Contagion testing in frontier markets under alternative stressful S&P 500 market scenarios

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Abstract

We use alternative approaches to identify stable and stressful scenarios in the S&P 500 market, to offer a new perspective for constructing contagion tests in recipient frontier markets vulnerable to disturbances from this source market. The S&P 500 market is decomposed into discrete conditions of: (1) tranquil versus turbulent volatility; (2) bull versus bear market phases; (3) normal periods versus asset bubbles and crashes. Based on these identified scenarios, we use various co-moment contagion tests to analyse the changing relationship between the S&P 500 market and major frontier markets in the Caribbean region that have prominent trade related exposure to the US. Our findings show that, outside of the events of the Great Recession, the Caribbean stock exchanges are largely independent of the S&P 500 market.

Keywords: contagion; correlation; crisis; S&P 500; stock market; volatility
JEL classification: C58; G01

1. Introduction

We provide a novel perspective for testing financial contagion in frontier markets by comparing different ways of decomposing a source market into stable and stressful conditions, and examining how the different co-moments of asset returns between a source market and recipient markets change under such scenarios. Following Dornbusch et al. (2000) and Forbes and Rigobon (2002), we define financial contagion in terms of marked changes in the co-moments of the distribution of assets returns during a financial crisis over and above changes due to market fundamentals.

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Such a characterisation allows us to distinguish between contagion and the associated concept of interdependence, where the latter implies that market correlations are significant and relatively consistent across all different states of the world.

Developments in the S&P 500 stock market are of vital interest for financial analysis because of its sheer size and the influence it exerts on financial markets around the world (Phillips and Shi, 2020). Our proposed methodology is applied to the three major frontier stock markets in the Caribbean region, i.e. Trinidad and Tobago, Jamaica, and Barbados stock exchanges, and we use the S&P 500 market as our source market of financial stress, given that the US is the uncontested most important trading partner for all of these Caribbean Community (CARICOM) territories. A reasonable point of view is that countries with similar macroeconomic environments are subjected to common adverse shocks (Hernández and Valdés, 2001). Table 1 provides an overview of the major export and import markets of these three Caribbean economies for selected years, documenting the large exposure of these frontier markets to the US economy relative to other markets. As noted by Fry-McKibbin et al. (2014) and Fry-McKibbin et al. (2018), such linkages are expected to constitute a pre-condition for contagion.

An application to frontier Caribbean stock markets is particularly relevant for investment and development policy purposes, given the heightened vulnerability of small island developing states (see, for example, Briguglio, 1995). It is plausible for such vulnerabilities to materialise in stock market relationships given that asset returns are assumed to reflect all available information, including developments in the real economy. Table 2 provides country and stock market statistics of Trinidad and Tobago, Jamaica, and Barbados for 2019. Of the three Caribbean countries, Trinidad and Tobago has the largest market capitalisation. On the other hand, Jamaica has the largest population size and stock exchange listings but the lowest real GDP per capita. Barbados has the highest real GDP per capita; yet the smallest population size, market capitalisation, and number of stock exchange security listings.

Several possible channels of contagion have been described in the economic literature (see, e.g., Dornbusch et al., 2000; Calvo and Reinhart, 1996, and references therein), including trade links, rational or irrational investors' behaviour, as well as financial institutions and regulations. Nevertheless, the identification of the exact contagion channel associated with documented cor-

Table 1: Major trading partners of Trinidad and Tobago (T&T), Jamaica, and Barbados (with each trading partner's share of the total market in italics).

Year	Top 3 export markets			Top 3 import markets		
	1	2	3	1	2	3
Trinidad and Tobago						
2015	US	Argentina	Columbia	US	Gabon	China
	41.73%	*6.75%*	*4.07%*	*31.95%*	*12.49%*	*7.10%*
2010	US	Jamaica	Barbados	US	Gabon	Columbia
	48.07%	*6.47%*	*3.40%*	*27.95%*	*12.90%*	*9.47%*
2005	US	Jamaica	France	US	Brazil	Venezuela
	58.58%	*7.46%*	*4.44%*	*29.16%*	*13.55%*	*6.03%*
2000	US	Jamaica	Barbados	US	Venezuela	Columbia
	46.59%	*7.82%*	*4.82%*	*35.38%*	*18.40%*	*7.94%*
1995	US	Jamaica	Barbados	US	UK	Germany
	42.91%	*8.43%*	*3.46%*	*50.59%*	*7.23%*	*5.89%*
Jamaica						
2015	US	Canada	Netherlands	US	T&T	China
	36.99%	*14.45%*	*8.74%*	*37.51%*	*9.50%*	*8.19%*
2010	US	Canada	UK	US	Venezuela	T&T
	49.65%	*12.31%*	*6.32%*	*35.89%*	*14.02%*	*13.80%*
2005	US	Canada	UK	US	T&T	Venezuela
	25.56%	*19.40%*	*10.72%*	*41.55%*	*15.03%*	*5.39%*
2000	US	UK	Netherlands	US	T&T	Japan
	39.16%	*11.45%*	*11.10%*	*45.46%*	*10.01%*	*6.00%*
Barbados						
2015	US	T&T	Guyana	US	T&T	China
	32.62%	*8.25%*	*5.32%*	*39.23%*	*15.79%*	*5.65%*
2010	US	UK	T&T	US	T&T	UK
	24.92%	*16.78%*	*8.44%*	*43.95%*	*7.18%*	*5.37%*
2005	US	T&T	UK	US	T&T	Japan
	13.42%	*10.82%*	*8.79%*	*35.91%*	*21.16%*	*7.64%*
2000	US	T&T	UK	US	T&T	UK
	15.80%	*13.22%*	*13.17%*	*41.55%*	*16.45%*	*8.08%*

Data source: compiled using World Integrated Trade Solution (WITS), World Bank data.

Table 2: Country and stock market statistics for selected Caribbean territories, 2019

	Trinidad and Tobago	Jamaica	Barbados
Population (in millions)	1.4	2.9	0.3
GDP per capita (in constant 2010 US$)	15,105.1	4,867.0	16,099.8
Stock market capitalisation for major market (in US$ millions)	21,106.37 (First Tier Market)	14,459.13 (Ordinary Market)	3,470.10 (Regular Market)
Stock exchange listings	33 companies	85 companies 120 securities	17 securities

Data sources: population and real GDP per capita data are compiled from the World Bank Indicators website. Market capitalisation data for all stock markets are obtained from TTSE AR (2019, p. 114). The number of listings quoted on the various stock exchanges are retrieved from TTSE AR (2019, p. 5) for Trinidad and Tobago; the Jamaica Stock Exchange website for Jamaica; and BSE MAR (2019, p. 5) for Barbados. The year 2019 for this overview is dictated by the latest data provided by the World Bank.

relation (and higher co-moments) shifts is rather complex and relatively under-explored in the literature. The few studies exploring the economic fundamentals which determine stock market interdependence between countries have produced mixed results: some suggest that trade intensity is the principal factor, others find bi-lateral trade has no impact, and others are inconclusive (see Paramati et al., 2015, and references therein). Regarding the link between financial contagion and trade linkages, the evidence suggests that a financial crisis is amplified if the epicentre country is better integrated into the trade network of the recipient country (Kali and Reyes, 2010).

