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Asset Pricing, Investment, and Trading Strategies

Edited by

Wing-Keung Wong

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Editor
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Editorial Office
MDPI
St. Alban-Anlage 66
4052 Basel, Switzerland

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About the Editor

Wing-Keung Wong, obtained his Ph.D. from the University of Wisconsin-Madison, USA, with a major in Business Statistics (Statistics and Finance) and obtained his Bachelor's degree from the Chinese University of Hong Kong, Hong Kong, with a major in Mathematics and a double minor in Economics and Statistics. Currently, he is a Chair Professor at the Department of Finance, Asia University. He was a Full Professor at the Department of Economics, Hong Kong Baptist University, and Deputy Director at Risk Management Institute, National University of Singapore.

He appears in "Who's Who in the World". He is ranked in the top 1% by SSRN and in the list of top Taiwanese economists and Asian economists and top economists by RePEc. He has published more than three hundred papers, including papers published in some top journals. He has more than 11100 citations in Google Scholar and more than 9600 citations in Researchgate. His h-index is 59, and his i10-index is 225 based on Google Scholar citations.

He has been providing consultancy to several government departments and corporations, giving lectures and seminars to several universities, serving as editor, guest leading editor, advisor, associate editor for some international journals, and appointed as an external examiner.

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Article

Time-Varying Risk Aversion and the Profitability of Carry Trades: Evidence from the Cross-Quantilogram †

Riza Demirer [1], Rangan Gupta [2], Hossein Hassani [3,*] and Xu Huang [4]

[1] Department of Economics & Finance, Southern Illinois University Edwardsville, Edwardsville, IL 62026-1102, USA; rdemire@siue.edu
[2] Department of Economics, University of Pretoria, Pretoria 0002, South Africa; rangan.gupta@up.ac.za
[3] Research Institute of Energy Management and Planning (RIEMP), University of Tehran, Tehran 1417466191, Iran
[4] Faculty of Business and Law, De Montfort University, Leicester LE1 9BH, UK; xu.huang@dmu.ac.uk
* Correspondence: hassani.stat@gmail.com; Tel.: +98-436765383224
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Abstract: This paper examines the predictive power of time-varying risk aversion over payoffs to the carry trade strategy via the cross-quantilogram methodology. Our analysis yields significant evidence of directional predictability from risk aversion to daily carry trade returns tracked by the Deutsche Bank G10 Currency Future Harvest Total Return Index. The predictive power of risk aversion is found to be stronger during periods of moderate to high risk aversion and largely concentrated on extreme fluctuations in carry trade returns. While large crashes in carry trade returns are associated with significant rises in investors' risk aversion, we also found that booms in carry trade returns can be predicted at high quantiles of risk aversion. The results highlight the predictive role of extreme investor sentiment in currency markets and regime specific patterns in carry trade returns that can be captured via quantile-based predictive models.

Keywords: quantile; correlogram; dependence; predictability

JEL Classification: C22; F31

1. Introduction

Carry trade strategies aim to exploit deviations from the uncovered interest parity by investing in currencies that yield high interest rates and funding these positions by borrowing low-yielding currencies. Christiansen et al. (2011) note that the popularity of carry trades largely stems from the fact that the average carry trade strategy outperforms individual currency returns, while it offers lower return volatility compared to individual currencies. Despite their impressive risk-adjusted returns, these highly popular, speculative strategies are often exposed to severe crashes (e.g., Burnside et al. 2007; Brunnermeier et al. 2009), due to their high exposure to crash risks driven by funding constraints (Brunnermeier et al. 2009) or illiquidity risks (Plantin and Shin 2011).

In a recent study, Dietrich (2018) shows that the perception of future risk, proxied by implied currency volatility, captures predictive information over payoffs to carry trades with increases in the implied currency volatility predicting lower carry trade returns, and at the same time decreases in implied currency volatility causing higher carry trade returns. This finding indeed supports earlier evidence that carry trades generally perform well during calm markets (Plantin and Shin 2011), while carry trade crashes tend to occur when risk appetite decreases and funding conditions tighten

(Brunnermeier et al. 2009). Against this background, we extend these discussions in a novel direction by examining the predictability of payoffs to carry trades by means of the recently developed time-varying risk aversion index of Bekaert et al. (2017), which has been shown to contain significant predictive information over gold market volatility (Demirer et al. 2019), an asset that is often considered a traditional hedge against market crashes. Constructed based on a set of observable financial variables, including the realized and risk-neutral equity return variance and realized corporate bond return variance, among others, the risk aversion index presents a proxy for the time variation in the price of risk, independent from the time variation in market uncertainty. To that end, the use of this recently proposed index in this context allows enlarging our understanding of the role of changes in risk preferences over the profitability of speculative trading strategies in the currency market.

As a second novelty, we utilized the cross-quantilogram methodology of Han et al. (2016) to explore the directional predictability patterns at various quantiles that represent bull, bear, and normal market states. Linton and Whang (2007) introduced the quantilogram to measure predictability in different parts of the distribution of a stationary time series based on the correlogram of "quantile hits" and applied the quantilogram to test the hypothesis that a given time series has no directional predictability. Since the method is based on quantile hits, it does not require moment conditions like the ordinary correlogram and statistics like the variance ratio that are derived from it, and so it works well for heavy tailed series, which characterizes many financial time series, including returns to carry trading strategies (e.g., Burnside et al. 2007 and Brunnermeier et al. 2009). Moreover, this methodology allows researchers to consider very long lags in comparison with regression type methods. However, the approach by Linton and Whang (2007) is univariate and hence cannot be used to analyze the role played by a predictor. Given this, Han et al. (2016) extended the quantilogram to a cross-quantilogram, utilizing conditional quantiles rather than unconditional quantiles, thus allowing to measure directional dependence between two time-series (which in our case happens to be the directional predictability of carry trade returns due to risk-aversion) after parsimoniously controlling for the information at the time of prediction.

A unique feature of the cross-quantilogram methodology is its quantile-based focus, which allows us to capture predictability patterns at different quantiles that represent various market states, including extreme and normal market states. This feature of the cross-quantilogram fits perfectly in our context, considering that extreme speculator sentiment in currency markets is more correlated with future market movements than moderate sentiment (Wang 2004) and the evidence in Christiansen et al. (2011) that carry trade returns display regime-specific patterns, performing poorly during bear markets or high volatility states driven by sudden reversions during such periods (Burnside et al. 2008; Baillie and Chang 2011). Furthermore, as noted by Chung and Hong (2007), directional predictability instead of the predictability of the conditional mean has multiple advantages: First, the direction of changes provides important insights to market practitioners, since technical trading rules widely used by foreign exchange dealers are heavily based on predictions of direction of changes. Second, from the perspective of a statistician, it is relatively easier to predict the direction of changes than that of the predictions of the conditional mean, as directional predictability depends on all conditional moments. Finally, from an economist's point of view, the directional predictability of currency returns is more relevant as it is better able to capture a utility-based measure of predictability performance (such as economic profits). In addition, market timing (a form of active asset allocation management) is essentially the prediction of turning points in currency markets. To the best of our knowledge, this is the first attempt to study directional predictability of returns to the carry trade strategy emanating from risk aversion via the cross-quantilogram methodology.

Utilizing daily data for the Deutsche Bank G10 Currency Future Harvest Total Return Index to track the performance of a typical carry trade strategy, we show that risk aversion captures predictive information over payoffs to the currency carry trade strategy. While directional predictability is observed primarily at medium to high levels of risk aversion, we show that risk aversion can be useful in predicting the occurrence of both the crashes and booms in carry trades. Overall, the findings can provide a useful guideline for stress testing in carry trade strategies as they can help to explain the implications of extreme sentiment changes on the subsequent performance of these strategies. The remainder of the paper is organized as follows: Section 2 describes the methodology of cross-quantilograms, while Section 3 presents the data and results and Section 4 concludes the paper.

2. Methodology: The Cross-Quantilogram

In this section, we briefly describe the cross-quantilogram methodology developed by Han et al. (2016). Let $\{(y_t, x_t) : t \in \mathbb{Z}\}$ be strictly stationary time series with $y_t = (y_{1t}, y_{2t})^T \in \mathbb{R}^2$ and $x_t = (x_{1t}, x_{2t}) \in \mathbb{R}^{d_1} \times \mathbb{R}^{d_2}$, where $x_{it} = \left[x_{it}^{(1)}, \ldots, x_{it}^{(d_i)}\right]^T \in \mathbb{R}^{d_i}$ with $d_i \in \mathbb{N}$ for $i = 1, 2$. $F_{y_i|x_i}(.|x_{it})$ is used to denote the conditional distribution function of the series y_{it} given x_{it} with density function $f_{y_i|x_i}(.|x_{it})$, and the corresponding conditional quantile function is defined as $q_{i,t}(\tau_i) = inf\left\{v : F_{y_i|x_i}(v|x_{it}) \geq \tau_i\right\}$ for $\tau_i \in (0, 1)$, $i = 1, 2$. Let T be the range of quantiles we are interested in for evaluating the directional predictability, with T assumed to be a Cartesian product of two closed intervals in $(0, 1)$, i.e., $T \equiv T_1 \times T_2$, where $T_i = \left[\underline{\tau}_{i,} \overline{\tau}_i\right]$ for some $0 < \underline{\tau}_i < \overline{\tau}_i < 1$.

Han et al. (2016) considered a measure of serial dependence between two events $\left\{y_{1t} \leq q_{1,t}(\tau_1)\right\}$ and $\left\{y_{2,t-k} \leq q_{2,t-k}(\tau_2)\right\}$ for an arbitrary pair of $\tau = (\tau_1, \tau_2)^T \in T$ and for an integer k, where the event $\left\{1[y_{it} \leq q_{i,t}(.)]\right\}$, $(i = 1, 2)$ is described as the quantile-hit or quantile-exceedance process. The cross-quantilogram is then defined as the cross-correlation of the quantile-hit process as

$$\rho_\tau(k) = \frac{E\left[\psi_{\tau 1}(y_{1t} - q_{1,t}(\tau_1))\psi_{\tau 2}\left(y_{2,t-k} - q_{2,t-k}(\tau_2)\right)\right]}{\sqrt{E\left[\psi_{\tau_1}^2(y_{1t} - q_{1,t}(\tau_1))\right]}\sqrt{E\left[\psi_{\tau_2}^2\left(y_{2,t-k} - q_{2,t-k}(\tau_2)\right)\right]}} \tag{1}$$

for $k = 0, \pm 1, \pm 2, \ldots$, where $\psi_a(u) \equiv 1[u < 0] - a$.

