of Frontier country returns.

Figure B.1
US Components of Frontier Country Returns Estimated by Model 1 and Model 2

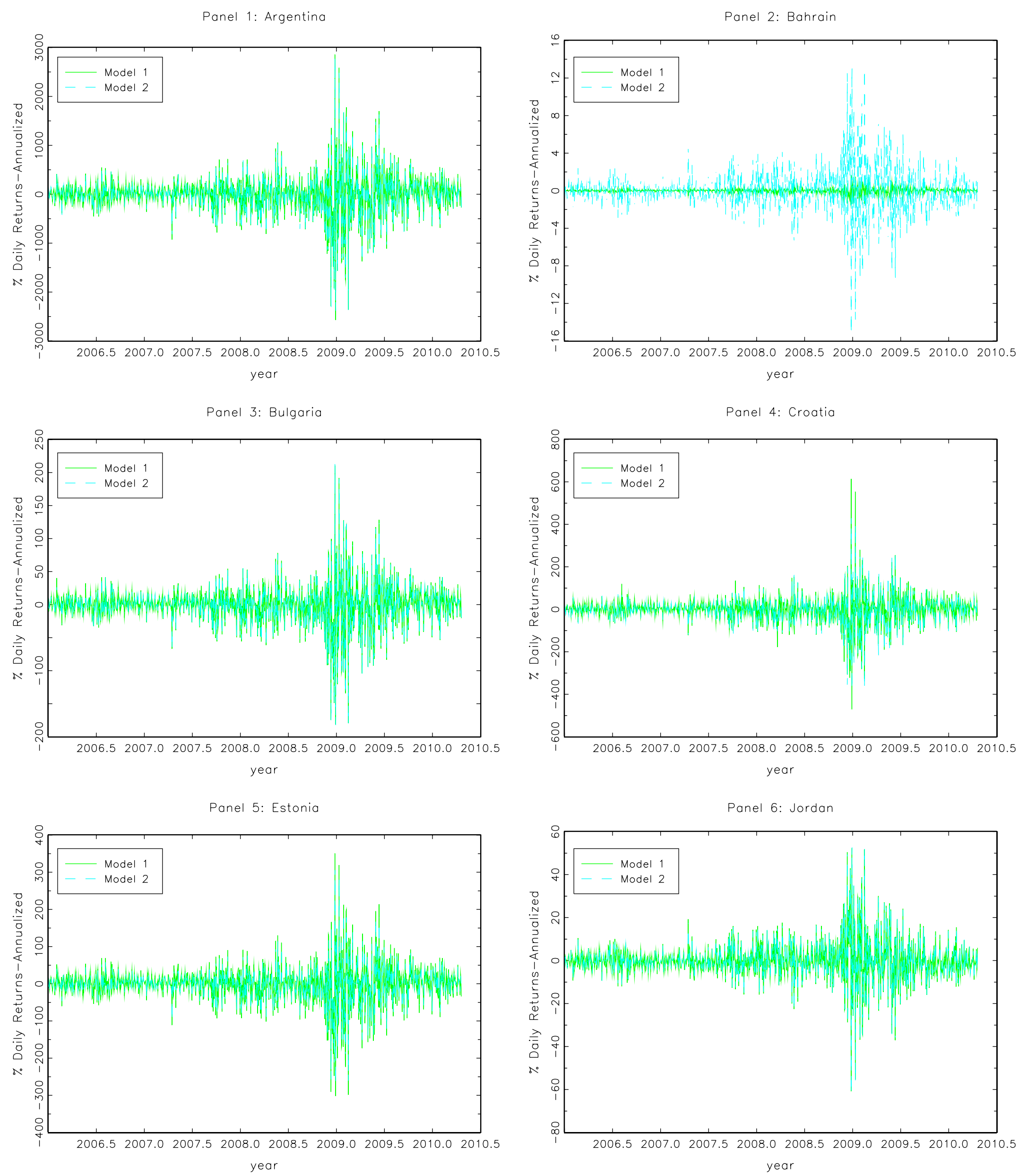


Figure B.2
US Components of Frontier Country Conditional Volatility Estimated by Model 1 and Model 2