Many studies have produced evidence which supports the view that contagion is a regional rather than global phenomenon (see Kaminsky and Reinhart, 2000, and references within). Yet, despite the importance of the US to Caribbean economies, there is limited published research on financial contagion from the US to these frontier markets of the region. One of the few studies include Samarakoon (2011), who considers the transmission of shocks between the US 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 these two stock markets in our sample composition. In another study, Cozier and Watson (2019) provide no compelling evidence of financial integration between the CARICOM and the New York Stock Exchange (NYSE), based on the analysis of GARCH-copula models.

In this paper, we consider three various lenses for examining stressful market conditions 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. Our first approach to identify periods of crisis adopts a practitioner's rule to classify tranquil versus turbulent phases in the S&P 500 index, based on the stock market's expectations of volatility calculated by the Chicago Board Options Exchange (CBOE) Volatility Index, generally known under its ticker as the 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 phases in the S&P 500 market 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 market, identified with the Phillips and Shi (2020) psymonitor methodology. Asset bubbles, particularly those originating in the US financial market, are also widely acknowledged important sources of contagion (see, for example, the discussion in Hon et al., 2007).

We make use of these identified stable and stressful conditions to evaluate the stock market relationships between the US and the selected Caribbean countries across three different contagion tests, 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. Moreover, a higher order co-moment analysis of joint returns distribution is a useful approach for understanding financial integration, as it does not entirely rely on second order moments using correlations and also does not require the specification of a particular economic model (Fry-McKibbin et al., 2018).

Hence, our consolidated contribution to the contagion literature is that we illustrate how contagion can be tested during various sources of stress (i.e., turbulent volatility, bearish phases, and asset bubbles and crashes) across various co-moment tests (i.e., correlation, co-volatility, and co-skewness). Furthermore, our applications offer a fresh view to examine the market connectivity between the S&P 500 market 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 co-moments) and also to Jamaica (through the co-skewness only), but not for Barbados. Such results are robust to different approaches for identifying the alternative stable and stressful periods in the S&P 500 market and when we control for macroeconomic fundamentals. However, we find that many of the identified intermittent market linkages disappear when the Great Recession is censored. This underscores the prominence of the GFC event (see, also, Fry-McKibbin et al., 2014), even in frontier markets.

The rest of the paper is structured as follows. Section 2 details our empirical procedures. Subsequently, in Section 3, we describe the dataset and how the asset returns shocks are estimated. In Section 4, we present and analyse the main results and those obtained from a battery of robustness exercises. Lastly, 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 three different co-moment contagion tests to examine 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

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 CBOE's 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, for example, 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, for example, Kenourgios, 2014). As we are interested in comparing turbulent with non-turbulent volatility periods, we characterise all VIX values above 20 as turbulent and values otherwise as tranquil. One obvious advantage of applying the practitioner's rule on the VIX is that it is not sample sensitive. This is a particularly attractive feature given that the availability of data varies across the recipient Caribbean countries we consider, as we discuss in the Data section.

2.1.2. Bull and bear market phases

The rule-based algorithms in Pagan and Sossounov (2003) and Lunde and Timmermann (2004) are two commonly employed non-parametric approaches for identifying bull and bear phases in asset prices (Hanna, 2018). Kole and Van Dijk (2017) show that these approaches are preferred for in-sample identification of market phases, whereas Markov-switching models are preferred for forecasting, as only the mean return of the market index matters in-sample and this is precisely what the rule-based methods capture[1]. Given that we do not perform out-of-sample analysis, a non-parametric approach is deemed the more appropriate approach for our study. Pagan and Sossounov (2003) demonstrate that their rule-based algorithm identifies turning points which are

[1] See also the discussion in Harding and Pagan (2003) who explain that Markov-switching models are less attractive when compared to non-parametric methods for dating cycles, as the former depends on the validity of the underlying statistical model.

synchronous to scenarios considered as bull and bear markets in the US stock market. Accordingly, we use their well-established algorithm to sort bull and bear phases in the S&P 500 market. 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. These minimum durations are set to 16 months in the case of cycles and 4 months in the case of phases. However, if a rise or fall in the asset price is greater than 20%, then the minimum phase rule is ignored and a switch of market phase is triggered. A 6 month censor, again suggested in Pagan and Sossounov (2003), is also used 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 time-stamps in the S&P 500 market detected in Phillips and Shi (2020), which contains an example of the *psymonitor* approach specified in Phillips et al. (2015a,b) and covers our sample period. Psymonitor is globally recognised by policy-makers and the financial industry as an early warning device for crises (see, for example, the discussion in Phillips and Shi (2020)). Furthermore, such an approach is considered to be particularly appropriate for the analysis of datasets which include the GFC period and its aftermath (see, for example, the discussions in Homm and Breitung, 2012, and Figuerola-Ferretti et al., 2019). The psymonitor provides consistent real-time dating for the start and end of bubbles and market crashes (including flash crashes). Under the null hypothesis, a normal asset price behaviour follows a martingale process with a mild drift function. Rejection of the null implies a mild explosivity, which is indicative of an irregular asset market behaviour. The psymonitor test 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. This procedure repeats the ADF test on a sequence of samples, steadily rolling the window frame throughout the sample. When the null of no mild explosivity in asset prices is rejected, this period is date-stamped.

2.2. Contagion tests

Four contagion tests are employed to examine whether financial market relationships change across various co-moments. In the subsequent contagion tests, the S&P 500 index is the source market (denoted as i) and the recipient market is a given Caribbean stock exchange (denoted as j). It is well-known that Pearson correlation is conditional on market volatility and becomes spuriously over-inflated when the volatility associated with a crisis increases, which leads to a false positive detection of contagion (Boyer et al., 1999; Loretan and English, 2000; Forbes and Rigobon, 2002). Hence, we follow the empirical literature[2] and correct for the potential heteroskedasticity bias in the stressful market periods as described in Eq. (1):

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

where x represents the stable periods and y represents stressful scenarios, such that $\sigma^2_{x,i}$ and $\sigma^2_{y,i}$ are the real 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 following contagion tests to treat with possible heteroskedasticity bias in the co-moments.