To construct the sample analogue of the cross-quantilogram based on observations $\{(y_t, x_t)\}_{t=1}^T$, Han et al. (2016) first estimated conditional quantile functions using the linear quantile regression model of Koenker and Bassett (1978). Let $q_{i,t}(\tau_i) = x_{it}^T \beta_i(\tau_i)$ with a $d_i \times 1$ vector of unknown parameters $\beta_i(\tau_i)$ for $i = 1, 2$. To estimate the parameters $\beta(\tau) \equiv \left[\beta_1(\tau_1)^T, \beta_2(\tau_2)^T\right]^T$, Han et al. (2016) solved

$$\hat{\beta}_i(\tau_i) = arg \min_{\beta_i \in \mathbb{R}^{d_i}} \sum_{t=1}^{T} \varrho_{\tau_i}\left(y_{it} - x_{it}^T \beta_i\right),$$

where $\varrho_a(u) \equiv u(a - 1[u < 0])$. Let $\hat{\beta}_\tau \equiv \left[\hat{\beta}_1(\tau_1)^T, \hat{\beta}_2(\tau_2)^T\right]^T$ and $\hat{q}_{i,t}(\tau_i) = x_{it}^T \hat{\beta}_i(\tau_i)$ for $i = 1, 2$. This yields the sample cross-quantilogram formulated as

$$\hat{\rho}_\tau(k) = \frac{\sum_{t=k+1}^{T} \psi_{\tau_1}(y_{1t} - \hat{q}_{1,t}(\tau_1))\psi_{\tau_2}\left(y_{2,t-k} - \hat{q}_{2,t-k}(\tau_2)\right)}{\sqrt{\sum_{t=k+1}^{T} \psi_{\tau_1}^2(y_{1t} - \hat{q}_{1,t}(\tau_1))}\sqrt{\sum_{t=k+1}^{T} \psi_{\tau_2}^2\left(y_{2,t-k} - \hat{q}_{2,t-k}(\tau_2)\right)}}, \tag{2}$$

for $k = 0, \pm 1, \pm 2, \ldots$. Given a set of conditional quantiles, the cross-quantilogram considers dependence in terms of the direction of deviation from conditional quantiles and hence measures the directional predictability from one series to another. Note that, by construction: $\hat{\rho}_\tau(k) \in [-1, 1]$, with $\hat{\rho}_\tau(k) = 0$ corresponding to the case of no directional predictability.

The testing procedure involves the null hypothesis $H_0 : \rho_\tau(1) = \ldots = \rho_\tau(p) = 0$ against the alternative that $\rho_\tau(k) \neq 0$ for some $k \in \{1, \ldots, p\}$, assuming that $\tau \in T$ and p are given. In essence, this is a test for the directional predictability of events up to p lags $\left\{y_{2,t-k} \leq q_{2,t-k}(\tau_2)\ : k = 1, \ldots, p\right\}$ for $\left\{y_{1t} \leq q_{1,t}(\tau_1)\right\}$, evaluated using the Box–Ljung statistic formulated as

$$Q_{\tau}^{(p)} \equiv T(T+2) \sum_{k=1}^{p} \hat{\rho}_{\tau}^{2}(k)/(T-k). \tag{3}$$

3. Data and Empirical Findings

3.1. Data

The two variables of interest in our empirical analysis are the log-returns in percentage (first-difference of the natural logarithm times 100) for the Deutsche Bank G10 Currency Future Harvest Total Return Index (G10CHI) and the time-varying risk aversion index at daily frequency.[1] Focusing on G10 currencies (US Dollar, euro, Japanese yen, British pound, Swiss franc, Australian dollar, New Zealand dollar, Canadian dollar, Norwegian Krone, and Swedish krona), the G10CHI index tracks the performance of a typical carry trade strategy that invests in a basket of high-yielding currencies funded by short positions in a basket of low-yielding currencies, rebalanced every 3 months. Clearly speculative in nature, the investment strategy attempts to capitalize on the expectation that high-yielding currencies will on average outperform currencies with relatively lower interest rates. The index value is quoted in excess return terms representing the return from an unfunded investment.

In the case of time-varying risk aversion, we utilize the risk aversion index of Bekaert et al. (2017).[2] These authors developed a new measure of time-varying risk aversion based on a dynamic asset pricing model of two main risky asset classes, i.e., equity and corporate bonds, which incorporates a stochastic risk aversion term in addition to macroeconomic factors that drive cash flows. In this pricing framework, they assume a utility function in the hyperbolic absolute risk aversion (HARA) class and show that the price of risk is linked to the coefficient of relative risk aversion as well as the volatility of consumption growth. This framework, thus, allows risk aversion to enter the pricing kernel as a second factor that is not fully driven by fundamentals (proxied by consumption growth). The construction of the risk aversion series involves the use of observable financial information at high (daily) frequencies. Ultimately, this measure relies on a set of six financial instruments, namely, term spread, credit spread, a detrended dividend yield, realized and risk-neutral equity return variance, and realized corporate bond return variance. As discussed earlier, an important feature of this measure is that it distinguishes time variation in economic uncertainty (the amount of risk) from time variation in risk aversion (the price of risk) and thus provides an unbiased representation for changes in the risk preferences in the marketplace. The sample period covers 15 March 1993 to 30 December 2016, including 5944 observations. Note that while the start date is defined by the availability of the G10CHI index data,[3] the end date is due to the availability of the risk aversion index data.

3.2. Empirical Findings

As can be seen in the summary statistics reported in Table 1, both the risk aversion and carry trade return series (G10CHI) have excess kurtosis, indicating the occurrence of extreme observations in both variables. While the risk aversion index is positively skewed, possibly as the sample period covers periods of high market uncertainty and crisis like the 2007/2008 global financial crisis, carry trade returns are found to experience negative skewness, indicating greater likelihood of losses during

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1 The risk aversion index is stationary by design, while the log-return of the G10CHI ensures its stationarity, as per the requirement of using mean-reverting series for the cross-quantilogram estimation. Complete details of standard unit root tests conducted on the two variables are available upon request.

2 The data can be downloaded from: https://www.nancyxu.net/risk-aversion-index.

3 The data are available for download from: https://index.db.com/dbiqweb2/home.do?redirect=productpagelist&region=ALL&regionHidden=ALL&assetClass=FX&assetClassHidden=FX&returnStream=ALL&returnStreamHidden=ALL.

the sample period. Excess kurtosis, coupled with negative skewness observed for carry trade returns, is indeed consistent with Burnside et al. (2007) and Brunnermeier et al. (2009) that carry trades are often exposed to significant crashes. Overall, both the series are non-normal, which in turn motivates the use of a quantile-on-quantile based approach via the cross-quantilogram in our empirical analysis.[4]

Table 1. Summary statistics of carry trade return series and risk aversion index.

Statistics	G10CHI Return (%)	Risk Aversion Index
Mean	0.0274	2.7018
Median	0.0557	2.5312
Maximum	6.0717	27.1459
Minimum	−8.0140	2.2310
Std. Dev.	0.6337	0.8310
Skewness	−1.0322	13.7736
Kurtosis	17.7566	305.1085
Jarque-Bera	54,986.7400	22,792,372.0000
p-value	0.0000	0.0000
Observations	5944	

Note: G10CHI is Deutsche Bank G10 Currency Future Harvest Total Return Index. Std. Dev: stands for standard deviation; *p*-value corresponds to the Jarque–Bera test with the null of normality.

Figures 1–3 present the sample cross-quantilograms for the directional predictability from risk aversion to carry trade returns when risk aversion is in the low ($\alpha_2 = 0.1$), median ($\alpha_2 = 0.5$) and high ($\alpha_2 = 0.9$) quantiles, respectively. Similarly, the quantiles for the distribution of carry trade returns is denoted by α_1, ranging between 0.05 and 0.95. In each figure, the red dashed lines represent the 95% bootstrapped confidence intervals for no directional predictability with 1000 bootstrapped replicates. The corresponding Box–Ljung (portmanteau) statistics (in Equation (3)) to test the null of nonpredictability are reported in Figures A1–A3 in Appendix A.

Based on the size of the statistics, we generally observe stronger predictability patterns in Figures 2 and 3 as the level of risk aversion rises, suggesting that the predictive power of risk aversion over carry trade returns is generally more prevalent during periods of moderate to high risk aversion. In Figure 1, where risk aversion is in the lowest quantile, we observe generally insignificant cross-quantilogram estimates for the median quantile 0.50, suggesting that low risk aversion is not helpful in predicting whether carry trade return is located below or above its median.[5] On the other hand, at moderate to high levels of risk aversion in Figures 2 and 3, we observe that risk aversion can help to predict extreme low/high fluctuations in carry trade returns. For example, in Figure 3, when risk aversion is in the high quantile ($\alpha_2 = 0.90$), we see negative and highly significant cross-quantilogram estimates at

[4] As part of preliminary analysis, we conducted a wide variety of linear and nonlinear (nonparametric) conditional mean-based test of causality. In particular, the standard linear Granger causality test produced a test-statistic of 14.80, with a *p*-value of 0.00; the nonlinear tests of Diks and Panchenko (2006) had a test statistic of 2.14, with a *p*-value of 0.02; and the various nonlinear tests of Péguin-Feissolle et al. (2013) based on unknown functional forms, i.e., General Taylor-based, Semi-Additive Taylor-based, P-General Taylor-based, and Artificial Neural Network (ANN)-based had test statistics of 20.02, 10.24, 20.02, and 20.41, respectively, with all having *p*-values of 0.00. Naturally, all these tests rejected the null of no-Granger causality from risk aversion to carry trade returns. Further, the nonparametric Singular Spectrum Analysis (SSA)-based test of Hassani et al. (2010) yielded a value of 0.46 (i.e., <1), again suggesting predictive content of risk aversion for carry trade returns. Moreover, the nonparametric Convergent Cross Mapping (CCM) test of Sugihara et al. (2012) showed that carry trade returns has greater cross map skills to risk aversion than it is the other way round, thus confirming that risk aversion does indeed cause carry trade returns. Complete details of these tests are available upon request from the authors. Finally, the frequency-domain Granger causality test of Breitung and Candelon (2006) showed that risk aversion has predictive content for carry trade returns at a cycle length of less than 4 days, then at a cycle length of beyond 5 days, i.e., basically at short-, medium-, and long-horizons. While these conditional mean-based tests are helpful, they are silent about the causal relationship contingent on the state of these two variables, as well as of the sign of the impact, unlike our more powerful cross-quantilogram approach.

[5] The lack (weak evidence) of predictability around the median of the carry trade returns was also confirmed based on the quantiles (of the carry trade returns)-based causality test of Jeong et al. (2012). Complete details of these results are available upon request from the authors.

low quantiles of carry trade returns (α_1 = 0.05 and 0.10). This implies that when risk aversion is very high (higher than its 90% quantile), it is more likely to observe large carry trade crashes the next day. This is in line with Menkhoff et al. (2012) that carry trades tend to perform poorly during periods of increasing risk aversion and with Brunnermeier et al. (2009) that carry trade crashes tend to occur when risk appetite decreases and funding conditions tighten.[6] The corresponding Box–Ljung statistics for the null of non-predictability, reported in Figures A2 and A3 in the Appendix A, further confirm significant predictability patterns for all lags in the low quantile of carry trade returns, although the evidence is mixed at low risk aversion in Figure A1. Overall, the evidence so far indicates robust predictability patterns due to risk aversion that can be used to predict subsequent crashes in carry trade strategies.

