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Abstract

We consolidate alternative ways for identifying stable and stressful scenarios in the S&P 500 market to construct contagion tests for recipient markets vulnerable to disturbances from this source market. The S&P 500 is decomposed into discrete conditions of: (1) Tranquil versus turbulent volatility; (2) Bull versus bear market phases; (3) Normal periods versus asset bubbles and crises. We analyse the relationship between the S&P 500 and major emerging Caribbean stock markets and find that, despite the prominent trade related exposure to the US, financial linkages are much less pronounced than might be expected outside of the Great Recession.

JEL-Codes: C580, G010.

Keywords: Caribbean, contagion, correlation, S&P 500, stock market, United States.

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1. Introduction

We introduce a novel perspective for testing for financial contagion in embryonic markets by comparing different ways of decomposing a source market into stable and stressful conditions, as well as considering various possible co-movement channels. In line with the existing literature (see, e.g. Dornbusch et al. (2000), Forbes and Rigobon (2002)) we define financial contagion in terms of changes in the moments of the distribution of assets returns during a financial crisis over and above changes due to market fundamentals. Such definition allows us to clearly discern between contagion and the associated concept of interdependence, which would require instead a high correlation across markets during all different states of the world.

We apply our proposed methodology to the three major emerging stock-markets in the Caribbean Region, i.e. Trinidad and Tobago, Jamaica, and Barbados stock exchanges, and we use the S&P 500 as our source market of financial stress, given the uncontested importance of the US economy on the CARICOM region.

Our first approach to identify periods of crisis adopts a practitioner's rule to classify tranquil versus turbulent phases in the S&P 500, based on the stock market's expectations of volatility calculated by the Chicago Board Options Exchange Volatility Index, VIX. Stock volatility is a common proxy for market uncertainty ((Bloom et al., 2007)) and the VIX index is widely considered to be an investors' fear gauge ((Min and Hwang, 2012)), which motivates the development of contagion tests around low and high VIX regimes.

Our second approach is based on identifying bullish and bearish market phases in the S&P 500 with a rule-based algorithm suggested in Pagan and Sossounov (2003). Indeed, there is evidence to suggest that market correlations tend to rise and fall in bearish and bullish phases, respectively (see Syllignakis and Kouretas (2011) and references therein).

A third approach is based on asset bubbles and crises in the S&P 500, identified with the Phillips and Shi (2018) PSY methodology. Asset bubbles, particularly those originating in the US financial market, are also widely acknowledged important sources of contagion (see, e.g. the discussion in Hon et al. (2007)).

Altogether, these various lenses for examining stressful market conditions can help policy makers and investors to understand the type of US financial environment during which shocks will be able to proliferate and propagate in recipient markets particularly exposed to developments in this source market.

We use these identified stable and stressful conditions to evaluate the stock market relationships between the US and selected Caribbean countries across three different contagion channels, i.e. the correlation and co-skewness contagion tests introduced in Fry et al. (2010), and the co-volatility contagion test introduced in Fry-McKibbin et al. (2014). Such analysis is a particularly appropriate approach for gauging how relationships are affected in suddenly changing conditions in a source market, as opposed to cointegration and interdependence tests, which are more applicable for the assessment of long run relationships and could omit to identify shorter periods of contagion.

Our application to selected Caribbean stock markets is of particular relevance for policy purposes, given the high vulnerability of small island developing states (see, e.g.Briguglio (1995)). In spite of the importance of the US on these economies, there is limited published research on financial contagion from the US to Caribbean financial markets. Samarakoon (2011) considers the transmission of shocks between the U.S. stock market and various foreign markets (including Trinidad and Tobago and Jamaica) within a VAR framework, to tests for contagion originating from the Global Financial Crisis (GFC), finding little evidence of contagion from the US to the two stock markets in our sample. Cozier and Watson (2019) also fail to provide convincing evidence of financial integration between the CARICOM and the U.S. market, based on the analysis of GARCH-Copula models.

Our main contributions to the contagion literature are that we test for contagion using various sources of stress (i.e. turbulent volatility, bearish phases, and asset bubbles and crises) across various co-movement channels (i.e., correlation, co-volatility, and co-skewness). Hence, our applications provide a fresh perspective for examining the market connectivity between the S&P 500 and Caribbean equity markets, by testing whether financial linkages change when conditions in the S&P 500 index change.

Our findings show that the relationship between the US and Caribbean stock markets vary both under alternative source market conditions and by recipient country. We provide evidence of financial contagion from the US stock market to Trinidad and Tobago (based on all tests) and also to Jamaica (based on the co-skewness channel only), but not for Barbados. However, when the Great Recession is censored, we find that most of these intermittent market linkages disappear.

The rest of the paper is structured as follows. Section 2 details our empirical procedures. In Section 3 we describe the dataset and calculate the adjusted asset returns. In Section 4, we present and analyse the results. Subsequently, we conclude in Section 5.