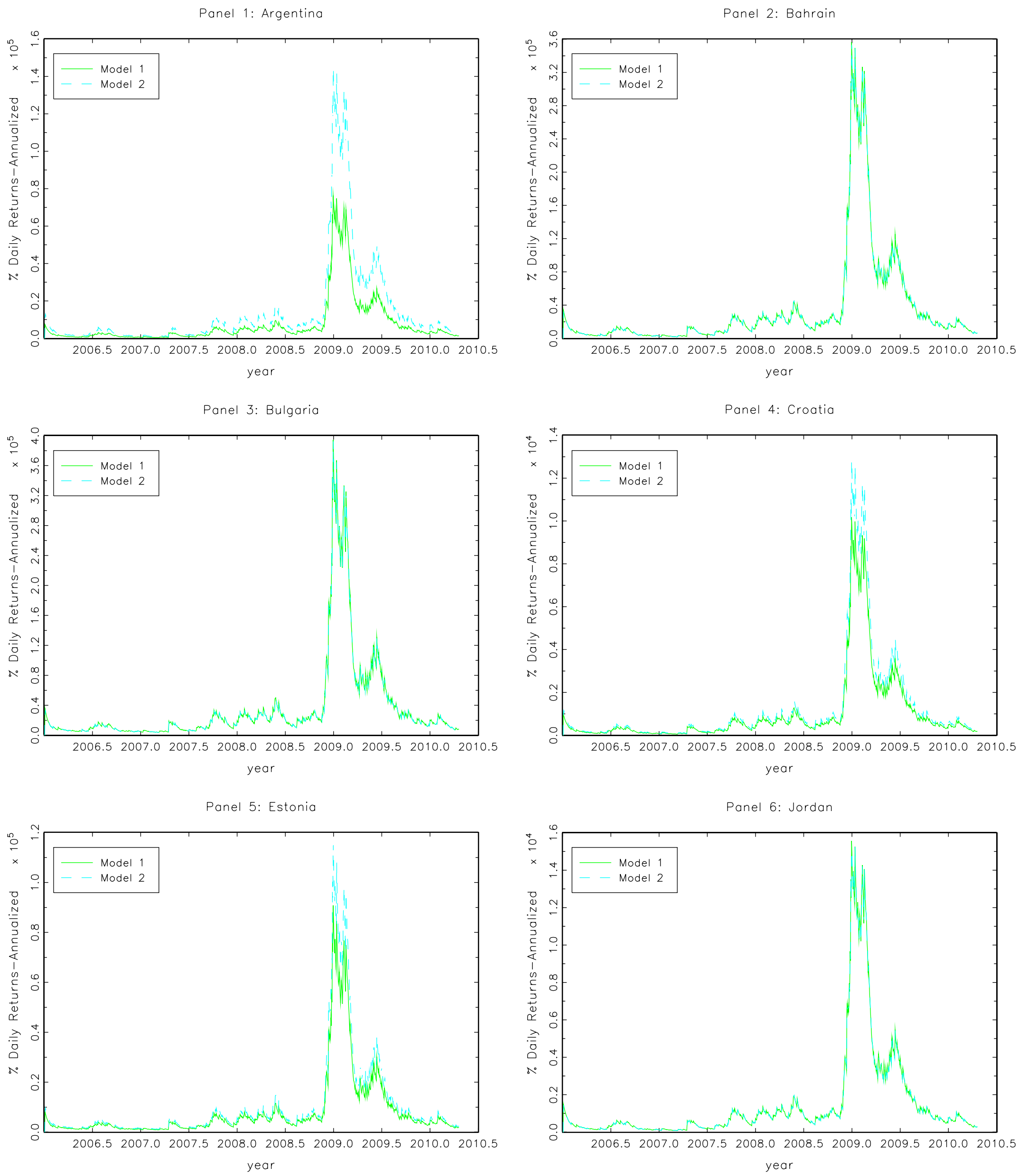


Figure B.3
US Components of Frontier Country Returns Estimated by Model 1 and Model 3