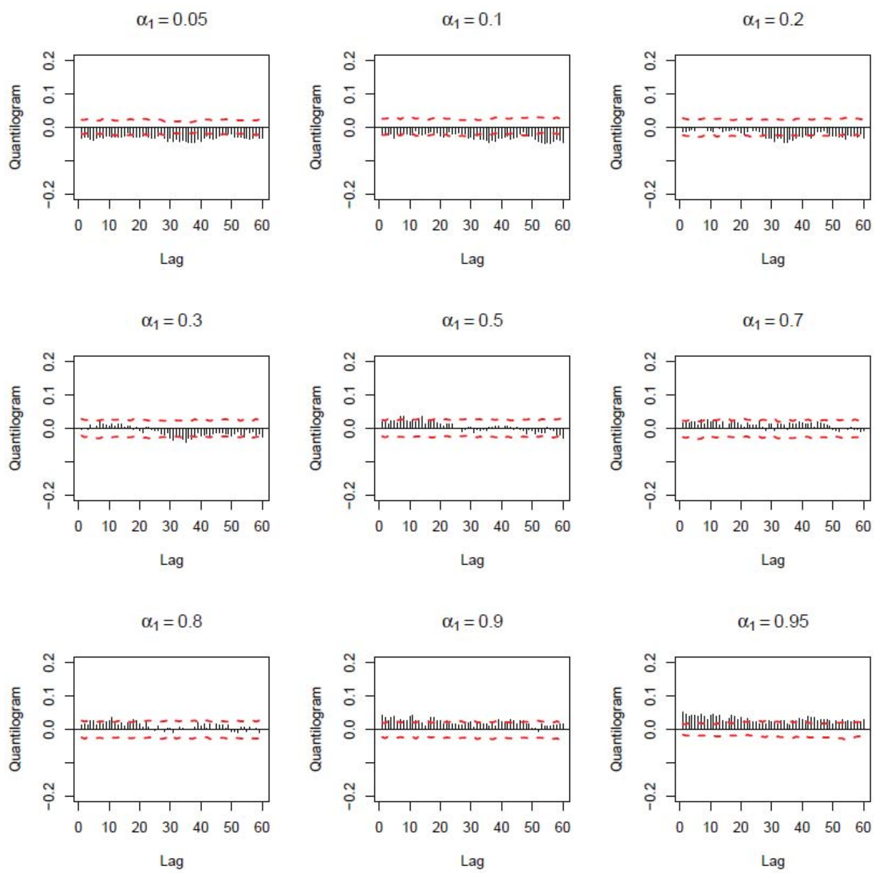

Figure 1. Sample cross-quantilograms for *low* risk aversion quantile (α_2 = 0.10). Note: The figures display the sample cross-quantilogram for the directional predictability from risk aversion to carry trade returns when risk aversion is in the low quantile (α_2 = 0.1). α_1 refers to the quantiles for the distribution of carry trade returns. Red dashed lines represent the 95% bootstrapped confidence intervals for no directional predictability with 1000 bootstrapped replicates.

[6] This pattern of negative relationship at lower quantiles and positive signs at higher quantiles relative to the median was also confirmed by the exceedance correlations of Ang and Chen (2002), complete details of which are available upon request from the authors.

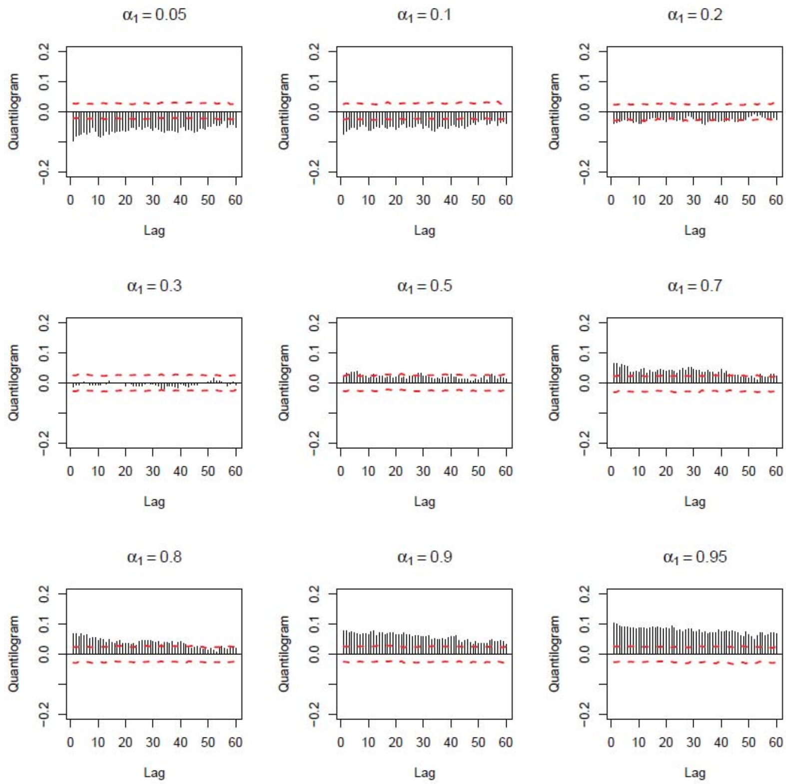

Figure 2. Sample cross-quantilograms for *median* risk aversion quantile (α_2 = 0.50). Note: The figures display the sample cross-quantilogram for the directional predictability from risk aversion to carry trade returns when risk aversion is in the median quantile (α_2 = 0.5). α_1 refers to the quantiles for the distribution of carry trade returns. Red dashed lines represent the 95% bootstrapped confidence intervals for no directional predictability with 1000 bootstrapped replicates.

Although risk aversion is found to negatively affect carry trade returns at quantiles below the median of the latter, we see that the effect turns positive at high quantiles of carry trade returns. Once again in Figures 2 and 3, we observe positive and highly significant cross-quantilogram estimates at high quantiles of carry trade returns (α_1 = 0.90 and 0.95). This means that high level of risk aversion can also predict large gains in carry trade strategies. Although it sounds counterintuitive at first, a plausible explanation is offered by Daviou and Paraschiv (2014), who examined investor behavior during periods of extreme fluctuations in market risk measured by the Chicago Board Options Exchange (CBOE) volatility index (VIX). Noting that practitioners use high values of the VIX as a signal of undervaluation in financial markets as relatively more risk-averse investors rush to unload their risky holdings during periods of high uncertainty, Daviou and Paraschiv (2014) argued that investors in fact do not necessarily lose confidence during extreme increases in risk. Instead, they argued, investors build confidence over sharp, subsequent declines in risk. To that end, the finding that extreme high level of risk aversion predicts large carry trade payoffs, implied by the positive cross-quantilogram estimates, can be due to under valuation of high yield currencies or over valuation of low yield currencies in the face of extremely high uncertainty (or risk aversion), as more risk-averse investors cover their short positions in low-yielding currencies by buying them back by selling off their positions in high-yielding currencies. This undervaluation of high yield currencies or overvaluation of low yield currencies, in turn, leads to large gains in subsequent periods for investors who operate on the expectation of sharp declines in risk. To that end, the findings add support to Egbers and Swinkels (2015) in that measures of investor sentiment (or market risk) could be used as timing indicators to exit and enter the currency carry trade within a conditional trading strategy to improve the profitability of carry trades.[7]

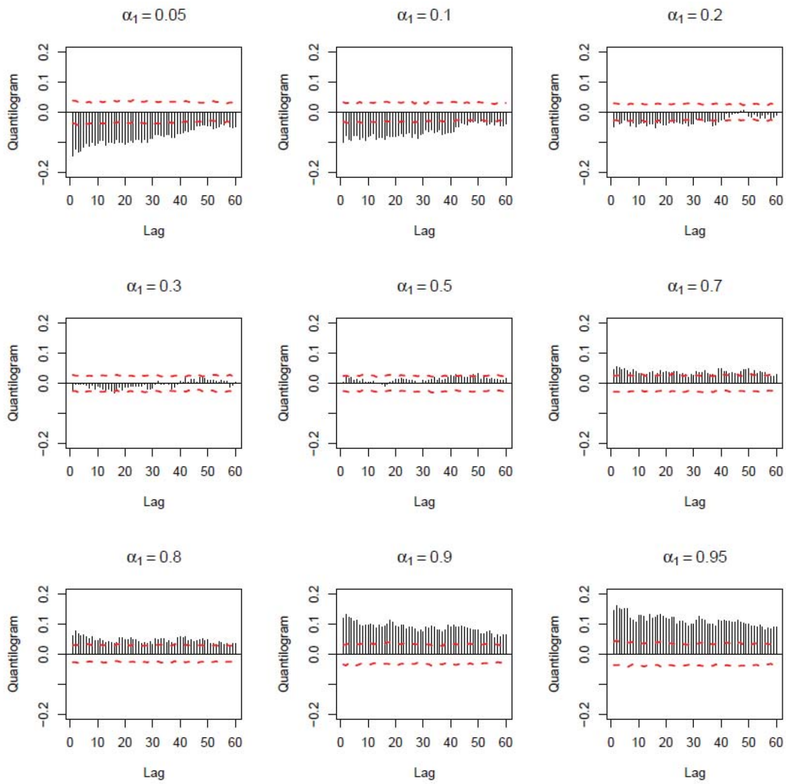

Figure 3. Sample cross-quantilograms for *high* risk aversion quantile (α_2 = 0.90). Note: The figures display the sample cross-quantilogram for the directional predictability from risk aversion to carry trade returns when risk aversion is in the high quantile (α_2 = 0.9). α_1 refers to the quantiles for the distribution of carry trade returns. Red dashed lines represent the 95% bootstrapped confidence intervals for no directional predictability with 1000 bootstrapped replicates.

4. Conclusions

This study examined the predictive power of time-varying risk aversion over the payoffs to the currency carry trade strategy that exploits mispricing patterns in low- and high-yielding currencies. Utilizing the cross-quantilogram methodology by Han et al. (2016) and the risk aversion index recently developed by Bekaert et al. (2017), we presented significant evidence of directional predictability from

[7] Robustness checks based on the G10 Currency Future Harvest, G10 Currency Harvest and Global Currency Harvest indexes in US dollars and Euro (derived from the same data source reported in Footnote 2) yield qualitatively similar results. Moreover, as suggested by an anonymous referee, we conducted our analysis for the G10CHI returns for subsamples covering from the start to 2007, and from 2007 to the end. Not surprisingly, we found that while the pattern of directional predictability remains the same, the effects are way stronger in the second subsample—a result that makes perfect sense, as the latter period corresponds to heightened risk aversion in the wake of the global financial crisis. Understandably, our full-sample results are driven by the post-crisis period. Complete details of these results are available upon request from the authors.

risk aversion to carry trade returns. While the predictive power of risk aversion was found to be stronger at moderate to high levels of risk aversion, we found that risk aversion possesses significant predictive ability over extreme fluctuations in carry trade returns, with directional predictability patterns observed both for crashes and booms in carry trades. The results overall highlight the role of extreme sentiment in predicting currency market fluctuations and suggest that quantile-based approaches such as the cross-quantilogram can be utilized to stress test speculative trading strategies by uncovering the implications of extreme fluctuations in market risk or risk appetite over subsequent returns.