2. Methodology

We use three different approaches to decompose a source market into discrete stable and stressful scenarios. Subsequently, we adapt four contagion channels to test how the relationship between a source and recipient market might change under the alternative source market conditions. This section documents these empirical procedures.

2.1. Approaches to decompose the US market into discrete stable and stressful conditions

We consider three alternative approaches to classify the S&P 500 market into stable and stressful scenarios, to determine which type of classification might be useful for financial risk analysis in emerging markets potentially vulnerable to the US market movements.

2.1.1. Tranquil and turbulent volatility

Our first approach identifies periods of high versus low volatility in the US stock market based on the Chicago Board Options Exchange Volatility Index, generally known under its ticker, VIX. The VIX measures the 30-day expected volatility of the US stock market derived from real-time, mid-quote prices of the S&P 500 call and put options. We adopt the practitioner's rule which associates low volatility to VIX values below 12, normal volatility to VIX values between 12 and 20, and high volatility to values above 20 (see, e.g. Edwards and Preston (2017)). The implied volatility of the VIX reflects market expectations regarding future price movements and provides a better forecast than the realised volatility, especially during turmoil periods (see, e.g. Kenourgios (2014)). As we are interested in comparing turbulent with non-turbulent volatility periods, we characterise all VIX values below 20 as tranquil and values otherwise as turbulent.

2.1.2. Bull and bear market phases

Bull and bear phases in the S&P 500 market are sorted using an algorithm suggested in Pagan and Sossounov (2003). This procedure involves the determination of local peaks and troughs in asset prices which are the highest or lowest values, respectively, within a specified interval on either side of a given month. Following Pagan and Sossounov (2003), we set this interval as 8 months for the S&P 500 market. Moreover, a minimum duration for individual phases and cycles restricts which turning points trigger a switch between phases. We use a 6 month censor, again suggested in Pagan and Sossounov (2003), to prevent extreme values towards the end of an interval from distorting phases in the S&P 500 market.

2.1.3. Normal periods, and asset bubbles and crises

We use the bubble and crises dates, applicable to our sample period, in the S&P 500 market which are detected in Phillips and Shi (2018). This is based on the *psymonitor* approach postulated in Phillips et al. (2015a,b), which is a generalisation of the sup ADF unit root test suggested in Phillips et al. (2011), and provides consistent real-time dating for the start and end of bubbles and market crashes (including flash crashes). Psymonitor applies a rolling window right-tailed ADF test that has a double-sup window selection criteria to compute the ADF statistic in a double recursion over both feasible ranges of the window start points and a feasible range of window sizes. The procedure repeats the ADF test on a sequence of samples, steadily rolling the window frame throughout the sample. Such test is adopted by policy-makers and the financial industry as an early warning device for crises.

2.2. Contagion tests

Our empirical analysis is based on four established contagion tests to assess whether crises in the source market affect the individual CARICOM market. In the analysis that follows, the S&P 500 (the source market) is denoted as i and the recipient CARICOM market (Trinidad & Tobago, Barbados, and Jamaica) is denoted as j.

The starting point of contagion analysis typically involves the calculation of the Pearson correlation coefficient, ρ. Given the fact that such coefficient is conditional on the market volatility, it becomes spuriously over-inflated when the volatility associated with a crisis increases, which leads to a false positive detection of contagion (see, e.g. Boyer et al. (1999); Loretan and English (2000); Forbes and Rigobon (2002)). Hence, we follow the empirical literature[1] and correct for the potential heteroskedasticity bias in the stressful market periods as described in Eq. (1):

$$\hat{\nu}_{y|x_i} = \frac{\hat{\rho}_y}{\sqrt{1 + ((s^2_{y,i} - s^2_{x,i})/s^2_{x,i})(1 - \hat{\rho}^2_y)}} \tag{1}$$

where x represents the stable periods and y represents stressful scenarios, such that $s^2_{x,i}$ and $s^2_{y,i}$ are the return variances of the stable and stressful periods in the source market, respectively; and $\hat{\rho}_y$ is the correlation between the source and recipient markets during stressful scenarios. This adjusted linear correlation coefficient is used in each of the subsequent contagion tests to treat with possible heteroskedasticity bias in the co-movement channels.

2.2.1. Correlation channel

We use Fry et al. (2010) two-sided version of the Forbes and Rigobon (2002) significance test for a change in the adjusted stressful period correlation (i.e., $\hat{\nu}_{y|x_i}$) compared to the stable period correlation from the S&P 500 to a Caribbean stock exchange given in Eq. (2):

$$CR_{\overline{FR}}(i \to j) = \left(\frac{\hat{\nu}_{y|x_i} - \hat{\rho}_x}{\sqrt{Var(\hat{\nu}_{y|x_i} - \hat{\rho}_x)}} \right)^2 \tag{2}$$

where $\hat{\rho}_x$ is the Pearson correlation in the calm sample and, under the null hypothesis of "no contagion", the test statistic is asymptotically distributed as $CR_{\overline{FR}}(i \to j) \xrightarrow{d} \chi^2_1$.