2.2.1. Correlation test

We use the two-sided version of the Forbes and Rigobon (2002) significance test, suggested in Fry et al. (2010), for a change in the correlations between a source and recipient market during stressful and stable scenarios (denoted as $CR_{\overline{FR}}$). As Eq. (2) shows, by using $\hat{\rho}_{y|x_i}$ defined in Eq. (1), we are able to evaluate whether there is a difference in the correlations between the real S&P 500 and Caribbean stock exchange returns while controlling for potential heteroskedasticity bias

[2] 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).

under stressful scenarios in the source market:

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

where $\hat{\rho}_x$ is the Pearson correlation in the stable sample and, under the null hypothesis of "no contagion", the test statistic is asymptotically distributed as $CR_{\overline{FR}}(i \to j) \xrightarrow{d} \chi_1^2$. In addition, the variance in the denominator of Eq. (2) is the standard error of the numerator and is decomposed in Eq. (3):

$$Var\left(\widehat{\rho}_{y|x_i} - \widehat{\rho}_x\right) = Var\left(\widehat{\rho}_{y|x_i}\right) + Var\left(\widehat{\rho}_x\right) - 2Cov\left(\widehat{\rho}_{y|x_i}, \widehat{\rho}_x\right) \tag{3}$$

where the second term on the right hand side of the equation is a sampling variance of the correlation coefficient. An approximation for large samples, and moderate or small correlations has been derived in (Hotelling, 1953, p. 212) as $Var\left(\widehat{\rho}_x\right) = \frac{1}{T_x}\left(1 - \rho_x^2\right)^2$. As the relevant population value ρ_x is unknown in practice, it is replaced in the calculation by the corresponding sample value[3].

2.2.2. Co-volatility test

We apply the co-volatility (CV) contagion test in Eq. (4), suggested in Fry-McKibbin et al. (2014), to determine whether the volatility in S&P 500 market (denoted as r_i^2) is transmitted to the volatility of a particular real Caribbean stock exchange returns (denoted as r_j^2) during the stressful S&P 500 market sample (denoted as y) compared to stable sample (denoted as x):

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

where the standardisation parameters $\hat{\xi}_x(r_i^2, r_j^2)$ and $\hat{\xi}_y(r_i^2, r_j^2)$ are respectively defined in Eq. (5) and (6):

$$\hat{\xi}_x(r_i^2, r_j^2) = \frac{1}{T_x} \sum_{t=1}^{T_x} \left(\frac{x_{i,t} - \hat{\mu}_{xi}}{\hat{\sigma}_{xi}} \right)^2 \left(\frac{x_{j,t} - \hat{\mu}_{xj}}{\hat{\sigma}_{xj}} \right)^2 - (1 + 2\hat{\rho}_x^2) \tag{5}$$

[3] For a further decomposition and computation of the other terms, see the Appendix in Fry et al. (2010, p. 435-436).

$$\hat{\xi}_y(r_i^2, r_j^2) = \frac{1}{T_y} \sum_{t=1}^{T_y} \left(\frac{y_{i,t} - \hat{\mu}_{yi}}{\hat{\sigma}_{yi}} \right)^2 \left(\frac{y_{j,t} - \hat{\mu}_{yj}}{\hat{\sigma}_{yj}} \right)^2 - (1 + 2\hat{\rho}^2_{y|x_i}) \tag{6}$$

Under the null hypothesis of "no co-volatility contagion", the test is asymptotically distributed as $CV(i \to j) \xrightarrow{d} \chi^2_1$.

2.2.3. Co-skewness tests

We also consider potential contagion operating from higher moments of the real asset returns distribution. In particular, we employ the two variants of the co-skewness (CS) contagion test put forward in Fry et al. (2010) to test whether the mean real returns of the S&P 500 market (denoted as r_i^1) affect the volatility of real Caribbean stock returns (denoted as r_j^2) under stressful S&P 500 market scenarios (i.e., CS_1); as well as whether the S&P 500 market volatility (denoted as r_i^2) affects the mean real returns of Caribbean stock markets (denoted as r_j^1) under stressful S&P 500 market scenarios (i.e., CS_2). These tests are specified in Eqs. (7) and (8):

$$CS_1(i \to j; r_i^1, r_j^2) = \left(\frac{\hat{\psi}_y(r_i^1, r_j^2) - \hat{\psi}_x(r_i^1, r_j^2)}{\sqrt{(4\hat{\rho}^2_{y|x_i} + 2)/T_y + (4\hat{\rho}^2_x + 2)/T_x}} \right)^2 \tag{7}$$

$$CS_2(i \to j; r_i^2, r_j^1) = \left(\frac{\hat{\psi}_y(r_i^2, r_j^1) - \hat{\psi}_x(r_i^2, r_j^1)}{\sqrt{(4\hat{\rho}^2_{y|x_i} + 2)/T_y + (4\hat{\rho}^2_x + 2)/T_x}} \right)^2 \tag{8}$$

where 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. (9) and (10), respectively:

$$\hat{\psi}_x(r_i^m, r_j^n) = \frac{1}{T_x} \sum_{t=1}^{T_x} \left(\frac{x_{i,t} - \hat{\mu}_{xi}}{\hat{\sigma}_{xi}} \right)^m \left(\frac{x_{j,t} - \hat{\mu}_{xj}}{\hat{\sigma}_{xj}} \right)^n \tag{9}$$

$$\hat{\psi}_y(r_i^m, r_j^n) = \frac{1}{T_y} \sum_{t=1}^{T_y} \left(\frac{y_{i,t} - \hat{\mu}_{yi}}{\hat{\sigma}_{yi}} \right)^m \left(\frac{y_{j,t} - \hat{\mu}_{yj}}{\hat{\sigma}_{yj}} \right)^n \tag{10}$$

where r^m (r^n) is the standardised real returns for market i (j) in the CS_1 (CS_2) test version and squared standardised returns in the CS_2 (CS_1) test version. The test statistics in Eqs. (7) and (8), under their respective null hypotheses of "no co-skewness contagion", follow an asymptotic distribution defined as $CS(i \rightarrow j) \xrightarrow{d} \chi_1^2$.

3. Data

The data for the approaches to decompose the S&P 500 market into discrete stable and stressful regimes employs a time series of the VIX for the VIX clustering; the S&P 500 price index is used for the bull/bear market clustering; and the S&P 500 price dividend ratio is utilised for the asset bubble and crash clustering. Frontier markets in the Caribbean region, akin to the capital markets of small and developing economies, are relatively illiquid due to the limited amount of companies listed on these stock exchanges in comparison to those of advanced markets (CBTT FSR, 2019). Hence, our analysis uses monthly data to control for spurious results created by sporadic trading spikes. The start dates of the individual samples we use for the three Caribbean stock markets varies based on data availability. 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 A1 provides the sources and definitions of all the data used in the empirical analysis.