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Appendix A

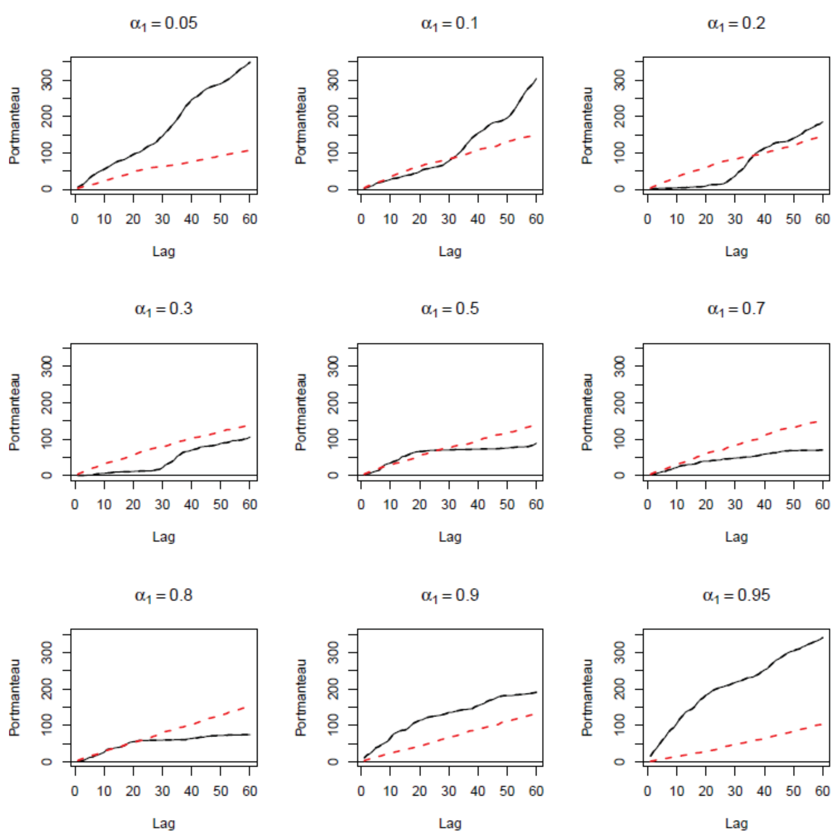

Figure A1. Box–Ljung test statistic for *low* risk aversion quantile (α_2 = 0.10). Note: The black line is the portmanteau test statistic and the red dashed line is the 95% bootstrap confidence intervals for 1000 bootstrap iterations.

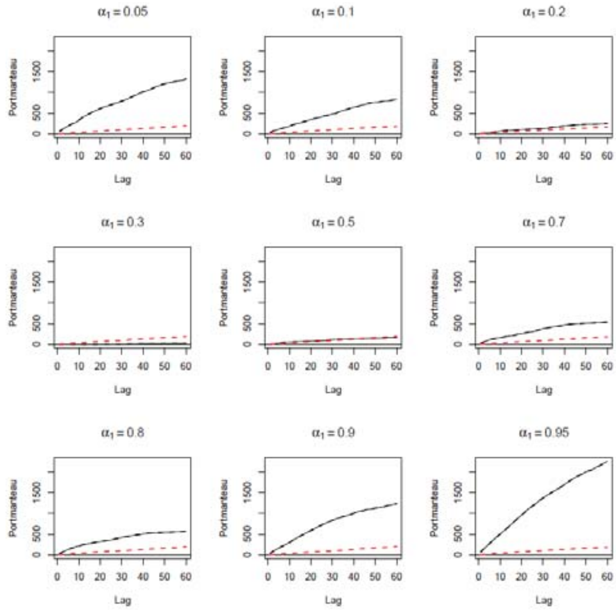

Figure A2. Box–Ljung test statistic for *median* risk aversion quantile (α_2 = 0.50). Note: The black line is the portmanteau test statistic and the red dashed line is the 95% bootstrap confidence intervals for 1000 bootstrap iterations.

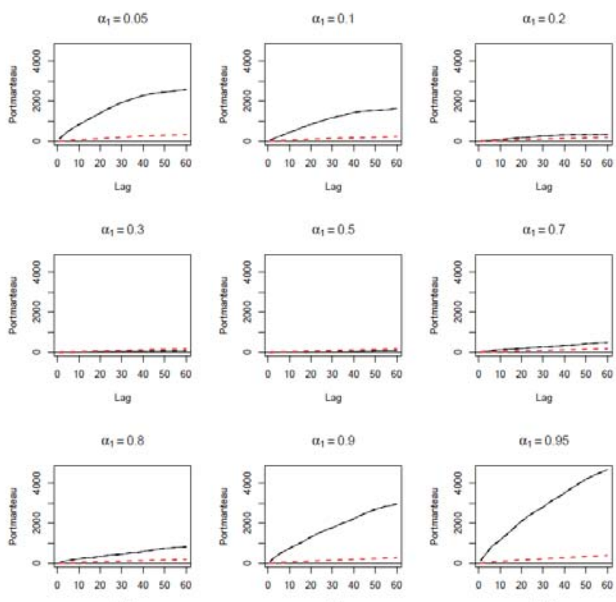

Figure A3. Box–Ljung test statistic for *high* risk aversion quantile (α_2 = 0.90). Note: The black line is the portmanteau test statistic and the red dashed line is the 95% bootstrap confidence intervals for 1000 bootstrap iterations.

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Article

State Ownership and Risk-Taking Behavior: An Empirical Approach to Get Better Profitability, Investment, and Trading Strategies for Listed Corporates in Vietnam

Tran Thai Ha Nguyen [1,2], Massoud Moslehpour [1,3], Thi Thuy Van Vo [2] and Wing-Keung Wong [4,5,6,*]

1 Department of Business Administration, Asia University, Taichung 41354, Taiwan; nguyen.tranthaiha@sgu.edu.vn (T.T.H.N.); mm@asia.edu.tw (M.M.)
2 Faculty of Finance and Accounting, Saigon University, Ho Chi Minh City 700000, Vietnam; vothuyvan@sgu.edu.vn
3 Department of Management, California State University, San Bernardino, CA 92407, USA
4 Department of Finance, Fintech Center, and Big Data Research Center, Asia University, Taichung 41354, Taiwan
5 Department of Medical Research, China Medical University Hospital, Taichung City 404, Taiwan
6 Department of Economics and Finance, The Hang Seng University of Hong Kong, Hong Kong
* Correspondence: wong@asia.edu.tw; Tel.: +886-4-2332-3456 (ext. 1946)

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Abstract: Corporate risk-taking behavior and investment is a crucial factor in order to seek higher profits and a better trading strategy. Competitive advantage and innovation, while maintaining profitability and state ownership, are considered as crucial resources. Furthermore, it is essential to connect the short-term and long-term business and investment objectives plus stakeholder's expectations to corporate sustainability and development. This connection is especially important in the context of transforming economies and getting better trading strategies. This study estimates the relationship between state ownership, profitability, corporate risk-taking behavior, and investment in Vietnam by using Generalized Method of Moments (GMM) methods. Using the data of 501 listed non-financial corporates during the period 2007–2015 from Ho Chi Minh City and Hanoi Stock Exchanges, we find that profitability is determined as a factor to reduce corporate risk-taking acceptance caused by the chances of entrenchment. Meanwhile, the impact of state ownership on the risk appetite of corporate has a non-linear effect. In particular, state ownership reduces corporate risk-taking behavior and investment but yet increases the risk-taking behavior and investment when the state ownership rate exceeds a threshold. One the one hand, this implies that the low level of state ownership not only prevents risk-taking behavior and investment but also results in more severe agency problems, causing unsustainability due to the imbalance of interests among various stakeholders. On the other hand, a dominant role of state ownership concentration causes a boost in corporate risk-taking decision-making in investment and trading strategy, leveraging the connection of significant external resources to deal with uncertain problems. The study contributes to existing theories of corporate governance in the context of a socialist-oriented market.

Keywords: market efficiency; state ownership; risk-taking behavior; investment; Vietnam; GMM; nonlinearity; trading strategy

JEL Classification: G30; G38

1. Introduction

Risk-taking behavior and trading strategy play a vital role in the choice of corporate investment activities and are critical to creating the development of a corporate since they provide opportunities for innovation, and improve performance and competitive advantages (Cheng et al. 2020; Li and Liu 2017; Zhai et al. 2015; Shoham and Fiegenbaum 2002). Under uncertain business environments, corporates make different decisions that reflect strategic choices with uncertain consequences to improve their competitive advantage and performance (Hoskisson et al. 2016). For example, choices related to spending on research and development, acquisitions and divestitures, or competition actions. These choices mirror, as an indicator of, corporate risk-taking behavior. Stulz (2015) argued that corporates cannot maximize the shareholders' wealth and their revenue without taking risks. Thus, a corporate achieves efficiency, capital accumulation, and technological innovation through risk-taking activities and investments. However, excessive risk-taking behavior and investment can have a negative impact on corporate performance, since it consumes corporate resources such as capital, labor, and equipment. Excessive risk-taking can create an imbalance among all stakeholders, including the owner (Younas and Zafar 2019). Therefore, an investigation of corporate risk-taking behavior and investment is essential, not only for scholars but also for practicers in improving corporate governance.

Literature has shown that corporate risk-taking behavior, investment, and trading strategy is associated with structure and corporate governance (Faccio et al. 2016; Su et al. 2016), relying on the risk preferences and investment horizons of different shareholders (Vo 2018). Uddin (2016) believed that the government having ownership in a corporate directly influences its risk-taking decisions on investment and trading strategy, which determine the performance, survival, and growth of the corporate in the competitive market environment. Previous studies recognize that corporate activities are also affected by the unequal treatment between the public and non-public sectors in taking some risks to gain competitive advantages and achieve innovation (Zhou et al. 2016; Song et al. 2016). State-owned enterprises (SOEs), with their political connections, typically receive a multitude of financial and policy incentives that help to increase their performance and competitiveness (Ben-Nasr et al. 2015). Therefore, SOE managers believe that they can also reduce external uncertainties through political relations (Schweizer et al. 2019). However, political connections can derail corporate strategy in various ways (Fan et al. 2007). SOEs generally suffer from excessive interference and a lack of independence needed to conduct business activities (Bhatti and Sarwet 2011; Fan et al. 2007). They have also reoriented the goals and activities of corporates, thereby making them very different from governance principles (Abramov et al. 2017). Besides, SOE managers tend to focus on achieving social objectives and short-term political goals instead of maximizing their performance (Kang and Kim 2012). The above arguments raise an interesting question, that is whether or not corporates with state connections should take more risky investments to maintain their performance.