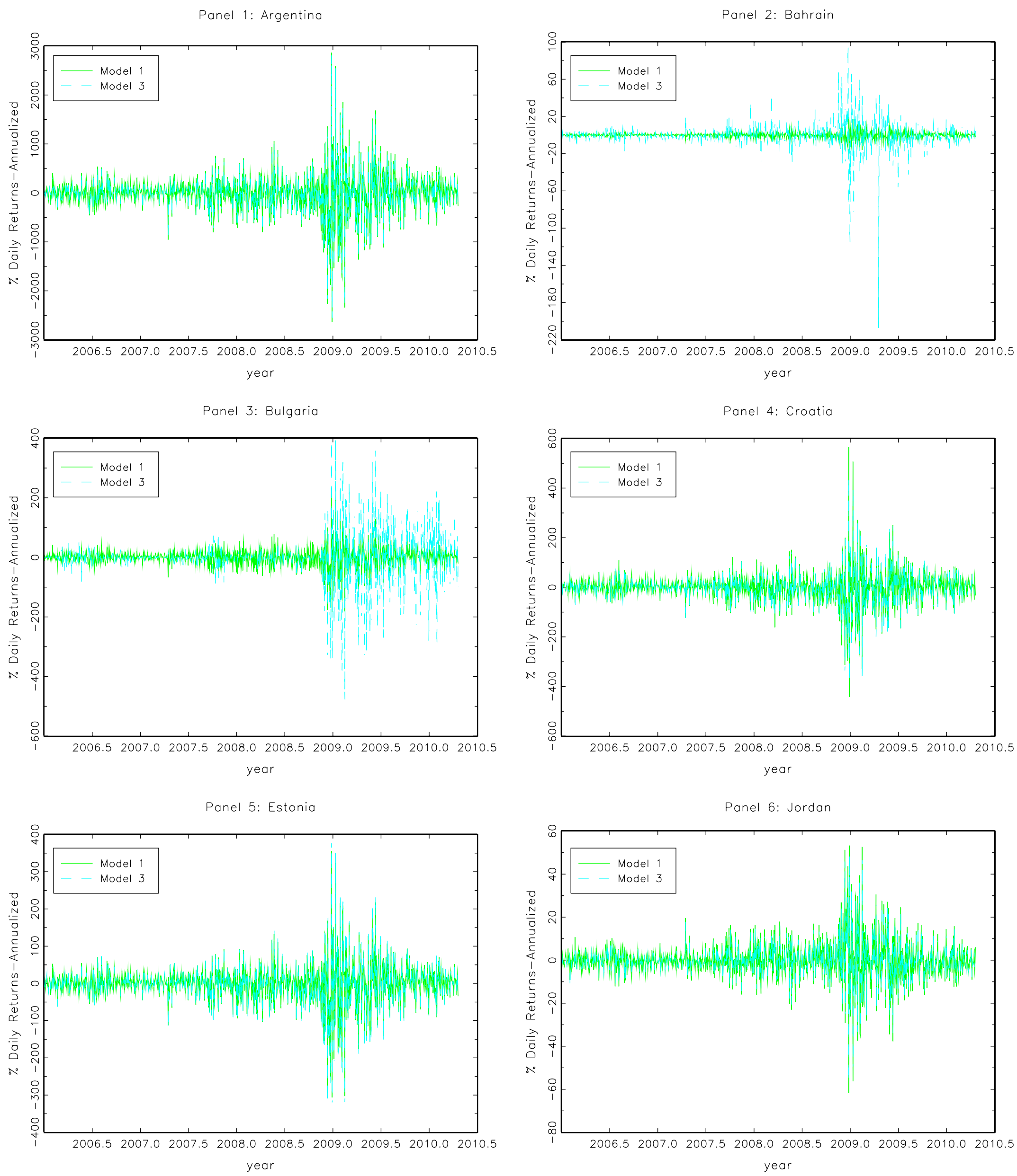


Figure B.4
US Components of Frontier Country Conditional Volatility Estimated by Model 1 and Model 3