Following Samarakoon (2011), we compute real return shocks by working with ε_t of Eqs. (11) times 100:

$$r_t = \alpha_0 + \alpha_1 r_{t-1} + \varepsilon_t \tag{11}$$

where r_t are the real returns of the relevant stock price index P_t, with $r_t = \Delta \ln P_t$. The Bayesian information criterion suggests an optimal lag length of 1 for each of the models and the Lagrange multiplier test indicates an absence of serial correlation issues in the residuals, at the 5% level of significance, for up to 36 lags.

4. Results and discussion

In this section, we first consider the performance of the source market under the various identified stressful scenarios illustrated in Figure 1. Subsequently, we examine how real stock returns in both the source and recipient markets behave under the aforementioned identified stressful scenarios. We then analyse the results from the correlations and the tests for contagion. Subsequent to this, we perform robustness analyses.

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 $VIX_t > 20$. 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 subprime mortgage crisis and the GFC.

Next, graph (B) illustrates the bear phases in the real S&P 500 index detected by the Pagan and Sossounov (2003) sorting procedure[4]. Notable bearish market periods in the real 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 (2020) 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). The authors 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 (2020) analysis ends in July 2018, which is before our sample ends, we extend their application to November 2018 and find no bubbles or crashes detected within this additional period. Due to sample size limitations in both Jamaica and Barbados[5], testing for contagion across the various co-moments with this approach are demonstrated

[4]The algorithm is fed with data a year prior to the our longest sample start date (i.e., from 1993m1) in order to prime the model.

[5]The main asset bubble identified in S&P 500 market over our period of investigation reflects the internet bubble of the late 1990s and early 2000s. Therefore, months under a bubble state in the S&P 500 market largely predates our samples for Jamaica and Barbados.

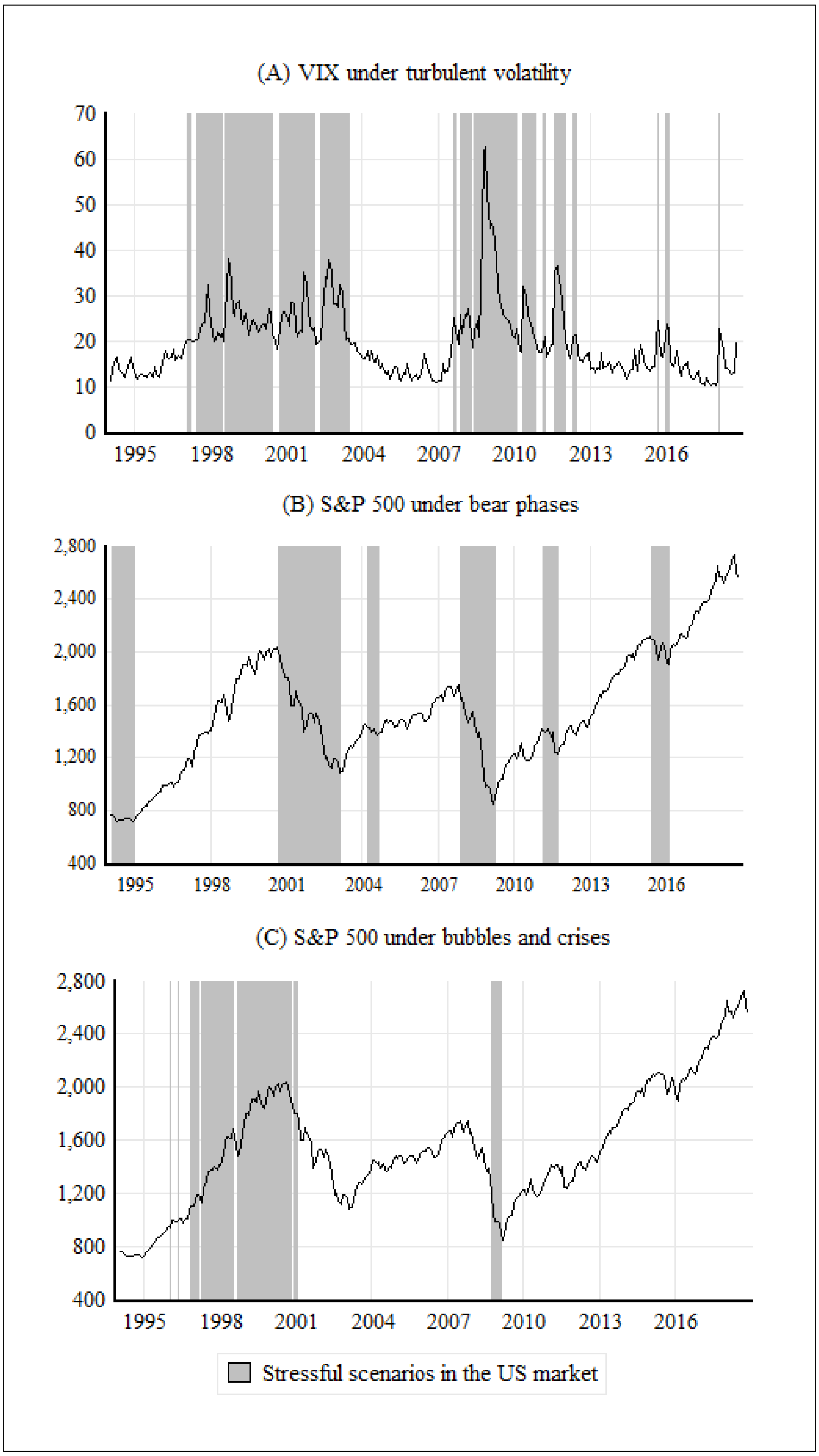

Figure 1: the VIX under turbulent volatility (A), the real S&P 500 index under bearish market phases (B), and the S&P 500 index under the dot-com asset bubble and subprime mortgage crisis identified by the psymonitor approach (C).

with the S&P 500 and Trinidad and Tobago stock markets.

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

In Table 3, the descriptive statistics of the S&P 500 real return shocks show a rise in volatility of real assets returns during stressful scenarios, indicating elevated investor uncertainty in this source market during such conditions. The mean has a tendency to fall under market stress as well, with the exception of the asset bubble periods which conveys the exuberance associated with speculative market behaviour. Furthermore, the negative (positive) mean of the real return shocks experienced under stressful (stable) scenarios are significantly different from zero for turbulent (tranquil) volatility and bear (bull) phases. Moreover, the average real return shocks in the source market are significantly different between tranquil versus turbulent volatility and bull and bear market phases, but the test for equality of means show that the average returns are equal between normal periods versus asset bubbles and crashes. Turning to higher moments of asset distributions, as risk averse investors typically have a preference for positive skewness to negative skewness, lower average real return shocks in stressful conditions can usually be partly explained by a trade-off for positive skewness in stressful conditions (see Fry et al., 2010, and references therein). Yet, this source market shows a contradictory tendency for increasing negative skewness in stressful scenarios. Nevertheless, kurtosis values for S&P 500 returns are typically elevated under stressful scenarios. This is consistent with *a priori* expectations that, as high kurtosis increases the likelihood of extreme values in the tail of an asset distribution, rising kurtosis are associated with crisis periods (Fry-McKibbin and Hsiao, 2018).