Moreover, Vietnam is identified as an excellent research sample for the influences of state ownership because it is not only an emerging transitional country but also has a history of a centrally-planned economy with the dominance of state and state-owned firms (Vo 2018). Although, since the 1986 reform, the rate of state property ownership among SOEs in Vietnam has declined significantly, the role of state ownership is still important because it is often considered as the "tactful" tool for the intervention and orientation of the government into the market (Ben-Nasr et al. 2015). Thus, our study provides helpful insights into the relationships among state ownership and corporate risk-taking behavior, investment, and trading strategy, thereby contributing to the management theories and practical implications in the context of Vietnam. There are three important goals for this study. Firstly, most of the existing literature focuses on SOEs' behavior in developed markets, whereas few are conducted for transitional economies (Khaw et al. 2016). Vietnam offers an ideal setting to examine the link between state ownership and risk-taking behavior, investment, and trading strategy for the typical characteristics of a socialist-oriented market and where SOEs have received strong support from the government. Moreover, prior studies on the Vietnamese market focus on investigating the relationship between state ownership and firm performance (e.g., Nguyen et al. 2019; Phung and Mishra 2015;

Quang and Xin 2014; Nguyen et al. 2013) without pointing out whether state ownership promotes or reduces risk-taking behavior and investment by corporates. Therefore, the first goal of this study will fill this research gap.

Secondly, the study highlights the critical role of ownership structure and the duality of state–corporate relations. On the one hand, prior studies suggested a positive association between state ownership and corporate risk-taking behavior and investment (Zhai et al. 2015; Wang et al. 2008). On the other hand, other studies assert that state ownership is negatively associated with risk-taking activities and investments (Vo 2018; Zhou et al. 2016). Since government objectives reflect the interests of the government, discord might be caused between government and other shareholders in deciding corporate risk-taking activities and investments. Thus, the level of government shareholding can have a non-linear effect on corporate risk-taking behavior and investment (Uddin 2016). The next goal of this study will address this ambiguous issue. Thirdly, the study also considers the role of corporate efficiency and growth of revenue, debt, and fixed assets in association with corporate risk-taking acceptance. This study, therefore, adds to the current literature on the analysis of the risk-taking behavior and investment of SOEs in Vietnam, a transitional economy where state-owned corporates remain dominant, and thus enriching studies of state ownership. This contribution is essential in the context of a transition economy, often characterized by weak institutions and uncertainties.

In addition to the introduction, the structure of the paper is as follows: Section 2 presents the literature review. Section 3 states hypotheses and discuss the theory used in our paper, Section 4 describes empirical models and the data collection procedures in our paper, and Section 5 shows the results; Section 6 discusses, and Section 7 gives the conclusions and implications of the study.

2. Literature Review

Risk-taking behavior is a combination of several factors, such as agency theory, prospect theory, and resource dependence theory, as well as political connections (Sharma et al. 2020; Díez-Esteban et al. 2017; Uddin 2016). Risk-taking behavior illustrates the manager's risk-bearing with an organization's needs (Nobre et al. 2018). Risk-taking behavior reflects strategic choices with uncertain consequences to improve the competitive advantage and performance of the corporate. Thus, innovative strategies and competitive determinants will impact whether organizations will be risk-aversive or risk-assertive (Shoham and Fiegenbaum 2002).

Theoretically, the manager's risk-taking behavior reflects the effect of the level of equity holdings relative to managers' compensation, hence reflecting the agency problem. Typically, equity-based compensation will provide managers the incentive to undertake more risky but value-increasing investment projects and vice versa (Chen and Ma 2011). However, managers may be overconfident about their capabilities, lack understanding of market uncertainties, or try to find luck with risks (Kraus et al. 2011; Vereshchagina and Hopenhayn 2009). As such, it is accepted that risk does not yield a risk premium and does not lead to better performance. Therefore, Gillette et al. (2003) showed that the corporate insiders who are involved in the management of firms have both negative and positive incentives for taking risks due to the divergence of their interests in the firm. Thus, Hoskisson et al. (2016) proposed that the risk-taking behavior of a corporate can be significantly influenced by concentrated ownership and institutional ownership (the owner who holds their stock long term) because those owners have a stronger influence in corporate decision-making.

Friedman (1962) argued that the role of government is to establish a policy and legal framework, enforce rights to reduce monopolies, and prevent misconduct. However, the fact is that the government is also involved in the economy through different forms. For example, it can establish wholly-owned corporates in the early stages of market development and transfer ownership to private owners through full or partial privatization (Uddin 2016). This makes the government a majority or minority shareholder, which allows them to influence the decisions of the corporates, including risk-taking, directly. The empirical results of previous studies of state ownership and risk-taking behavior are also found to be disparate across countries, especially in transition economies (Song et al. 2016;

Ben-Nasr et al. 2015). Khan et al. (2019) shed light on the prominent status of state-owners, that they are more likely to engage in social activities, indicating that they try to harmonize the interests of stakeholders. Thus, corporates with political connections have better performance and sustainability and less risk-taking behavior (Abramov et al. 2017).

The risk avoidance behavior of SOEs becomes stronger in markets with weak corporate governance and poor investor protection environments. Transition markets, such as Vietnam or China, are characterized by the dominance of state ownership in firms, especially in the past (Vo 2018; Luo et al. 2017). Moreover, in the defective business environment, corporates need to take more risks to reap higher profits. This makes the role of internal owners overwhelm the voices and interests of outside minority shareholders. The outside shareholders often succumb to the political pressure of the state, who is also a corporate owner (Durnev et al. 2004). However, SOEs do not need to take more risks because they already have a competitive advantage and better access to financial resources as well as a tax reduction (Vo 2018).

Moreover, instead of pursuing risky projects (uncertain return), state-owners appointed by the government are often asked to focus on socio-political objectives to ensure balance and the stability of society. State owners strive to protect previous achievements and the reputation of the government, such as creating jobs, social services, and public utilities, in political tenure, instead of investing in risky projects that might lead to uncertainty in markets (Boubakri et al. 2013; Fogel et al. 2008). In addition, SOE managers generally face difficulties in corporate governance because of state intervention, a lack of corporate governance skills, and a lack of the necessary independence (Lin et al. 2009). For this reason, they will not bet their political career on risky projects. This is especially true in socialist-oriented economies where the government often focuses on ensuring social stability and creating employment and, as such, avoid risky activities (Abramov et al. 2017; Fogel et al. 2008).

Conversely, some studies suggest that SOEs are willing to risk risky projects because they know that they receive strong support from the government to overcome the risks of the inefficient business environment (Farag and Mallin 2016; Zhai et al. 2015). Uddin (2016) claimed that internal owners involved in managing a business might be more risk-taking acceptant if the growth of corporate value is worth to them. Moreover, corporate state-owners also implement economic goals such as increasing government revenue through corporate income tax and dividends or developing capital markets through leading projects (De la Torre et al. 2007). These goals will be possible in a relatively stable, competitive, and transparent economy where SOE managers have enough independence and information to make their decisions (Uddin 2016; Vo 2018). Under increasing competitive pressure, SOEs also take risks to establish a leading position and contribute more to government revenues. The relationship with the government is itself a political pressure on SOEs, especially firms with the state being the majority shareholders. Therefore, Chong et al. (2018) suggested that state ownership can affect corporate risk-taking, but the non-linear effect of these political connections needs to be considered.

In summary, we realize that there are various findings regarding the influence of state ownership on firms' risk-taking behavior, not only related to aspects of agency problems but also political links and resource dependence. The tension in the nexus between profitability and stability gives rise to agency conflicts of interest. Therefore, this study explains this relationship by analyzing the influence of state ownership on the risk-taking behavior of listed corporates in Vietnam.

3. Theories and Hypotheses

Literature has considered that the risk-taking behavior of corporates could be explained through the lens of prospect theory and (Kahneman and Tversky 1979; Wong and Chan 2008). The prospective theory provides an explanation for an individual or organization's decision making under risk through the target. The individuals or organizations refuse to accept more risk when the expected result is higher than the target (i.e., profit). Conversely, they try to fill the gap by accepting more risk when the expected outcome is below the target (Frugier 2016). In other words, prospect theory explains risk-taking behavior through the identification of targeted outcomes, providing clues for trying to identify causal mechanisms that explain the different levels of risk-taking behavior at organizations. Agency theory also identifies that risk-taking avoidance is caused by conflicts between managers, who are concerned about market and business risks, and shareholders, who diversify their portfolios to earn higher profits (Jensen and Meckling 1976). Basically, the major key to driving a corporate's risk-taking behavior is expected profitability. When a corporate has already expected profitability and managers are compensated based on profitability, they prefer getting a stable income without taking any high-risk decisions. Therefore, the first hypothesis of the study is:

Hypothesis 1 (H1). *Profitability has a negative impact on corporate risk-taking behavior.*

Although agency theory refers to the conflict between managers and shareholders, it may also explain the behavior of state owners as inside owners. On the one hand, these authors maintain that outside shareholders prefer higher risk-taking for a higher return. Meanwhile, it is not the same case for inside owners such as managers or founding shareholders as their interests are tied to total wealth portfolios, personal gains and losses, and chances of entrenchment (Uddin 2016). State ownership also leads to the situation in which the de facto owner and SOE staff are state agents. Therefore, agency theory is also relevant to SOEs, e.g., the conflict of interest between shareholders and agents. SOE agents have little incentive to strive for achieving high economic efficiency; they tend to avoid risks to ensure safety for their positions and benefits. Su et al. (2016) argued that corporates with low risk-taking behavior often have more severe agency problems in order to uphold personal benefits.

Political connections are a useful link to external resources with considerable power and influence. Political connections are defined as informal social connections with officials at the constituent parts of public authorities (Sun et al. 2012). Uddin (2016) suggested that although a corporate's risk reflects the diversity of shareholder benefits, the government is the most politically powerful shareholder, regardless of its level of ownership. Thus, the government's interest reflects the level of risk-taking of corporates (Sharma et al. 2020). Previous research on political connections shows that it often has an impact on corporate operating, although there are some exceptions (Ang et al. 2013). The literature on political connection shows that the advantages of political relations can bring better results (Ling et al. 2016; Boubakri et al. 2013), competitive advantages (Frynas et al. 2006), higher bailout packages from the government (Faccio et al. 2006), or lower capital costs (Boubakri et al. 2012). SOE agents have little incentive to strive for achieving high economic efficiency. Instead, they tend to avoid risks to ensure safety for their positions and benefits. This leads to more severe incentive issues and a more pronounced loss of economic efficiency in SOEs (Young et al. 2014).