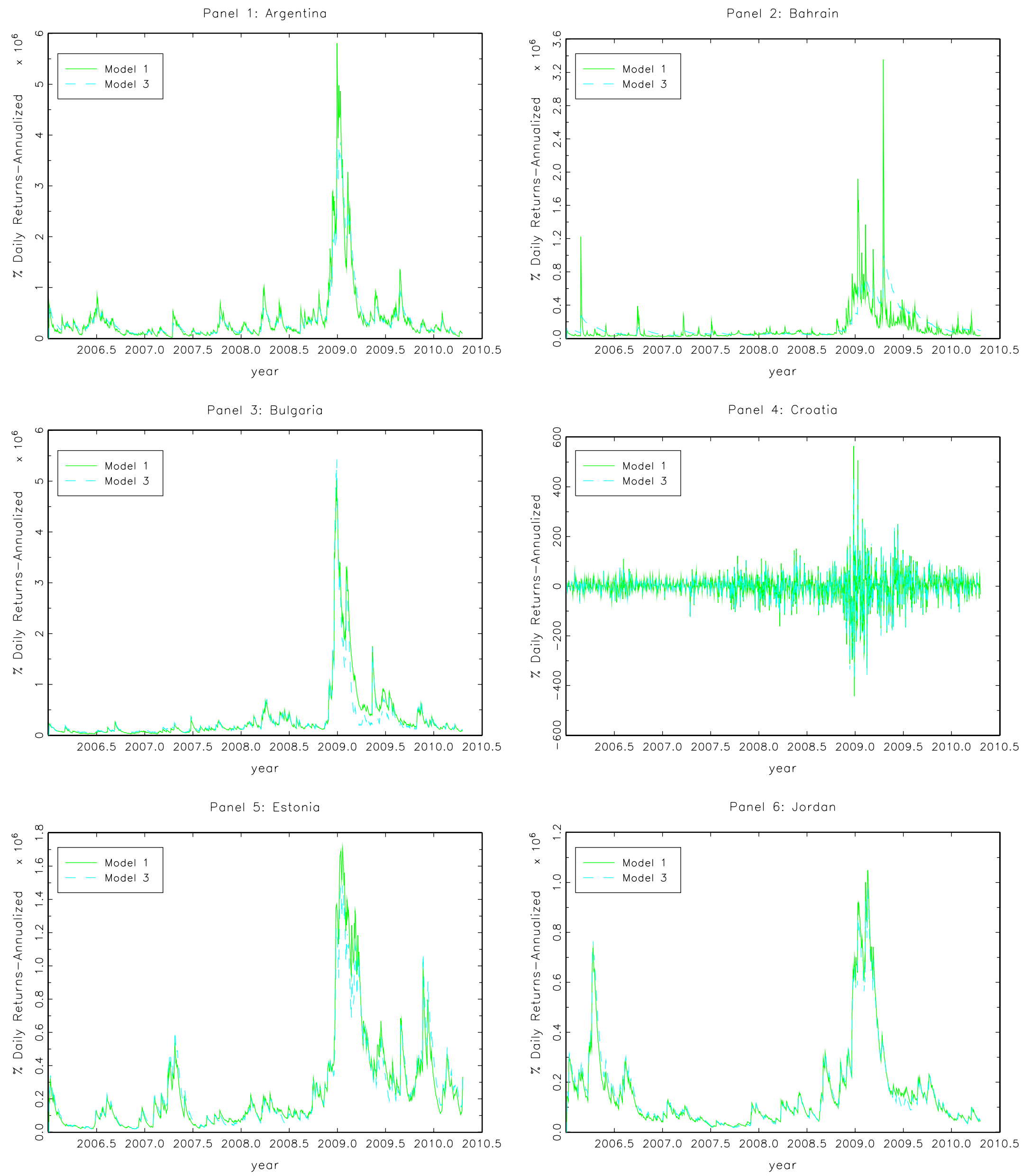


Figure B.5
Own-Country Lagged Components of Frontier Country Returns Estimated by Model 1 and Model 4