2.2.2. Co-volatility channel

We apply the co-volatility contagion test in Eq. (3), suggested in Fry-McKibbin et al. (2014), to determine whether the volatility in S&P 500 is transmitted to the volatility of Caribbean stock exchanges during stressful S&P 500 market conditions:

$$CV(i \to j; r^2_i, r^2_j) = \left(\frac{\hat{\xi}_y(r^2_i, r^2_j) - \hat{\xi}_x(r^2_i, r^2_j)}{\sqrt{(4\hat{\nu}^4_{y|x_i} + 16\hat{\nu}^2_{y|x_i} + 4)/T_y + (4\hat{\rho}^4_x + 16\hat{\rho}^2_x + 4)/T_x}} \right)^2 \tag{3}$$

where T_x and T_y are the stable and stressful sub-samples, and the standardisation parameters $\hat{\xi}_x(r^2_i, r^2_j)$ and $\hat{\xi}_y(r^2_i, r^2_j)$ are respectively defined in Eq. (4) and (5):

$$\hat{\xi}_x(r^2_i, r^2_j) = \frac{1}{T_x} \sum_{t=1}^{T_x} \left(\frac{x_{i,t} - \hat{\mu}_{xi}}{\hat{\sigma}_{xi}} \right)^2 \left(\frac{x_{j,t} - \hat{\mu}_{xj}}{\hat{\sigma}_{xj}} \right)^2 - (1 + 2\hat{\rho}^2_x) \tag{4}$$

$$\hat{\xi}_y(r^2_i, r^2_j) = \frac{1}{T_y} \sum_{t=1}^{T_y} \left(\frac{y_{i,t} - \hat{\mu}_{yi}}{\hat{\sigma}_{yi}} \right)^2 \left(\frac{y_{j,t} - \hat{\mu}_{yj}}{\hat{\sigma}_{yj}} \right)^2 - (1 + 2\hat{\nu}^2_{y|x_i}) \tag{5}$$

and all other notation follows the aforementioned contagion test, and under the null hypothesis of "no contagion", the co-volatility test follows the same asymptotic distribution, i.e. $CV(i \to j) \xrightarrow{d} \chi^2_1$.

[1] See, for example, Boyer et al. (1999); Loretan and English (2000); Forbes and Rigobon (2002); Fry et al. (2010); Fry-McKibbin et al. (2014); Fry-McKibbin and Hsiao (2018).

2.2.3. Co-skewness channels

We also consider potential contagion channels operating from higher moments of the assets return distribution. In particular, Fry et al. (2010) demonstrate the importance of co-skewness in contagion testing, as it has been shown that financial crises affect not only the mean and volatility but also the higher moments of financial returns. This is explained in terms of the preference for positive skewness from risk-averse agents who are expected to trade-off lower returns for positive skewness during periods of crisis. We employ the two variants of the co-skewness contagion test put forward in Fry et al. (2010) which are specified in Eqs. (6) and (7):

$$CS_1(i \to j; r_i^1, r_j^2) = \left(\frac{\hat{\psi}_y(r_i^1, r_j^2) - \hat{\psi}_x(r_i^1, r_j^2)}{\sqrt{(4\hat{v}^2_{y|x_i} + 2)/T_y + (4\hat{\rho}_x^2 + 2)/T_x}} \right)^2 \tag{6}$$

$$CS_2(i \to j; r_i^2, r_j^1) = \left(\frac{\hat{\psi}_y(r_i^2, r_j^1) - \hat{\psi}_x(r_i^2, r_j^1)}{\sqrt{(4\hat{v}^2_{y|x_i} + 2)/T_y + (4\hat{\rho}_x^2 + 2)/T_x}} \right)^2 \tag{7}$$

where r_i^1 and r_i^2 are the S&P 500 returns mean and standard deviation, correspondingly, and r_j^1 and r_j^2 are the same for a given Caribbean stock market returns. Furthermore, the standardisation parameters $\hat{\psi}_x(r_i^m, r_j^n)$ and $\hat{\psi}_y(r_i^m, r_j^n)$ take the form defined in Eqs. (8) and (9), respectively:

$$\hat{\psi}_x(r_i^m, r_j^n) = \frac{1}{T_x} \sum_{t=1}^{T_x} \left(\frac{x_{i,t} - \hat{\mu}_{xi}}{\hat{\sigma}_{xi}} \right)^m \left(\frac{x_{j,t} - \hat{\mu}_{xj}}{\hat{\sigma}_{xj}} \right)^n \tag{8}$$