Thus, the existence of state ownership is considered to have a significant influence on the corporate's risk-taking behavior, thereby changing its investment and trading strategies to achieve high profitability. Based on the above arguments, it is important to state that the involvement of state ownership in a corporate leads to less risk-taking behavior, as in the below hypothesis:

Hypothesis 2 (H2). *State ownership has a negative impact on corporate risk-taking behavior.*

The theory of resource dependence emphasizes that corporates encounter dependencies when they need resources from outside, and influencing and responding to external dependencies is a key task of management (Lux et al. 2010). External links between firms and important sources are a coping mechanism to reduce the risk and uncertainty faced by corporates (Pfeffer and Salancik 1978). Government policy and regulation is a significant force in the external environment (Hillman et al. 1999). However, this interaction depends on the relative strength of the involved parties when internal and external organizations exchange resources and the dependence level of each (Casciaro and Piskorski 2005; Pfeffer and Salancik 1978). Therefore, a corporate will be more dependent on environmental uncertainty and the power of external resources (Santos and Eisenhardt 2005; Pfeffer and Salancik 1978). Díez-Esteban et al. (2017) discovered that this relationship is affected by the nature of the dominant shareholder, which is an important factor in corporate decision-making. This view was confirmed by Uddin (2016), who argued that (i) how the government, as the country's most powerful political institution, works with other insiders in public; and (ii) how the corporate and the government on the board affect decision making affect the corporate's attitude toward risk-taking, leading to more cautious reactions (accepting or avoiding risks), with changes in operating results.

SOEs receive external resources from political links in the forms of financial support from the government, tax breaks, or better access to information (Faccio 2010; Faccio et al. 2006). Besides, managers of large SOEs believe that they are "too big to fail" or, in other words, protected from bankruptcy due to the consequences of risky investments (Najid and Rahman 2011). Therefore, ownership links with the government transmit a signal to encourage venture investments because of the government advocates and protection of risky investments (Uddin 2016; Zhai et al. 2015). Although the government gives priority to socio-political goals to maximize social stability and employment (helping to ensure the government's political tenure), the government also receives a lot of taxes, dividends, and long-term capital gains if corporates can make successful risk investments. These goals are contradictory in the short term but not in the long run, so the economically stable government can provide more social and employment services to its citizens in a more sustainable way (Uddin 2016).

Thus, the study argues that corporate risk-taking behavior is affected because of the difference in the interests of state ownership and external shareholders, who are more concerned about performance, survival, and growth rather than focusing on both social and political objectives. It depends whether the government is a minority or majority shareholder, deciding whether SOEs managers become more prudent in reducing their risk taking to avoid earnings uncertainty. Conversely, if the government is a majority shareholder with a higher profits target, it puts a pressure on SOEs' managers to make riskier investments. Therefore, the state owners have a reasonable motivation to undertake risky decisions to achieve them. Besides, once successfully implementing risky investments, SOEs can help the government to ensure economic objectives in the long term, such as higher social stability and higher employment in the future. This awareness is important for monitoring ownership structure and restructuring trading strategies in SOEs for better investment and profitability. Thus, this study states the third hypothesis as follows:

Hypothesis 3 (H3). *When the level of state ownership is below a threshold, as its ownership rises, the firm takes fewer risks. When the level of state ownership is above a threshold, the firm takes more risks.*

4. Data and Methodology

In this section, we discuss the data and methodology being used in our study. We first discuss the data being used in our study.

4.1. Data

The data consist of 506 corporates listed on the Ho Chi Minh Stock Exchange (HOSE) and Hanoi Stock Exchange (HNX) from 2007 to 2015, with 4171 observations. This period is in an important stage of the equitization process with significant changes in government shares in state-owned corporates. In the period 2007–2011, the number of equitized corporates was 388, while 591 corporates were equitized, merged, and dissolved in the period 2011–2015. It was also marked by an important 929/QD-TTg decision, which was issued by the prime minister on approving the scheme on SOE restructuring in 2011–2015. Moreover, Vietnam was affected by the economic crisis, causing the stock market to be unfavorable and affecting its equitization process as well as the selection of investment and trading strategies in this period. Thus, this sample is useful and reliable for investigating the relationship between state ownership and risk-taking behavior to get better investments and trading strategies. Thus, we select the period in our study. This is a set of unbalanced panel data in which some corporates have more observations than others due to the availability of data, listing time, and our attempt to maximize the number of observations. The annual financial data and the ownership information of corporates are obtained from the FiinPro® Platform, affiliated with Nikkei Inc. and QUICK Corp.

4.2. Variables

Risk is a dependent variable that measures risk-taking behavior such that:

$$Risk_{ROA} = \frac{ROA_{i,t}}{\sigma ROA_i} \text{ and } Risk_{ROE} = \frac{ROE_{i,t}}{\sigma ROE_i},$$

where $ROA_{i,t}$, and $ROE_{i,t}$ are the returns on assets and equity of corporate i at time t, and σROA_i and σROE_i are the standard deviations of ROA and ROE for firm i in the sample, respectively. We hypothesize that a more volatile performance is more relevant to the risk and risk-taking activities by corporates. $Risk_{ROA}$ and $Risk_{ROE}$ are indicators that are the inverse of corporate risk-taking behavior. Higher values for these indices means less risky behavior from corporates and vice versa. These measures are common proxies for corporate risk-taking in the extant literature and also have been used in many studies (Faccio et al. 2016; Vo 2018).

$Profitability_{i,t-1}$ are variables which measure the corporate's performance in earning profits from their assets or equity, represented by $ROA_{i,t-1}$ and $ROE_{i,t-1}$. Basically, the higher these indicators are, the more profitable the corporate is. The difference between *ROA* and *ROE* tends to reflect the debt burden. *ROA* shows the profit earned per unit of assets, and it, more importantly, reflects the ability of the corporate in using its resources to earn profits. Meanwhile, *ROE* reflects how effectively the corporate uses shareholder capital (Lin et al. 2019; Mun and Jang 2015).

$Gov_{i,t}$ represents state ownership, which is measured by the percentage of state holdings of corporate i at the end of year t. It can be understood that the state ownership level can be measured by shareholding by state agencies and SOEs. SOEs can be parent SOEs or non-parent SOEs (Hope 2013). Many listed corporates are originally spun off from their unlisted parent SOEs and floated on the stock market. Fro some listed corporates, their parent SOEs remain the major shareholder and control their resources in subsidiary firms.

$Control\ variables_{i,t}$ is a set of variables that clearly explain corporate risk-taking behavior, including size ($Size_{i,t}$), which is the logarithm of the total assets at the end of the year; fixed assets ($Fixed_{i,t}$), which is the ratio of fixed assets to total assets; the level of mature debt ($Debt_{i,t}$), which is the short-term debt to total assets ratio; and growth ($Growth_{i,t}$), which is the difference in revenue between t and $t-1$ year of corporate i. These variables have been used in previous studies on corporate risk management (Thanh et al. 2019; Khuong et al. 2019; Nguyen et al. 2019; Mishra 2011).

4.3. Models

We extend the models of Faccio et al. (2016), Vo (2018), and others to develop the following new prior models to study the relationship between state ownership and corporate risk-taking behavior:

$$Risk_{i,t} = \alpha_1 + \alpha_2 Profitability_{i,t-1} + \alpha_3 Gov_{i,t} + \alpha_4 Size_{i,t} + \alpha_5 Fixed_{i,t} + \alpha_6 Debt_{i,t} + \alpha_7 Growth_{i,t} + \varepsilon_{i,t}, \quad (1)$$

$$Risk_{i,t} = \beta_1 + \beta_2 Profitability_{i,t-1} + \beta_3 Gov_{i,t} + \beta_4 Gov^2{}_{i,t} + \beta_5 Size_{i,t} + \beta_6 Fixed_{i,t} + \beta_7 Debt_{i,t} + \beta_8 Growth_{i,t} + \varepsilon_{i,t} \quad (2)$$

In the model in Equation (2), $Gov_{i,t}$ represents state ownership, which is measured by the percentage of state holdings of corporate i at the end of year t. We note that if β_3 is significantly positive and β_4 is significantly negative, then there is an inverted U-shaped relationship. On the other hand, if β_3 is significantly negative and β_4 is significantly positive, there is a U-shaped relationship between corporate risk-taking and state ownership. Taking the first derivative of both sides concerning *Gov*, we get: $Gov' = \beta_3 + 2\beta_4 Gov$. Finding the maximum value of *Gov* requires $Gov' = 0$. Solving this equation, we find the threshold value of *Gov* (ς) as follows:

$$\varsigma = \frac{\beta_3}{-2\beta_4} \quad (3)$$

Based on the thresholds of *Gov* (ς), this study separates the level of state ownership into two regimes: higher and lower than the threshold. Then, we check the robustness of the study's findings by re-developing two equations:

$$Risk_{it} = \begin{cases} \beta_{11} + \beta_{12}\text{Profitability}_{it-1} + \beta_{13}Gov_{it} + \beta_{14}Size_{it} + \beta_{15}Fixed_{it} + \beta_{16}Debt_{it} \\ +\beta_{17}Growth_{it} + (\varsigma_i + \varepsilon_{it}), if\ Gov < \varsigma, \\ \beta_{21} + \beta_{22}\text{Profitability}_{it-1} + \beta_{23}Gov_{it} + \beta_{24}Size_{it} + \beta_{25}Fixed_{it} + \beta_{26}Debt_{it} \\ +\beta_{27}Growth_{it} + (\varsigma_i + \varepsilon_{it}),\ if\ Gov \geq \varsigma. \end{cases} \quad (4)$$

By applying the GMM method, our findings will be confirmed as robustness if $Gov < (\varsigma)$ is negatively statistically significant for risk-taking behavior, and $Gov \geq (\varsigma)$ is positively statistically significant for risk-taking behavior and vice versa.

4.4. Methodology

It can be seen that both the models in Equations (1) and (2) are dynamic models with the participation of variable ROA in periods t and $t-1$ as independent and dependent variables. Regression methods for panel data such as ordinary least squares (OLS), the fixed effects model (FEM), or the random-effects model (REM) may produce biased and inconsistent results because of the correlation between $\varepsilon_{i,t}$ and $ROA_{i,t-1}$, i.e., an endogenous problem. To solve this, we considered the difference Generalized Method of Moments (diff-GMM) method proposed by Arellano and Bond (1991), in which the models in Equations (1) and (2) are transformed into first-order difference models, and the lag of them is used as instrumental variables. This transformation eliminates the unobserved effects and allows the creation of orthogonal conditions between $\varepsilon_{i,t}$ and explanatory variables, thereby solving the endogenous problem. However, Arellano and Bover (1995) suggested that the variance of the estimates in diff-GMM may increase asymptotically and create considerable bias. Blundell et al. (2001) found that estimation in first differences had a large bias and low precision due to the inertial degree of consideration, even with a large number of individuals (N).

Therefore, they proposed that the system Generalized Method of Moments method (sys-GMM), which displayed the lowest bias and highest precision for used series, is moderately or highly consistent. Moreover, the GMM method with two steps has a higher efficiency than that with one step due to the application of a suboptimal weighting matrix, which then produced the bias of uncorrected standard errors when the instrument count was high. Therefore, Roodman (2009) suggested a principle that the number of instrumental variables must be less or equal to the number of groups (N) as a reasonable condition. Both estimation methods are considered appropriate only when two conditions are met: (1) The suitability of the instrument variables is determined through the Hansen or Sargan tests. Specifically, the higher the *p*-value of the Sargan and Hansen statistics is, the more likely that the null hypothesis is accepted. (2) There is no second-order autocorrelation phenomenon in the error terms through the AR (2) test.