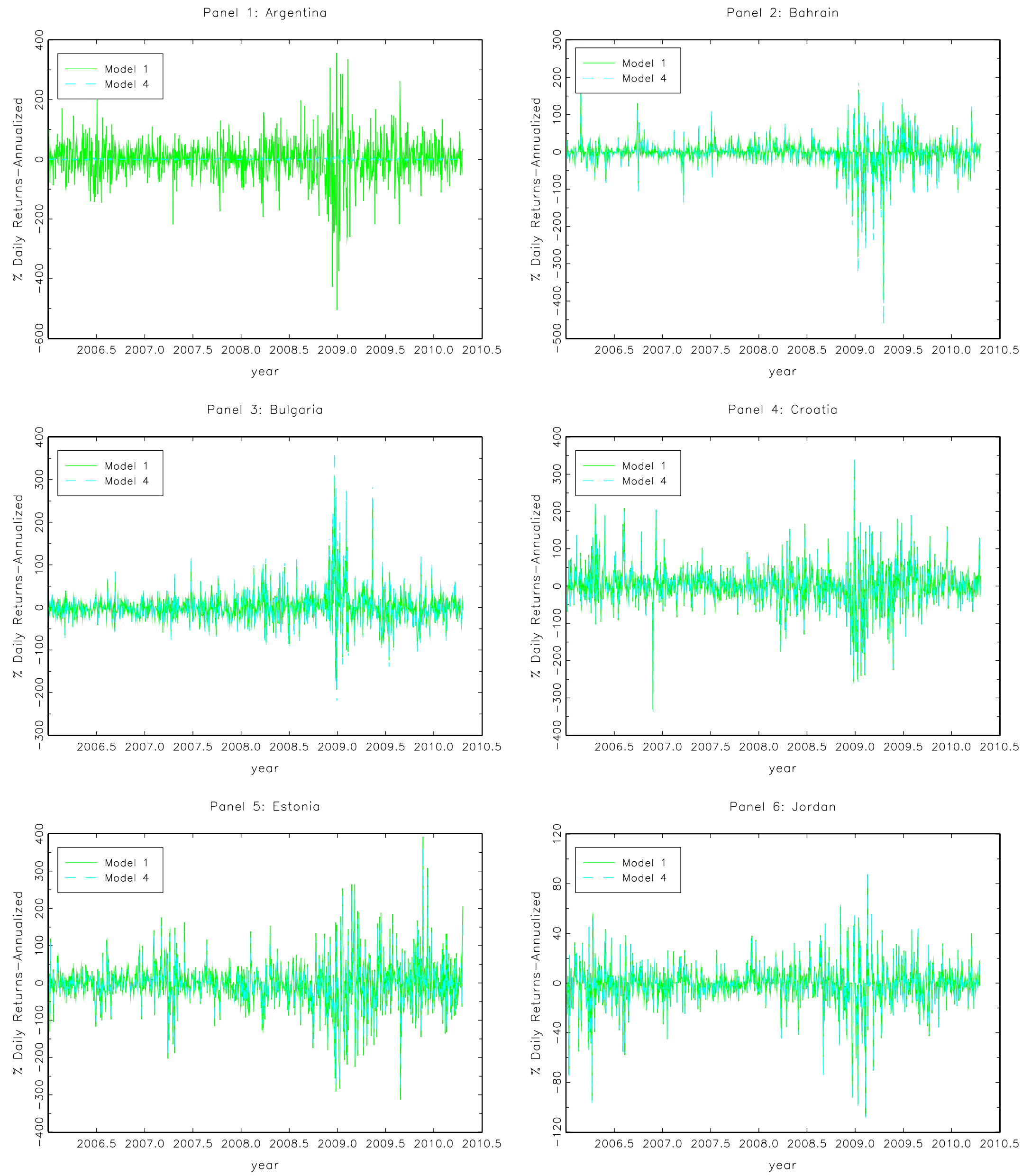


Figure B.6
Own-Country Components of Frontier Country Conditional Volatility Estimated by Model 1 and Model 4