We subsequently consider the performance of the recipient markets by observing the asset distributions of their real return shocks under stressful source market scenarios. For illustrative purposes, the real return shocks for the Caribbean markets under the three identified stressful regimes are displayed in Figure 2. The descriptive statistics of Table 3 for Trinidad and Tobago convey that this frontier stock market exhibits the lowest monthly average real returns during bear phases in the S&P 500 market and the highest market volatility under the psymonitor identified periods

Table 3: S&P 500 and Caribbean stock returns summary statistics under alternative S&P 500 market scenarios.

			Source (S&P 500) market					Recipient (Caribbean) market					Correlation	
Country	Regime	Obs.	Mean	*t*-test	S.D.	Skew.	Kurt.	Mean	*t*-test	S.D.	Skew.	Kurt.	ρ	$\bar{\rho}$
Trinidad & Tobago	Overall	299	0.019		3.481	-1.088	8.309	0.000		2.923	0.414	6.385	0.072	
	Tranquil	181	0.526***		2.259	0.162	3.769	-0.038		2.592	0.588	5.311	0.022	
	Turbulent	118	-0.759*	2.774***	4.691	-0.776	5.416	0.058	-0.262	3.379	0.254	6.312	0.109	0.053
	Bull phase	219	0.770***		2.656	0.238	5.493	0.091		2.993	0.797	5.634	-0.107	
	Bear phase	80	-2.036***	5.236***	4.516	-1.043	5.871	-0.248	0.928	2.724	-1.049	8.530	0.357	0.219
	Normal	244	0.001		3.233	-0.701	5.257	-0.013		2.655	0.687	5.523	-0.025	
	Bubble	55	0.097	-0.152	4.454	-1.698	10.809	0.056	-0.123	3.927	-0.035	5.721	0.285	0.211
Jamaica	Overall	225	-0.197		3.596	-1.295	8.597	-0.023		4.073	0.582	5.577	0.160	
	Tranquil	141	0.458**		2.159	-0.063	3.157	0.242		4.199	0.518	5.562	0.154	
	Turbulent	84	-1.299**	3.051***	5.008	-0.744	5.048	-0.468	1.296	3.835	0.666	5.594	0.164	0.072
	Bull phase	156	0.703***		2.434	0.377	6.228	-0.032		3.541	0.377	4.471	0.078	
	Bear phase	69	-2.233***	4.815***	4.799	-0.905	5.185	-0.003	-0.042	5.107	0.683	5.129	0.254	0.132
Barbados	Overall	191	0.020		3.362	-1.571	11.582	-0.062		2.677	-0.132	9.725	0.023	
	Tranquil	136	0.494***		2.089	-0.016	3.074	0.189		2.979	-0.327	8.883	0.013	
	Turbulent	55	-1.153	2.282**	5.186	-0.931	5.905	-0.683***	2.628***	1.574	0.192	3.558	-0.064	-0.026
	Bull phase	150	0.710***		2.436	0.409	6.363	-0.056		2.839	-0.220	9.584	0.025	
	Bear phase	41	-2.506***	4.127***	4.824	-1.433	6.628	-0.083	0.069	2.004	0.806	3.647	0.026	0.013

Notes: the tranquil and turbulent S&P 500 market months categorised using practitioner's rule on the VIX is given by the inequalities $VIX \leq 20$ and $VIX > 20$, respectively. Bull phase and bear phase are the S&P 500 market conditions identified by the Pagan and Sossounov (2003) rule-based algorithm. Bubble/crash are the asset bubbles and crashes in the S&P 500 market identified in Phillips and Shi (2020) and normal periods are the conditions where there is relatively normal asset price behaviour. The mean is the monthly average real return shocks (%), with standard deviation (S.D.), skewness (Skew.), and kurtosis (Kurt.) describing the second, third, and fourth moments of the real return shocks, respectively. For the mean real return shocks, the $***$, $**$, and $*$ denote the conventional 1% (strong), 5% (moderate), and 10% (weak) levels of significance, respectively, of a *t*-test for the significance of these real return shocks from zero. In the t-test for equal means columns, the test statistics from two sample Welch's *t*-tests for the equality of means are used to compare real stock return shocks during the stable and stressful condition (see Welch, 1947). ρ is the Pearson correlation coefficient; $\bar{\rho}$ is the adjusted Pearson correlation coefficient.

which capture the dot-com asset bubble and the GFC. Kurtosis values are higher for Trinidad and Tobago real stock returns under stressful periods in the S&P 500 index when compared to stable periods. In Jamaica, the highest volatility is experienced in bearish S&P 500 market conditions, while the lowest negative real returns are observed when the VIX is experiencing turbulent volatility. For Barbados, average real stock returns underperform the most during times when the VIX is turbulent, while both the highest real returns and volatility are recorded in this recipient market when the VIX is tranquil. Under stressful S&P 500 market scenarios, kurtosis falls for the real asset returns of Barbados. With the exception of Barbados during turbulent volatility in the S&P 500 market, there is no substantive empirical evidence provided from either *t*-tests for the signif-