5. Results and Findings

5.1. Descriptive Statistics

Table 1 presents the descriptive statistics of the variables in this study.

Table 1 shows the summary statistics of all the variables. It presents the descriptive statistics of the entire sample of 4171 corporate-year observations. The mean (median) risk-taking behavior ($Risk_{ROA}$) of the sample corporates is 2.169 (1.832), lower than that for $Risk_{ROE}$ at 2.307 (1.888). The mean (median) state ownership (*Gov*) is only 2.73% (2.80%), notably lower than the Vo (2018) observations. The difference is mainly caused by the sample size; Vo (2018) used an average of 2000 observations in the Ho Chi Minh Stock Exchange (HoSE), while our study uses data of listed corporates in the Ho Chi Minh Stock Exchange (HoSE) and Hanoi Stock Exchange (HNX), with 4171 observations.

Table 1. Definition and description of variables.

Code	Definition	Obs	Mean	Median	Min	Max
$Risk_{Roa}$	Risk-taking behavior based on *Roa*	4171	2.169	1.832	−2.772	12.794
$Risk_{Roe}$	Risk-taking behavior based on *Roe*	4171	2.307	1.888	−2.917	18.066
Roa	Return/total assets	4171	0.069	0.054	−0.646	0.784
Roe	Return/equity	4171	0.132	0.133	−7.836	0.982
Gov	Percentage of state holdings by the state	4171	0.273	0.280	0.000	0.967
Size	Logarithm of total assets	4171	26.676	26.584	21.370	31.906
Fixed	Fixed assets/total assets	4171	0.282	0.230	0.000	0.978
Debt	Short-term debt/total debt	4171	0.624	0.785	0.000	1.000
Growth	$Revenue_t/Revenue_{t-1}$	4171	0.136	0.118	−4.643	7.070

(Source: HOSE and HNX).

5.2. Correlation Matrix

Table 2 presents the correlation matrix of the variables. It can be seen that the coefficients between state ownership and the two variables of risk-taking are significantly positive, indicating that higher state ownership is associated with a lower level of corporate risk-taking behavior. Moreover, the table also shows a negative correlation between the variables of risk-taking and the firm size, fixed assets, and level of debt, and a positive correlation with growth.

Table 2. Definition and description of variables.

	$Risk_{Roa}$	$Risk_{Roe}$	*Roa*	*Roe*	*Gov*	Size	Fixed	Debt	Growth
$Risk_{Roa}$	1.00								
$Risk_{Roe}$	0.86 ***	1.00							
Roa	0.61 ***	0.53 ***	1.00						
Roe	0.44 ***	0.42 ***	0.68 ***	1.00					
Gov	0.17 ***	0.18 ***	0.11 ***	0.11 ***	1.00				
Size	−0.07 ***	−0.08 ***	−0.07 ***	0.02	0.06 ***	1.00			
Fixed	−0.07 ***	−0.04 **	−0.03	−0.02	0.12 ***	0.09 ***	1.00		
Debt	−0.13 ***	−0.11 ***	−0.19 ***	−0.08 ***	−0.16 ***	0.04 **	−0.28 ***	1.00	
Growth	0.14 ***	0.13 ***	0.18 ***	0.20 ***	−0.05 ***	0.03 *	0.01	−0.04 *	1.00

Note: (*), (**), and (***) are 10%, 5%, and 1%, respectively.

5.3. Relationship between State Ownership and Corporate Risk-Taking Behavior

Empirical results of the models in Equations (1) and (2) are presented in Tables 3 and 4, respectively. It can be seen that the conditions of the GMM methods are satisfied. The p-value from the Hansen and Sargan tests is large, implying that the GMM regression results are reliable and that the chosen instrumental variables in the models are appropriate. The p-value of the AR (2) test for the first-order difference of error terms also shows that there is no correlation between the error terms and the explanatory variables at all levels.

The empirical results provide some interesting contributions. Firstly, the *Gov* and *Risk* exhibit a positive correlation and are statistically significant at 1%, 5%, and 10% with the GMM methods. As a higher value of *RISK* implies lower risk-taking behavior, this indicates that high state ownership (proxied by *Gov*) is associated with less risk-taking activity. This finding is consistent with previous studies, which also suggest that increased state ownership reduces corporate risk appetite (Vo 2018; Khaw et al. 2016; Boubakri et al. 2013). Uddin (2016) mentioned that the government also has political and social interests, such as in controlling the employment rate, ensuring social stability, and pursuing political and economic benefits related to increasing government income from dividends and corporate taxes. Thus, if economic objectives and even political targets are the priority in the long-term, the government may actively support SOEs; hence, there will be an increase in risky behavior by SOEs. However, agency problems may arise in this situation as the government has to deal with other shareholders to develop a governance mechanism that is deemed appropriate to the interests of different groups of shareholders (Sur et al. 2013). This is an uneasy situation; hence, whether or not the state ownership increases risky behavior is unclear, as major shareholders' interests ultimately determine corporate risk-taking behavior. Based on these arguments, this study examines the non-linear relationship between state ownership and risk-taking, presented in Table 4 as follows.

Table 3. State ownership and corporate risk-taking behavior.

Variable	$RISK_{ROA}$		$RISK_{ROE}$	
	2-Steps Diff-GMM	**2-Steps Sys-GMM**	**2-Steps Diff-GMM**	**2-Steps Sys-GMM**
Lag of profitability	4.819 **	11.339 ***	1.633 *	4.883 ***
	[2.08]	[4.50]	[1.70]	[4.44]
Gov	3.283 *	7.485 ***	4.058 **	9.348 ***
	[1.73]	[4.62]	[2.07]	[4.57]
Size	−1.016 **	0.261	−1.385 ***	0.013
	[−2.28]	[0.70]	[−3.30]	[0.03]
Fixed	−4.987 ***	−3.696 **	−5.479 ***	−4.560 ***
	[−3.85]	[−2.55]	[−4.16]	[−2.82]
Debt	−1.576 ***	−2.292 ***	−1.754 ***	−2.368 ***
	[−3.05]	[−3.50]	[−3.04]	[−2.75]
Growth	1.609 ***	1.514 ***	1.637 ***	1.657 ***
	[6.17]	[4.54]	[6.29]	[4.34]
AR (1) test (*p*-value)	0.000	0.000	0.000	0.000
AR (2) test (*p*-value)	0.858	0.812	0.754	0.282
Sargan test (*p*-value)	0.898	0.543	0.908	0.368
Hansen test (*p*-value)	0.838	0.871	0.974	0.642
Num. IV	40	43	40	43
Groups	501	501	501	501

Note: (*), (**), and (***) are 10%, 5%, and 1%, respectively. z-statistic in [ ].

The results from the GMM methods show a clearer non-linear relationship between state ownership and corporate risk-taking. In particular, the coefficient of *Gov*, β_3 is positive, whereas the coefficients of Gov^2, β_4 are negative and significant at the 5% and 10% levels, respectively. The thresholds (ς) for state ownership obtained from Equation (3) range from 40% to 48%. This result implies that for SOEs with minor government holdings, the principal–principal conflicts between minority shareholders and controlling shareholders is more serious due to the pressure from minority shareholders, who have political and economic interests, and majority shareholders, who require a higher yield and profitability. Therefore, SOE managers tend to be more prudent in risk-taking to avoid earnings uncertainty (Uddin 2016; Boubakri et al. 2013). On the contrary, if the government plays the role of the majority shareholder, it may encourage SOEs to take on risky projects for the economy, which may only be done by SOEs due to their importance and financial capability. Additionally, these SOEs generally receive greater government support in accessing finance and resources to cope with uncertain risks from the market (Zhai et al. 2015; Farag and Mallin 2016).

Table 4. Non-linear relationship between state ownership and corporate risk-taking behavior.

Variable	$RISK_{ROA}$		$RISK_{ROE}$	
	2-Steps Diff-GMM	**2-Steps Sys-GMM**	**2-Steps Diff-GMM**	**2-Steps Sys-GMM**
Lag of profitability	4.757 **	9.148 ***	2.171 **	3.461 ***
	[1.87]	[3.44]	[2.32]	[2.86]
Gov	11.253 **	19.934 ***	12.018 **	24.520 ***
	[2.03]	[2.94]	[2.34]	[3.61]
Gov^2	−14.064 **	−20.476 **	−13.842 **	−26.680 ***
	[−1.96]	[−2.15]	[−2.03]	[−2.71]
Size	−0.753	0.228	−0.567	0.123
	[−1.59]	[0.55]	[−1.61]	[0.29]
Fixed	−4.848 ***	−4.529 ***	−3.748 ***	−3.893 ***
	[−3.55]	[−2.91]	[−3.32]	[−2.65]
Debt	−2.052 ***	−2.679 ***	−2.315 ***	−2.979 ***
	[−3.58]	[−3.75]	[−3.83]	[−3.44]
Growth	1.418 ***	1.382 ***	1.325 ***	1.210 ***
	[5.87]	[4.39]	[5.32]	[3.45]
AR (1) test (*p*-value)	0.000	0.000	0.000	0.000
AR (2) test (*p*-value)	0.625	0.585	0.793	0.799
Sargan test (*p*-value)	0.874	0.938	0.845	0.872
Hansen test (*p*-value)	0.799	0.902	0.965	0.946
Num. IV	40	62	40	62
Groups	501	501	501	501
Gov (ς)	0.400	0.487	0.434	0.456

Note: (*), (**), and (***) are 10%, 5%, and 1%, respectively. z-statistic in [ ].

Tables 3 and 4 also provide results that can shed light on the risk-taking behavior of Vietnamese corporates. Firstly, profitability is found to have a significant reversal of impact on risky behavior in all equations. They illustrate that managers refuse to accept more risky behavior if the target profitability increases. Another explanation is that managers are rewarded based on the profits of the company's operations; they prefer a stable income with low-risk decisions. This study also provides reliable estimates of the impact of short-term debt rates and the degree of the use of fixed assets that promotes the corporate's risk appetite, with 1% statistical significance. Businesses may be more risk-taking in the search for more profitable projects for debt repayments, primarily short-term debts. Similarly, an increase in fixed assets requires businesses to look for more projects to improve the earnings of their assets, leading to higher risk appetite. Secondly, the level of corporate performance in the previous period is negatively related to the level of risk tolerance in this period. Greater efficiency is associated with higher cash flow, hence less risk-taking in this period. Finally, it is expected that firm size has a relationship with risk acceptance, but the empirical results are not precise and consistent. These findings are relevant for shareholders in monitoring their corporates to avoid agency problems and improve corporate performance.