$$\hat{\psi}_y(r_i^m, r_j^n) = \frac{1}{T_y} \sum_{t=1}^{T_y} \left(\frac{y_{i,t} - \hat{\mu}_{yi}}{\hat{\sigma}_{yi}} \right)^m \left(\frac{y_{j,t} - \hat{\mu}_{yj}}{\hat{\sigma}_{yj}} \right)^n \tag{9}$$

where $\hat{\mu}$ and $\hat{\sigma}$ are the mean and standard deviation, respectively, for a given market (i.e., i or j) under a given sample (i.e., x or y); and r^m (r^n) is the average returns for market i (j) in the CS_1 (CS_2) test version and squared returns in the CS_2 (CS_1) test version. The test statistics in Eqs. (6) and (7), when their associated null hypotheses of "no contagion" are true, are asymptotically distributed as $CS(i \to j) \xrightarrow{d} \chi_1^2$.

3. Data

Our analysis uses monthly data to control for spurious results created by trading spikes, since Caribbean stock markets are relatively illiquid compared to those of advanced markets. The start dates of the individual samples we use for the analysis of the three Caribbean stock markets varies based on availability of local data required for adjusting the returns. For Trinidad and Tobago, the sample commences from January 1994; Jamaica starts from March 2000; and Barbados begins from January 2003. All samples terminate in November 2018. Table A.2 provides the sources and definitions of the data used in this paper.

We follow the convention in the contagion literature and use returns net of market fundamentals in the contagion tests (see for example Forbes and Rigobon (2002); Fry et al. (2010); Fry-McKibbin and Hsiao (2018)). As such, we remove lead-lag effects and autocorrelation from the real stock returns by working with the residuals in Eqs. (10), (11), (12), and (13). SBIC suggests an optimal lag length of 1 for each of these models and the LM test indicates an absence of serial correlation in the residuals. The S&P 500 returns are adjusted using the residuals of the regression function described in Eq. (10) times 100.

$$\Delta \ln S\&P\ 500_t = \alpha_0 + \alpha_1 \Delta \ln S\&P\ 500_{t-1} + \alpha_2 \Delta \ln OP_{t-1} + \alpha_3 SSR_{t-1} + \varepsilon_t \tag{10}$$

where $\Delta \ln S\&P\ 500_t$ is the log difference of the real S&P 500 index, $\Delta \ln OP_{t-1}$ is the lag of the log difference of Brent crude oil prices, and SSR_{t-1} is the lag of the US shadow short rate. The returns of the Brent crude oil benchmark prices are used to account for developments in the oil market as there is an extensive empirical literature which seeks to explain the effects of oil price shocks on the US financial market (see, *inter alia*, Huang et al. (1996); Sadorsky (1999); Kilian and Park (2009); Kang et al. (2015a,b); Ready (2018); Thorbecke (2019)). Additionally, Forbes and Rigobon (2002) suggest using interest rates to adjust returns for the macroeconomic and policy environment. For this purpose we use the US shadow short rates which accommodates values below the zero lower bound to reflect the unconventional monetary policy actions pursued by the FED in the aftermath of the GFC.

Real Caribbean stock market returns are adjusted using the residuals of Eqs. (11), (12), and (13) times 100.

$$\Delta \ln TTSE_t = \alpha_0 + \alpha_1 \Delta \ln TTSE_{t-1} + \alpha_2 TIR_{t-1} + \alpha_3 \Delta \ln S\&P\ 500_{t-1} + \alpha_4 \Delta \ln OP_{t-1} + \alpha_5 SSR_{t-1} + \varepsilon_t \tag{11}$$

$$\Delta \ln JSE_t = \alpha_0 + \alpha_1 \Delta \ln JSE_{t-1} + \alpha_2 JIR_{t-1} + \alpha_3 \Delta \ln S\&P\ 500_{t-1} + \alpha_4 \Delta \ln OP_{t-1} + \alpha_5 SSR_{t-1} + \varepsilon_t \tag{12}$$

$$\Delta \ln BSE_t = \alpha_0 + \alpha_1 \Delta \ln BSE_{t-1} + \alpha_2 BIR_{t-1} + \alpha_3 \Delta \ln S\&P\ 500_{t-1} + \alpha_4 \Delta \ln OP_{t-1} + \alpha_5 SSR_{t-1} + \varepsilon_t \tag{13}$$

where $\Delta \ln TTSE_t$ is the returns of the composite stock price index for the so-called First Tier Market, which is the primary market of the Trinidad and Tobago Stock Exchange (TTSE); $\Delta \ln JSE_t$ is the returns of the Jamaica Stock Exchange (JSE) index measuring the performance of all the ordinary shares listed on the so-called Main Market; and $\Delta \ln BSE_t$ is the Barbados Stock Exchange (BSE) index for all locally listed companies. TIR_{t-1}, JIR_{t-1}, and BIR_{t-1} are the lags of the commercial bank lending rates to account for the domestic economic, policy, and financial activity in Trinidad and Tobago, Jamaica, and Barbados, respectively. Finally, lags of the S&P 500 returns, oil returns, and US shadow short rates are included in the Caribbean stock market regressions to account for international economic and financial fundamentals.