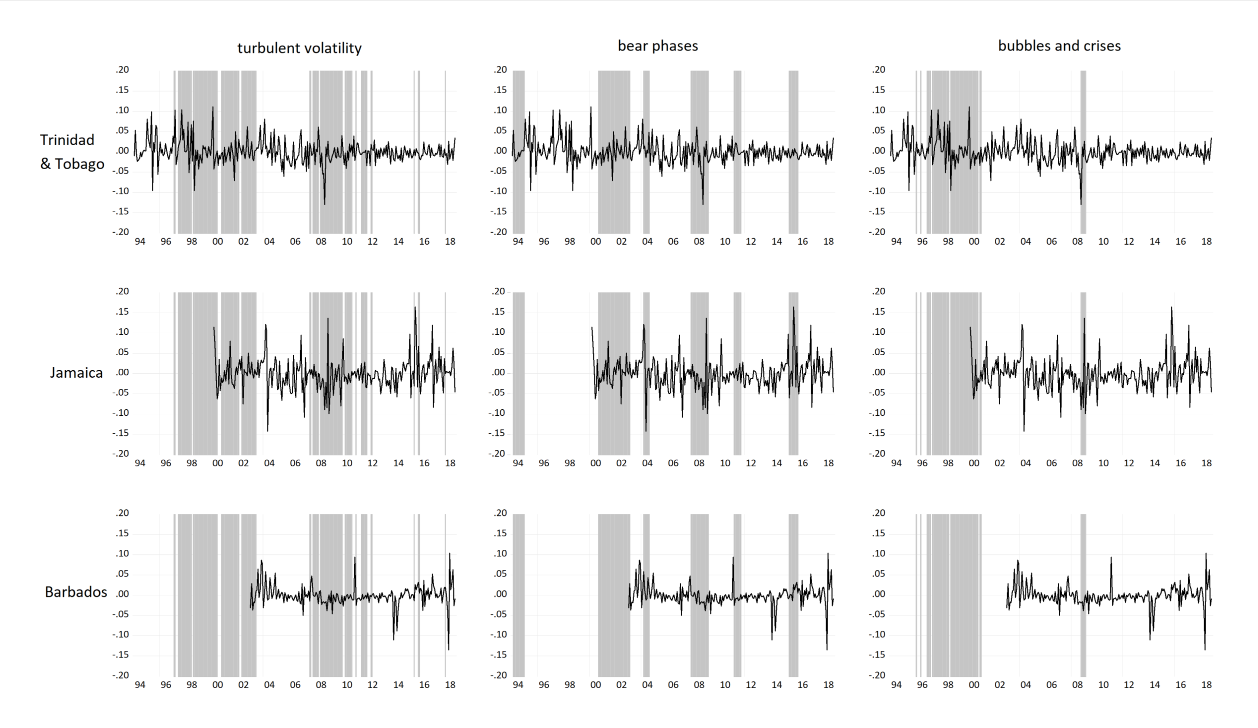

Figure 2: The return shocks of the Caribbean stock market indices and the regimes: tranquil versus turbulent ($VIX > 20$), bull versus bear phase (Pagan and Sossounov, 2003) and normal versus bubble/crash times in the S&P 500 market (Phillips and Shi, 2020) for our longest sample - i.e., from 1994M01 to 2018M11.

icance of the real returns from zero or the Welch (1947) t-test[6] for the equality of means in real Caribbean stock return shocks between stable and stressful conditions in the S&P 500 market.

We then compare the correlations between the real returns of the S&P 500 market and the real stock returns for each of the Caribbean territories, in stable period to stressful periods. We find relatively stronger relationships under S&P 500 market stress. However, the differences in the Pearson correlation coefficient (ρ) and its heteroskedasticity correction counterpart ($\bar{\rho}$) illustrates how the explosive volatility in a crisis can bias correlation estimates and lead to incorrect conclusions regarding contagion. Hence, we note that the correlations of asset returns between the S&P 500 market and the Caribbean stock markets are generally low. *Prima facie*, this contradicts the finding of Kali and Reyes (2010) who show that financial contagion is stronger if the epicentre

[6]The Welch (1947) two-sample t-tests to compare the equality of means has desirable properties over the Student's t-test. In particular, the former is robust to unequal variances and unequal sample sizes relative to the latter, reducing the incidence of a Type I error (Fagerland and Sandvik, 2009).

market has close trade ties with the recipient market, as well as those of Kaminsky and Reinhart (2000) who argue that contagion is a regional rather than global phenomenon. Reasonable explanations for the lack of financial integration are that, despite strong US and Caribbean trade linkages, the stock markets of emerging economies are relatively inefficient and illiquid which make them either sluggish to absorb current information (Arjoon et al., 2016) or generally insensitive.

Table 4: S&P 500 and Caribbean stock returns contagion estimates under alternative S&P 500 market scenarios.

Country	Regime	CR	CV	CS_1	CS_2
Trinidad & Tobago	Tranquil/Turbulent	0.127	85.075***	16.305***	14.812***
	Bull/Bear	12.275***	241.571***	8.155***	32.618***
	Normal/Bubble	4.324**	140.187***	26.466***	38.347***
Jamaica	Tranquil/Turbulent	0.763	0.010	2.078	3.552*
	Bull/Bear	0.285	0.776	0.208	4.851**
Barbados	Tranquil/Turbulent	0.145	1.309	0.104	0.034
	Bull/Bear	0.012	0.312	0.186	1.528

Notes: the tranquil and turbulent regime categorised using practitioner's rule on the VIX is given by the inequalities $VIX \leq 20$ and $VIX > 20$, respectively. Bull phase and bear phase are the S&P 500 market conditions identified by the Pagan and Sossounov (2003) rule-based algorithm. Bubble/crash are the asset bubbles and crashes in the S&P 500 market identified in Phillips and Shi (2020) and normal periods are the conditions where there is relatively normal asset price behaviour. For the contagion tests, $***$, $**$, and $*$ denote the conventional 1%, 5%, and 10% levels of significance, respectively, which corresponds to χ_1^2 critical values of 6.635, 3.841, and 2.706. Other abbreviations which apply are: CR ($r_{US} \rightarrow r_i$), CV ($r_{US}^2 \rightarrow r_i^2$), CS_1 ($r_{US} \rightarrow r_i^2$), and CS_2 ($r_{US}^2 \rightarrow r_i$) are the correlation, co-volatility, and the two variants of the co-skewness contagion tests, respectively, as defined in Eqs. (3)-(10).

The results of the contagion tests shown in Table 4 indicate that co-volatility and co-skewness contagion are detected from the S&P 500 market to the Trinidad and Tobago stock market, under all alternative stressful source market scenarios. For all stressful source market scenarios: the co-volatility test conveys that there is a statistically significant difference in the transmission of the S&P 500 market volatility to the Trinidad and Tobago stock market volatility; the CS_1 variant of the co-skewness test explains that the mean real returns of the S&P 500 market influence the real returns volatility of the Trinidad and Tobago stock market; while the CS_2 co-skewness test explains that the real returns volatility of the S&P 500 market affects the mean real returns of the Trinidad and Tobago stock market. On the other hand, the correlation contagion channel is identified as a source of contagion when comparing market relationships between the S&P 500 market and Trinidad and Tobago during bull versus bear states and normal periods versus asset bubbles/crashes but not between low and high volatility regimes implied by the VIX rule.

In the case of Jamaica, one of the co-skewness contagion tests which suggests that the S&P 500 market volatility affects the average Jamaican real stock returns is identified under both turbulent volatility and bear phases in S&P 500 market. The collective correlation analysis and contagion results for Trinidad and Tobago and Jamaica imply a general lack of financial integration between the US and these Caribbean stock markets in stable conditions but sensitivity to stressful periods sit well with the literature on both the heightened vulnerability of small island developing states (see, for example, Briguglio, 1995) and the view that the developing world is disproportionately negatively affected by global turmoil (see, for example, Dornbusch et al., 2000).