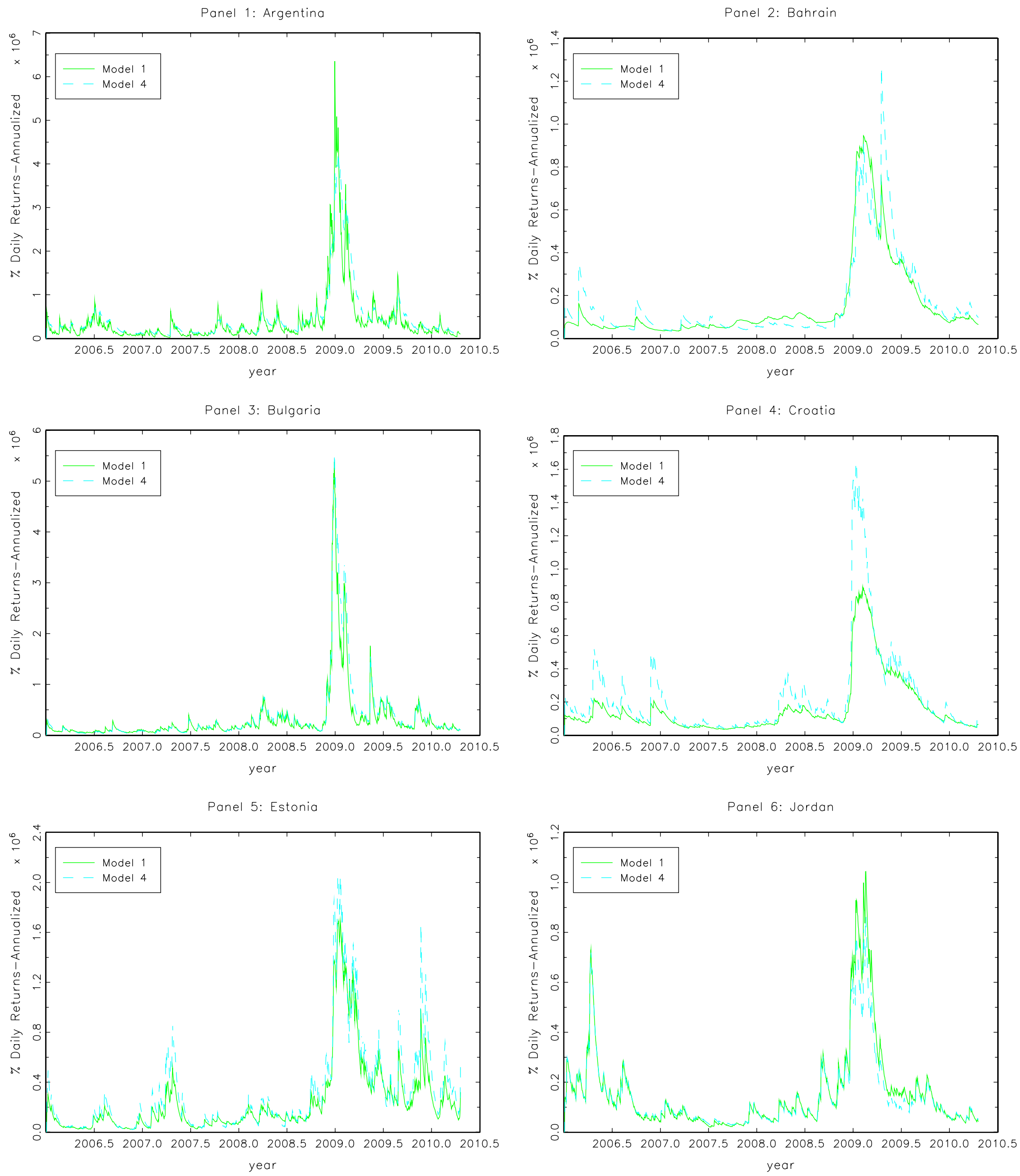


Figure B.7
US Components of Frontier Country Returns Estimated by Model 1 and Model 5