4. Results

4.1. Alternative stressful scenarios identified in the S&P 500 market

Figure 1 shows the three types of stressful scenarios in the S&P 500 market shaded in grey vertical bars. Graph (A) highlights periods when the $\text{VIX}_t \geq 20$. Two distinct high volatility regimes in the sample are characterised by the practitioner's rule. The first corresponds to the run-up to and collapse of the internet bubble in the late 1990s and early 2000s. The second relates to the sub-prime mortgage crisis and the GFC.

Next, graph (B) illustrates the bear phases detected by the Pagan and Sossounov (2003) sorting procedure. Notable bearish market periods in the S&P 500 index coincide with the dot-com crash in the early 2000s, the GFC between late 2007 to mid-2009, the S&P downgrading of the US AAA credit rating in the summer of 2011, and the global turbulence associated with stock markets in 2015/2016.

Using the S&P 500 price dividend ratio, the relevant bubbles and crises periods identified in Phillips and Shi (2018) are: January 1996, May 1996, November 1996 to February 1997, April 1997 to July 1998, September 1998 to October 2000, December 2000 to January 2001, and October 2008 to February 2009. These periods are overlaid on the S&P 500 index and depicted in graph (C). Phillips and Shi (2018) argue that the psymonitor approach appropriately identifies the dot-com bubble of the late 1990s into the very early 2000s (with breaks) and the subprime mortgage crisis in late 2008 to early 2009. As Phillips and Shi (2018) analysis ends in July 2018, which is before our sample ends, we extend their application to November 2018 and find no bubbles or crises detected within this additional period. Due to sample size limitations in both Jamaica and Barbados, testing for contagion across the various co-movement channels with this approach is demonstrated with the S&P 500 and Trinidad and Tobago stock markets.

4.2. S&P 500 and Caribbean stock returns under alternative S&P 500 market conditions

In this section, we first examine how stock returns in both the source and recipient markets behave under the aforementioned identified stressful scenarios. We then analyse the correlations and the tests for contagion. Subsequent to this, we describe the sensitivity of the results to the Great Recession. The relevant statistics and estimates are presented in Table 1.

4.2.1. Source and recipient market performance, correlations, and contagion analysis

By considering the descriptive statistics of the adjusted returns series under different conditions of the source (S&P 500) market, we note a general tendency for the volatility of assets returns to increase during the identified periods of crises, whilst the mean returns tend to decrease. The skewness of the distributions show a general tendency to switch from positive to negative during the identified crises. All returns distributions (with the exception of Barbados during turbulent phases identified under the VIX) are leptokurtic.

Examining the individual countries in our sample, we note that for Trinidad and Tobago, the lowest monthly average returns and highest market volatility are exhibited under the psymonitor identified periods. Kurtosis values are higher under stressful periods in the S&P 500 when compared to stable periods.

In Jamaica, the highest mean asset returns and volatility occur during bearish S&P 500 conditions, while negative returns are observed when the VIX is experiencing turbulent volatility.

Turning to Barbados, average stock returns underperform the most during times when the VIX is turbulent, while