There is no evidence of contagion from the S&P 500 market to the Barbados stock market which, together with the descriptive statistics shown in Table 3, indicates a lack of connectivity between this recipient market with the source market. The detection of significant co-moment contagion tests for Trinidad and Tobago and the lack thereof for Barbados can possibly be linked to characteristics of these markets. As Table 2 documents, Trinidad and Tobago has a market capitalisation six time larger than Barbados with twice as many listings. The comparatively lower financial activity in Barbados, relative to Trinidad and Tobago, might help to explain the insignificant co-moment contagion results. Furthermore, as Barbados is the only country in our sample with a fixed exchange rate regime with the USD, our results appear to resonate with the findings suggested in Calvo and Mishkin (2003) regarding the relevance of exchange rate regimes for vulnerability to contagion.

4.3. Robustness analysis

We provide three robustness procedures to evaluate the stability of our results. Firstly, in robustness analysis 1, we test sensitivity by using alternative specifications to determine the regimes. Secondly, in robustness exercise 2, we exclude the Great Recession from the sample. And thirdly, in robustness test 3, we pre-filter the real return series with macro control variables.

4.3.1. Robustness analysis 1: results sensitivity to alternative identification of stable/stressful S&P 500 market scenarios

In robustness analysis 1, we perform sensitivity analysis for all three clustering strategies. The practitioners rule of a VIX threshold of 20 is replaced with a non-hierarchical k-means cluster algorithm to determine two regimes of market uncertainty. The cluster analysis employs Euclidean distance as the measure of similarity/dissimilarity in order to maximise between cluster variance and minimise within cluster variance of the two VIX groupings. For comparative purposes, the periods of turbulent volatility identified by the $VIX > 20$ rule (top-left graph) with the high volatility grouping suggested by the cluster analysis (bottom-left graph) in Figure 3 in the S&P 500 market for our longest sample - Trinidad and Tobago. As cluster analysis is a sample dependent method, the three Caribbean countries are analysed with different VIX thresholds. Table 5 shows that using shorter samples, as is the case for Jamaica and Barbados, the VIX clustering would be slightly different.

The bull/bear clustering algorithm of Pagan and Sossounov (2003) is replaced with the algorithm of Lunde and Timmermann (2004). We compare the results of two popular rule-based algorithms for identifying bull and bear market phases. Figure 3 shows the results derived from employing feasible combinations for calibrating the Lunde and Timmermann (2004) algorithm suggested in Kole and Van Dijk (2017)[7] (bottom-centre graph) and the calibration for the Pagan and Sossounov (2003) as we document earlier in the methodology section (top-centre graph). There is an overlap between these two approaches of 219 months for bull markets and 47 months for bear markets in the real S&P 500 index for the 299 total observation months in our longest sample from 1994m1 to 2018m11. This indicates a similarity rate of 89%. The dissimilarity comes entirely from the 33 months which the Lunde and Timmermann (2004) approach classifies as bullish, where the Pagan and Sossounov (2003) method identifies as bearish. A comparison in

[7]In the Lunde and Timmermann (2004) semi-parametric rule-based algorithm, a shift in a market phase is determined by two threshold scalars: λ_1 and λ_2, where λ_1 (λ_2) activates a switch from a bear (bull) to a bull (bear) market. We set $\lambda_1 = 0.20$, which indicates a minimum increase of 20% in the market index since the last trough will activate a switch from a bearish regime to a bullish regime; and $\lambda_2 = 0.15$, which provides a rule that a minimum decrease of 15% since the last peak is needed to activate a switch from a bull phase to a bear phase. These feasible combination are suggested in Lunde and Timmermann (2004) and employed in Kole and Van Dijk (2017).

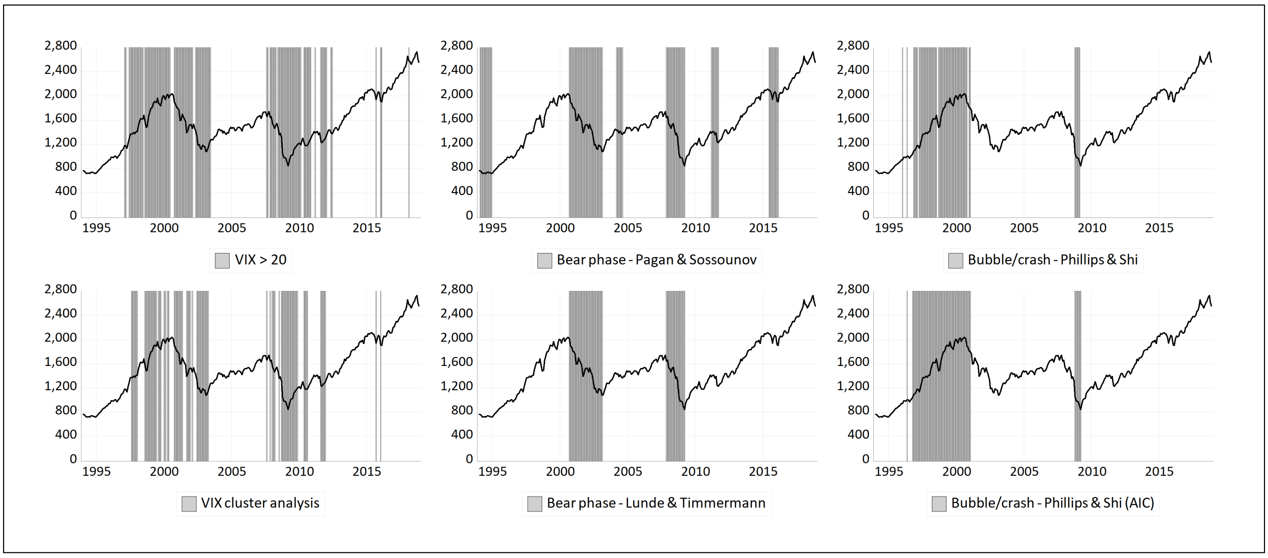

Figure 3: Comparison of alternative identification approaches for stable/stressful S&P 500 market scenarios. Top graphs show the stable/stress periods used for the main results and the bottom graphs show stable/stress periods used for robustness exercise 1, for our longest sample from 1994M01 to 2018M11.

Figure 3 of the results from the two approaches convey that the Lunde and Timmermann (2004) procedure is the more conservative of the two, understating historical bear market phases such as S&P downgrading of US sovereign debt in the summer of 2011 and the stock market selloff from the summer of 2015 up to the Brexit referendum result in early 2016.