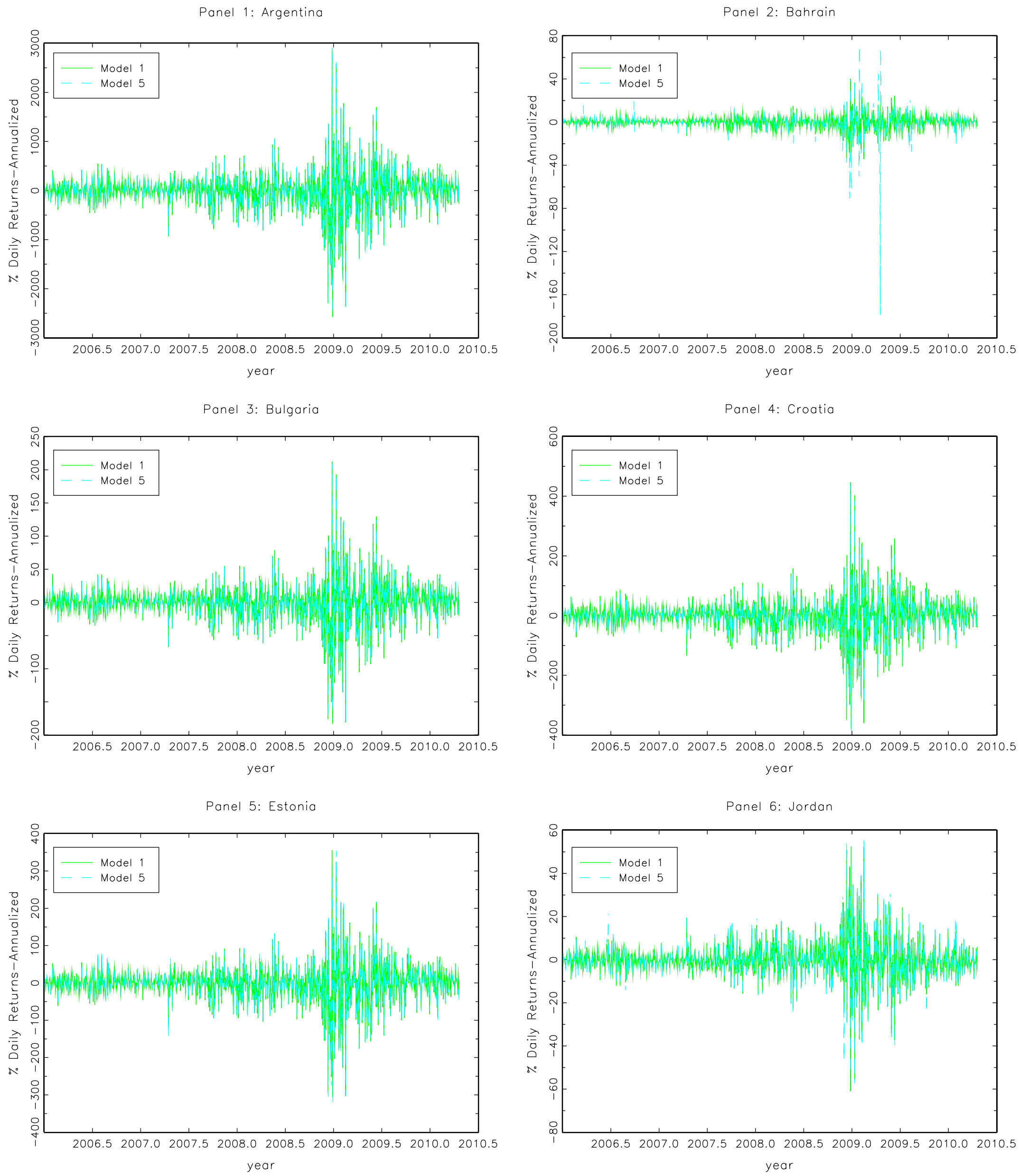


Figure B.8
US Components of Frontier Country Conditional Volatility Estimated by Model 1 and Model 5