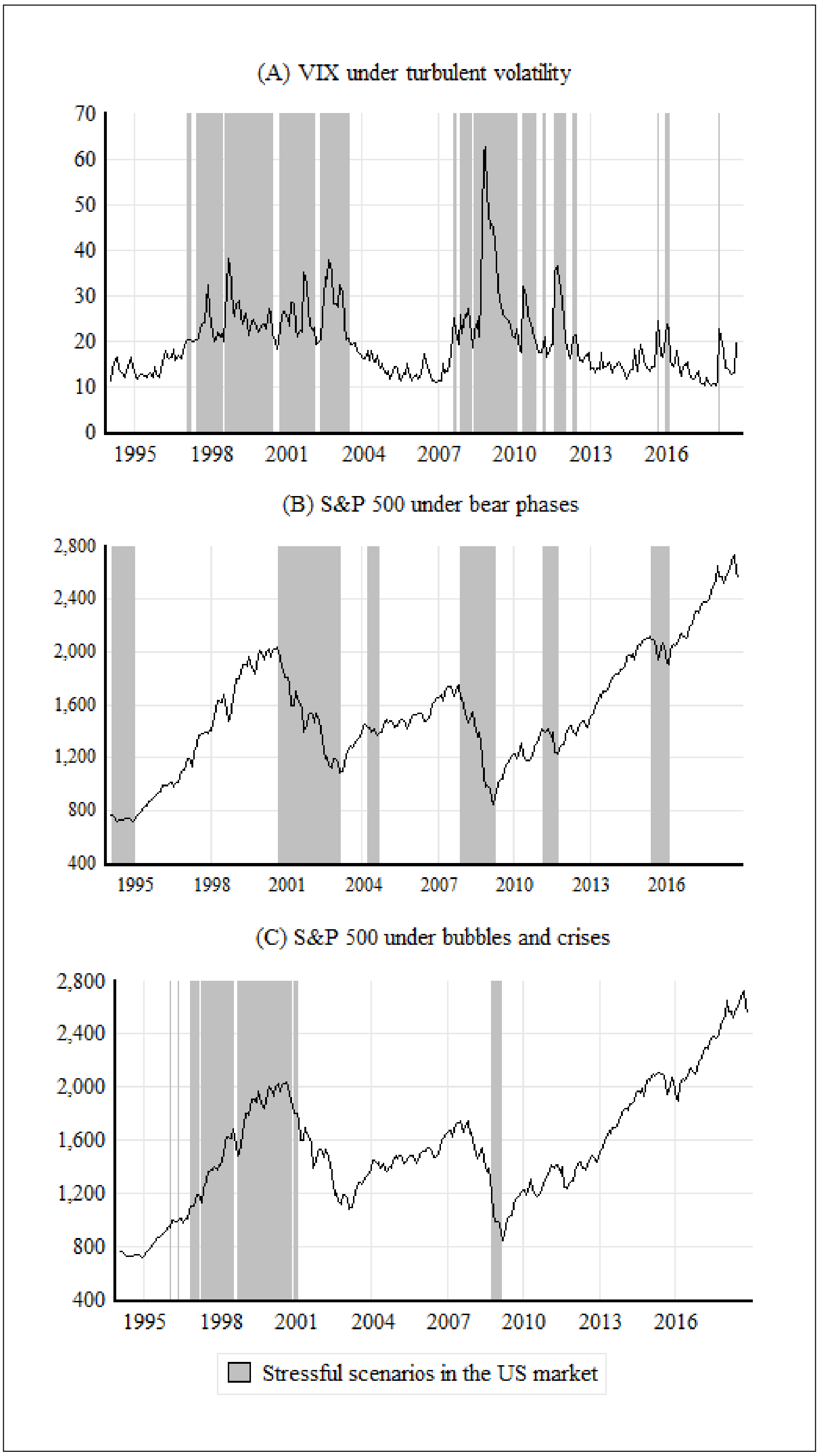

Figure 1: The VIX under turbulent volatility (A), the S&P 500 index under bearish market phases (B), and the S&P 500 index under the dot-com asset bubble and subprime mortgage crisis identified by the psymonitor approach (C).

both the highest returns and volatility are recorded when the VIX is tranquil. Kurtosis tends to decrease during crises in the source market.

Looking for evidence of contagion, we initially note that the correlations of asset returns for the countries in our sample and the US are generally low. The Pearson correlation shows a general tendency to increase during crises, which is considered as evidence in favour of contagion. On the other hand, its heteroskedasticity correction, $\bar{\rho}$, shows that the cross-market linkages appear weaker, confirming the importance of adopting of the corrected Pearson coefficient for our subsequent contagion tests.

Considering the results of the four contagion tests applied to the full sample (CR, CV, CS_1, and CS_2), for Trinidad and Tobago we find evidence of contagion across 11 out of the 12 possible channels. For Jamaica, only two out of the 8 channels considered are statistically significant, both occurring under the CS_2 testing. For the case of Barbados we have been unable to detect any significant contagion channel. As Barbados is the only country in our sample with a fixed exchange rate regime with the USD, our results seem in line with the findings suggested in Calvo and Mishkin (2003) regarding the relevance of exchange rate regimes for vulnerability to contagion.

4.2.2. Robustness analysis

The NBER's Business Cycle Dating Committee determines that the Great Recession in the US occurred from December 2007 to June 2009[2], which captures the subprime mortgage crisis. In the bottom half of Table 1, we check whether our results are sensitive to this unparalleled event. The correlations between the source and recipient equity markets behave differently in the full and censored samples, which highlights the distorting effects of the Great Recession period and underscores the importance of using the latter sample as an important sensitivity check. Although we observe statistically significant contagion channels when the Great Recession is censored, these estimates are unaccompanied by a marked increase in correlations during stressful scenarios in the S&P 500 market. In fact, all three Caribbean stock market returns perform better during bearish conditions in the S&P 500 index, which indicates that the source and recipient markets are not well synchronised once we omit the Great Recession.

Taken together, our results contradict the finding of Kali and Reyes (2010) who show that financial contagion is stronger if the epicenter market has close trade ties with the recipient market. Our results complement those of Cozier and Watson (2019) as well as Samarakoon (2011), who find little support for financial integration between the NYSE and Caribbean stock markets. Reasonable explanations for our results are that, despite strong US and Caribbean trade linkages, the stock markets of these emerging economies are relatively inefficient and illiquid, which make them either sluggish to absorb current information (Arjoon et al., 2016) or generally insensitive.