In Phillips and Shi (2020) the lag length determination in the ADF tests had been performed by using the Bayesian information criterion with a maximum lag length of 6. In the sensitivity analysis, we allow potentially for a higher lag length in the ADF tests following the Akaike information criterion with a maximum of 18 lags. This leads to slightly different crises clustering: May 1996, October 1996 to January 2001, and October 2008 to March 2009. The results obtained from the specifications using the different information criteria are demonstrated in Figure 3, where the top-right graph employs the ADF test with the Bayesian information criterion and the bottom-right graph employs the ADF test with the Akaike information criterion.

As Table 5 conveys, the overall results of the contagion tests to the sensitivity check for each of our clustering strategies are similar to our baseline analysis.

Table 5: Sensitivity and robustness analysis.

Country	Regime	CR	CV	CS_1	CS_2
Robustness 1 - sensitivity of results					
Trinidad & Tobago	Tranquil/Turbulent	0.066	70.879***	16.740***	16.083***
	Bull/Bear	10.805***	99.697***	5.169**	15.868***
	Normal/Bubble	1.156	130.584***	34.556***	22.690***
Jamaica	Tranquil/Turbulent	0.000	0.116	3.203*	2.487
	Bull/Bear	0.423	1.423	2.408	9.746***
Barbados	Tranquil/Turbulent	0.161	0.828	0.468	0.013
	Bull/Bear	0.326	0.068	0.047	1.036
Robustness 2 - exclusion of the Global Financial Crisis event					
Trinidad & Tobago	Tranquil/Turbulent	0.737	0.007	1.238	0.050
	Bull/Bear	1.042	0.028	13.844***	1.578
	Normal/Bubble	0.104	0.000	4.015**	1.333
Jamaica	Tranquil/Turbulent	3.187*	3.091*	0.070	0.050
	Bull/Bear	0.048	0.754	0.213	0.091
Barbados	Tranquil/Turbulent	1.074	2.151	1.622	0.689
	Bull/Bear	0.192	0.004	0.856	0.102
Robustness 3 - inclusion of control variables for economic fundamentals					
Trinidad & Tobago	Tranquil/Turbulent	0.010	72.352***	15.405***	15.420***
	Bull/Bear	12.387***	204.233***	9.781***	29.450***
	Normal/Bubble	3.109*	113.742***	22.697***	34.422***
Jamaica	Tranquil/Turbulent	0.839	0.063	2.065	3.917**
	Bull/Bear	0.167	0.142	0.422	6.035**
Barbados	Tranquil/Turbulent	0.269	1.403	0.141	0.096
	Bull/Bear	0.074	0.071	0.234	1.501

Notes: **Robustness 1:** the tranquil and turbulent regime categorised using a non-hierarchical k-means cluster algorithm to sort the VIX, Trinidad & Tobago VIX > 22.8, Jamaica VIX > 23.6 and Barbados VIX > 24.1. Bull phase and bear phase are the S&P 500 market conditions identified by the Lunde and Timmermann (2004) rule-based algorithm. Bubble/crash are the asset bubbles and crashes in the S&P 500 market identified using Phillips and Shi (2020) while using the Akaike information criterion with a maximum of 18 lags in the ADF tests. **Robustness 2:** the results for this sensitivity test omits the recession in the US induced by Global Financial Crisis, which is dated from December 2007 - June 2009. For all other explanations, refer to the notes of Table (4). **Robustness 3:** the results of this sensitivity test are based on real returns adjusted for economic fundamentals, as suggested in Eq. (12). For all other explanations, refer to the notes of Table (4).

4.3.2. Robustness analysis 2: exclusion of the Great Recession in the US

In robustness analysis 2, we exclude the global financial crisis time period from the analysis. The NBER's Business Cycle Dating Committee determines that the Great Recession in the US occurred from December 2007 to June 2009[8], which captures the infamous collapse of Lehman Brothers and subprime mortgage crisis. Fry-McKibbin et al. (2014) show that, in a study of nine episodes of international financial turbulence between 1997 and 2013, the Great Recession stands out as a true episode of global financial turmoil. In Table 5, we observe that many statistically significant contagion results vanish when compared to main results illustrated in Table 4, highlighting that the Great Recession is indeed an unparalleled event within our sample. Although our general results complement those of Cozier and Watson (2019) who find little support for financial integration between the NYSE and Caribbean stock markets, we contrastingly find that the Great Recession originating in the US does in fact matter to the recipient markets of both Trinidad and Tobago and Jamaica.

4.3.3. Robustness analysis 3: returns net of market fundamentals

In robustness analysis 3, 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 account for international economic and financial fundamentals by working with ε_t in Eqs. (12). The Bayesian information criterion suggests an optimal lag length of 1 for each of these models and the Lagrange multiplier test indicates an absence of serial correlation issues in the residuals, at the 5% level of significance, for up to 36 lags. Real Caribbean stock market returns are adjusted using ε_t of Eqs. (12) times 100.

$$r_t = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 i_{t-1} + \alpha_3 r^{us}_{t-1} + \alpha_4 i^{us}_{t-1} + \alpha_5 r^{op}_{t-1} + \varepsilon_t \tag{12}$$

where r_t are the real returns of the relevant stock price index. i_t are the domestic interest rates. Additionally, lags of the real S&P 500 returns, US shadow short rates, and real oil returns are included in the Caribbean stock market regressions to account for international economic and financial fundamentals.[9] The real returns of the US are adjusted by regressing on the own lag, on US shadow short rates and on oil returns. Both oil price and interest rate changes are known

[8] Dating of US recessions and expansions are available at www.nber.org/cycles/recessions.html.

[9] The results of the regressions for adjusting the returns can be provided upon request made to the corresponding author.

to be important determinants of real sector activity (see, for example, Doğrul and Soytas, 2010) and are, therefore, appropriately controlled for to ensure that any market linkages suggested are over and above the economic environment. Nevertheless, as Table 5 depicts, our results obtained from pre-filtering of the real return series using fundamentals are qualitatively similar to our main results in Table 4.

5. Conclusion

We contribute to the financial contagion literature by comparing alternative approaches to decompose a source market into dichotomous sub-samples of stable and stressful periods for the construction of contagion tests. Using the S&P 500 index, 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 market and Caribbean stock exchanges change during the various episodes identified in the S&P 500 market. Our application provides a new way of considering how the stock market relationship between the US and small-island frontier Caribbean markets are affected under alternative conditions in the US financial market. The main results show that there are both within and between country variations in the stock market relationships between the S&P 500 index and the Caribbean under different US financial 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. Our specific findings for Trinidad and Tobago as well as Jamaica to a lesser extent, which convey that these frontier recipient markets have a generally weak relationship when the source market is thriving in stable periods (e.g. regimes of tranquil volatility and bull phases) but are still adversely impacted by the events of the 2008/2009 Global Financial Crisis, underscores the heightened vulnerability of small island developing states to stressful external scenarios.

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Appendix A.

Table A1: Data definitions and sources

Series and abbreviations	Definition	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.