[2]See www.nber.org/cycles/recessions.html.

Table 1: SP 500 and Caribbean stock returns summary statistics, correlations, and contagion estimates under alternative US market conditions.

	US market condition	Obs.	Source (US) mkt. sum. stats. Mean	S.D.	Skew.	Kurt.	Recipient mkt. sum. stats. Mean	S.D.	Skew.	Kurt.	Correlation ρ	$\bar{\rho}$	Contagion test CR	CV	CS_1	CS_2
Full sample																
TTSE	Overall	299	0.02	3.48	-1.09	8.37	0.00	2.88	0.39	6.03	0.08	-	-	-	-	-
	Tranquil VIX	181	0.52	2.26	0.18	3.83	0.00	2.56	0.48	5.25	0.04	-	-	-	-	-
	Turbulent VIX	118	-0.74	4.69	-0.78	5.44	0.00	3.33	0.31	5.83	0.10	0.05	0.01	72.352***	15.405***	15.420***
	Bull phase	219	0.77	2.65	0.26	5.49	0.03	2.94	0.76	5.54	-0.09	-	-	-	-	-
	Bear phase	80	-2.04	4.52	-1.05	5.91	-0.09	2.73	-0.91	7.52	0.38	0.23	12.387***	204.233***	9.781***	29.450***
	Normal	244	-0.02	3.22	-0.70	5.28	0.05	2.61	0.60	5.28	-0.01	-	-	-	-	-
	Bubble/crisis	55	0.21	4.47	-1.72	10.92	-0.25	3.88	0.17	5.31	0.26	0.19	3.109*	113.742***	22.697***	34.422***
JSE	Overall	225	-0.24	3.58	-1.30	8.69	-0.02	4.05	0.65	5.78	0.17	-	-	-	-	-
	Tranquil VIX	141	0.41	2.15	-0.07	3.17	0.14	4.21	0.62	5.78	0.17	-	-	-	-	-
	Turbulent VIX	84	-1.33	5.00	-0.75	5.09	-0.28	3.76	0.65	5.50	0.19	0.08	0.839	0.142	2.065	3.917**
	Bull phase	156	0.65	2.42	0.39	6.28	-0.14	3.52	0.43	4.78	0.10	-	-	-	-	-
	Bear phase	69	-2.25	4.80	-0.91	5.23	0.25	5.06	0.69	5.15	0.28	0.14	0.167	0.063	0.422	6.035**
BSE	Overall	191	-0.04	3.35	-1.58	11.68	-0.03	2.63	-0.44	10.55	0.02	-	-	-	-	-
	Tranquil VIX	136	0.44	2.08	-0.02	3.09	0.10	2.94	-0.53	9.52	0.04	-	-	-	-	-
	Turbulent VIX	55	-1.23	5.17	-0.93	5.95	-0.37	1.61	-0.20	2.82	-0.04	-0.02	0.269	1.403	0.141	0.096
	Bull phase	150	0.65	2.42	0.42	6.44	-0.06	2.81	-0.48	10.17	0.04	-	-	-	-	-
	Bear phase	41	-2.56	4.82	-1.44	6.65	0.06	1.86	0.49	3.41	0.02	0.01	0.074	0.071	0.234	1.501
Censored sample (excludes the Great Recession)																
TTSE	Overall	280	0.17	3.10	-0.68	5.21	0.07	2.78	0.72	5.75	-0.04	-	-	-	-	-
	Tranquil VIX	180	0.52	2.26	0.18	3.81	-0.02	2.56	0.49	5.27	0.04	-	-	-	-	-
	Turbulent VIX	100	-0.46	4.15	-0.53	3.49	0.22	3.14	0.87	5.62	-0.10	-0.06	1.114	0.005	1.419	0.137
	Bull phase	216	0.71	2.55	-0.06	4.58	0.05	2.95	0.74	5.50	-0.08	-	-	-	-	-
	Bear phase	64	-1.66	4.01	-0.45	3.54	0.11	2.10	0.39	4.78	0.06	0.04	1.350	0.298	7.647***	0.936
	Normal	230	0.01	3.05	-1.03	5.44	0.11	2.57	0.63	5.59	-0.05	-	-	-	-	-
	Bubble/crisis	50	0.87	3.28	0.49	3.37	-0.12	3.61	0.87	4.96	-0.01	-0.01	0.064	0.000	4.075**	0.970
JSE	Overall	206	-0.06	3.10	-0.98	5.25	0.11	3.92	0.68	6.06	0.08	-	-	-	-	-
	Tranquil VIX	140	0.41	2.15	-0.07	3.15	0.14	4.23	0.62	5.74	0.17	-	-	-	-	-
	Turbulent VIX	66	-1.06	4.35	-0.57	3.03	0.04	3.21	0.87	5.75	-0.03	-0.02	3.249*	3.082*	0.073	0.017
	Bull phase	153	0.56	2.25	-0.31	3.83	-0.14	3.51	0.45	4.88	0.07	-	-	-	-	-
	Bear phase	53	-1.86	4.33	-0.32	3.07	0.82	4.90	0.69	5.71	0.17	0.09	0.031	1.449	0.099	0.082
BSE	Overall	172	0.20	2.67	-0.97	5.89	0.01	2.71	-0.47	10.42	-0.00	-	-	-	-	-
	Tranquil VIX	135	0.44	2.09	-0.02	3.07	0.09	2.95	-0.52	9.48	0.03	-	-	-	-	-
	Turbulent VIX	37	-0.70	4.06	-0.81	3.45	-0.27	1.55	-0.10	3.07	-0.20	-0.11	1.375	0.916	0.004	0.542
	Bull phase	147	0.56	2.24	-0.31	3.91	-0.05	2.81	-0.48	10.26	0.03	-	-	-	-	-
	Bear phase	25	-1.94	3.81	-0.74	3.72	0.39	1.96	0.59	3.17	-0.07	-0.04	0.265	0.116	0.772	0.441

Notes: $***$, $**$, and $*$ denote the conventional 1% (strong), 5% (moderate), and 10% (weak) levels of significance, respectively, which corresponds to χ^2_1 critical values of 6.635, 3.841, and 2.706 for the CR, CV, CS_1, and CS_2 contagion tests. The following abbreviations apply: ρ is the Pearson correlation coefficient; $\bar{\rho}$ is the adjusted Pearson correlation coefficient; and CR, CV, CS_1, and CS_2 are the correlation, co-volatility, and the two variants of the co-skewness contagion tests, respectively.

5. Conclusions

The main contribution of this paper is that we compare alternative approaches for decomposing a source market into dichotomous sub-samples of stable and stressful periods for constructing contagion tests. Using the S&P 500, we consider three important ways to classify this market into discrete periods of: (1) Tranquil and turbulent volatility; (2) Bull and bear market phases; and (3) Normal periods and asset bubbles and crises. Then, with correlation, co-volatility,and co-skewness contagion tests, we compare whether the financial relationships between the S&P 500 and selected Caribbean stock exchanges change during the various episodes identified in the source market. Our main results show that there are both within and between country variations in the stock market relationships between the S&P 500 and the Caribbean under different US market conditions. However, given the importance of the US trade relationships with the selected Caribbean territories, the financial market linkages are much less pronounced than might be expected outside of the events of the Great Recession in the US.

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Appendix A. Data appendix

Table A.2: Data definitions and sources

Series and abbreviations	Defintion	Source
Real S&P 500 index	A S&P Dow Jones Indices maintained index measuring the performance of 500 large companies listed on US stock exchanges, expressed in constant 2015 USD using the composite US CPI.	Calculated using S&P 500 index data from Yahoo! Finance and CPI data from FRED.
VIX	A Chicago Board Options Exchange (CBOE) volatility index measuring near term implied volatility from price inputs of the S&P 500 index options.	Federal Reserve Economic Data (FRED).
Real Trinidad and Tobago Stock Exchange (TTSE) index	The composite stock price index is used, which is market value weighted and collectively measures the price movement of the ordinary shares for companies listed on the so-called First Tier market of the TTSE and adjusted for inflation using a composite RPI (100=2015).	Calculated using data from the Central Bank of Trinidad and Tobago.
Real Jamaica Stock Exchange (JSE) index	The JSE (Main) index is used, which measures the performance of all the ordinary shares listed on the so-called Main Market, adjusted for inflation using the composite CPI (100=2015).	Calculated using data from the Jamaica Stock Exchange and CPI data from the Central Bank of Jamaica.
Real Barbados Stock Exchange (BSE) index	The BSE local index is used, which measures all local companies listed on the so-called Regular Market, and adjusted for inflation using a composite RPI (100=2015).	Calculated using data from the Barbados Stock Exchange and RPI data from the Central Bank of Barbados.
US Shadow Short Rates (SSR)	SSR is the shortest maturity rate from the estimated US shadow yield curve. The rate can assume values below the zero lower bound to accommodate the unconventional monetary policy actions (i.e., rounds of quantitative easing) in the US (see Krippner (2016)).	Leo Krippner, Research Programme, Reserve Bank of New Zealand.
Real Oil Prices (OP)	European Brent crude oil spot prices in constant 2015 USD using the composite US CPI.	Calculated from FRED.
Trinidad and Tobago Interest Rates (TIR)	Commercial banking median basic prime lending rate in Trinidad and Tobago.	Central Bank of Trinidad and Tobago.
Jamaica Interest Rates (JIR)	Commercial banking domestic currency average weighted loan interest rate in Jamaica.	Central Bank of Jamaica.
Barbados Interest Rates (BIR)	Commercial banking upper bound prime lending rate in Barbados.	Central Bank of Barbados.