5.4. Robustness Test

In this section, this study examines the robustness of empirical results, according to Equation (4). Based on the thresholds of *Gov* (ς) presented in Table 4, this study separates the level of state ownership into two regimes: higher and lower than the threshold. According to the literature review, this study assumes that a high level of state ownership increases corporate risk-taking behavior. In other words, *Gov* (ς) has a negative relationship with the *Z-score* and vice versa. Using GMM methods, we found consistent results, which are presented in Table 5.

Table 5. Relationship between state ownership and corporate risk-taking behavior

Variable	$RISK_{ROA}$		$RISK_{ROA}$		$RISK_{ROE}$		$RISK_{ROE}$	
	2-Steps Diff-GMM	**2-Steps Diff-GMM**	**2-Steps Sys-GMM**	**2-Steps Sys-GMM**	**2-Steps Diff-GMM**	**2-Steps Diff-GMM**	**2-Steps Sys-GMM**	**2-Steps Sys-GMM**
Lag of profitability	5.314 **	5.619 **	10.032 ***	10.412 ***	2.039 **	2.026 **	3.876 ***	3.512 ***
	[2.15]	[2.23]	[3.58]	[3.25]	[2.11]	[2.10]	[2.80]	[2.65]
Gov	7.434 **	2.753 *	13.661 ***	8.570 ***	9.792 ***	3.667 **	16.515 ***	8.188 ***
	[2.01]	[1.71]	[3.00]	[4.40]	[2.65]	[2.30]	[3.11]	[4.65]
Gov ≥ (ς)	−4.861 *		−6.367 *		−6.089 **		−8.282 **	
	[−1.87]		[−1.75]		[−2.21]		[−1.93]	
Gov < (ς)		4.153 *		9.138 **		6.043 **		9.391 **
		[1.66]		[2.13]		[2.19]		[2.29]
Size	−0.686	−0.515	0.412	0.606	−0.565	−0.569	0.155	0.188
	[−1.47]	[−1.31]	[1.02]	[1.29]	[−1.57]	[−1.63]	[0.37]	[0.46]
Fixed	−4.371 ***	−3.884 ***	−3.745 **	−3.789 **	−3.329 ***	−3.297 ***	−3.408 ***	−2.940 ***
	[−3.42]	[−3.32]	[−2.50]	[−2.37]	[−3.13]	[−3.08]	[−2.23]	[−2.11]
Debt	−1.813 ***	−1.779 ***	−2.559 ***	−2.996 ***	−2.165 ***	−2.189 ***	−2.698 ***	−2.826 ***
	[−3.30]	[−3.30]	[−3.48]	[−2.96]	[−3.60]	[−3.60]	[−3.12]	[−3.22]
Growth	1.385 ***	1.417 ***	1.291 ***	1.152 ***	1.316 ***	1.321 ***	1.193 ***	1.187 ***
	[5.89]	[6.14]	[4.18]	[2.87]	[5.37]	[5.35]	[3.41]	[3.49]
AR (1) test (*p*-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR (2) test (*p*-value)	0.712	0.739	0.587	0.375	0.939	0.945	0.686	0.896
Sargan test (*p*-value)	0.848	0.927	0.926	0.897	0.846	0.886	0.807	0.873
Hansen test (*p*-value)	0.780	0.933	0.893	0.856	0.981	0.989	0.862	0.962
Num. IV	41	52	42	26	60	61	54	62
Groups	501	501	501	501	501	501	501	501
Gov (ς)	0.400	0.400	0.487	0.487	0.434	0.434	0.456	0.456

Note: (*), (**), and (***) are 10%, 5%, and 1%, respectively and z-statistic in [ ].

The results from robust tests show that state ownership tends to reduce corporate risk-taking appetite. However, when state ownership exceeds the threshold (ς is approximately 40%), it tends to increase risk-taking behavior (significant at 5% and 10%) and vice versa. These results are consistent for both $Risk_{ROA}$ and $Risk_{ROE}$, confirming that state ownership has a significant impact on the level of corporate risk tolerance. In addition, for other factors such as *Fixed*, *Debt*, and *Growth* is consistently found statistical significance in empirical models.

6. Discussion

As discussed in the literature review, a decrease in risk-taking acceptance yields a serious agency problem that interferes with political connections. The serious agency problem forces internal managers to take less risky behavior to seize opportunities for entrenchment and benefits, which is met by outside shareholder costs (Uddin 2016). State connection forces SOEs to ensure stability for social goals rather than seeking risky projects to get higher profitability (Boubakri et al. 2013). Additionally, SOEs with state ownership have advantages in accessing information, financial resources, and state support through their political connections (Vo 2018). Indeed, our results show that SOEs have little incentive to engage in any risk-taking activity to gain a competitive position. Another reason is that SOE managers, who are generally appointed by the state, often face difficulties in corporate governance because of excessive control from the state and a lack of business management skills (Lin et al. 2009). They, therefore, hesitate to engage in any risky activity.

On the other hand, according to the theory of resource dependence, links to external sources are a coping mechanism to reduce risk and uncertainty (Pfeffer and Salancik 1978). Government policy and regulation are major forces in the external resources (Hillman et al. 1999), and they change the decision-making on any risk-taking behavior for corporates. In our case, the high state ownership in the SOEs reflects the role of SOEs in the market and economy as strategic corporates. Thus, these entities have available resources from the government to promote risky activities to achieve profitable investments and get better trading strategies under uncertainties (Zhai et al. 2015; Farag and Mallin 2016), a condition that can discourage other common enterprises.

Our empirical findings contribute to the literature on the ownership structure's operating and monitoring to avoid agency issues and get better investment and trading strategies. The agency problem has existed and is continuously controversial in transition economies where the state has significant shares in enterprises, and investor protection is often weaker than in developed countries (Vo 2018). Chen et al. (2013) use transaction costs and agency theory to propose that ownership structure provides an important mechanism to realize the necessary resources for innovation and competition in the context of emerging markets, thereby affecting the risk appetite of the corporates. Although risk-taking behavior is important for achieving a better trade and investment strategy (Faccio et al. 2011), state ownership relationships reduce the firm's craving for risk through conservatives, social goals, and government support. On the other hand, Su et al. (2016) suggest that a strong incentive for corporates to minimize their risk-taking activities is to protect the dominant shareholders' benefits. Similarly, Nguyen et al. (2019) show that lower than 25% or higher than 75% state ownership will yield positive effects on corporate performance in Vietnam, while it is negatively impacted by the level of state ownership between 25% and 75%. Our results, once again, support the importance of ownership restructuring as an important mechanism to enhance accountability and create incentives for corporate governance.

7. Conclusions

The sustainability of corporates differs because their ability to respond to uncertain economic conditions is different. Due to the uncertainty of the economic situation, corporates taking high risks may have higher agency costs, resulting in a negative impact on their sustainable development, investment, and trading strategy. The deviation in corporate profitability is a crucial representation of risk-taking behavior in order to seek profit, carry on their investment, and alter their trading strategy, while state ownership is considered as a competitive advantage, connecting the long-term business objectives and stakeholder expectations that relate to corporate sustainability, investment, and trading strategy, especially in the context of transforming economies. On the one hand, through the political connection, state ownership ensures corporate objectives which serve as the foundation for ensuring sustainable and steady development. On the other hand, it also creates an agency problem that can lead to an imbalance of interests of stakeholders, seriously affecting the sustainability, investment, and trading strategy of the firms. The influence of a state relationship can promote risky behaviors of firms, thereby shifting the costs of the stakeholder's sustainability into risky investments for the benefits of majority shareholders. Thus, the relationship between risk-taking behavior and state ownership is an exciting topic, especially in transition economies such as Vietnam. On the other hand, Vietnam is undergoing a robust privatization process with a shift in ownership structure from the state to the private sector, which is expected to boost economic growth as well as market development. The state still owns strategic and important corporates to maintain its dominant role in the socialist-oriented market. Therefore, insights into the role of state ownership help to promote radical reforms and policies to facilitate the development of corporates and the economy.

This study sheds light on the relationship between state ownership and the risk-taking behavior of corporates in Vietnam. Employing the GMM method on data of 501 listed corporates from 2007 to 2015, this study found substantial evidence for the negative impacts of state ownership on the risk-taking behavior of corporates. Firstly, the study provides evidence that state ownership reduces corporate risk-taking behavior. This result shows that state-owned corporates are controlled to ensure stability instead of taking risks for higher profits. This may be because SOEs already have competitive advantages and resources available; therefore, managers have no incentive to take the risk and choose a trading strategy having less risk. Moreover, according to the theory of the agency problem, SOE managers are often appointed by the state, and they are more interested in social–political objectives than activities that promote profits, get better investment opportunities, and obtain a better trading strategy for the corporate. It, therefore, improves the corporate image to the public and provides a competitive advantage in uncertain economic conditions. Secondly, the results show that political connections are a double-edged sword, as SOEs with stronger political connections may be more risk-taking and make investments and take trading strategies having higher risk but getting higher profit. The study also shows that state ownership has a U-shaped nonlinear relationship with the corporate's risk-taking and investment behavior. When the state is the majority shareholder, the SOE managers are under higher pressure for achieving economic objectives. This causes serious agency problems because higher economic pressure translates the interests of stakeholders into more risky investments and trading strategies for the majority shareholder's goals. The study highlights the need to develop an effective monitoring mechanism as well as corporate governance for SOEs. This is clear and relevant in the context of the transition economy when the state is promoting the equitization process. It leads to policy recommendations on the level of state ownership, which should include involvement in strategic or non-strategic corporates. Finally, the study also finds that an increase in corporate efficiency and growth of revenue would reduce corporate risk-taking behavior and investment activity, while an increase in debt and fixed assets would put pressure on corporates to implement more risk-taking behavior and investment. The results contribute to existing theories of corporate governance in the context of the socialist-oriented markets.

This is in line with the context of Vietnam with the presence of the weak and uncertain environment and the significant role of the government in accessing financial and business resources (Luo et al. 2017). In addition, state ownership may lead to a dependence of corporates on state support instead of actively innovating and making excellent investments to increase competitiveness. It might be suitable for SOEs in the early stages of development, but it may cause inequality in competition, leading to the crowding out of the private enterprises in the long-term (Van Thang and Freeman 2009). However, the extensive results show that the role of state ownership depends on the level of ownership; it can have a U-shape relationship with corporate risk-taking investment. Accordingly, if state ownership is the majority, the government can require SOEs to undertake important and risky projects for economic goals. Vo (2018) noted that risk-taking is of importance for the development of a corporate since it allows businesses to gain competitive advantage and innovation.

Therefore, this study provides some practical implications. First, the government should clearly define strategic and non-strategic businesses and restrict their investment and trading strategies. State ownership in non-strategic businesses not only limits incentives for finding corporate profits, investment, and trading strategies but also causes serious agency problems. As a result, privatization is an important strategy to promote the development of corporates in transition economies, especially small and medium private firms. Second, this study also supports the role of the government in holding strategic businesses. With support from the government, SOE managers can promote corporate activities to gain a dominant position in the socialist-oriented economy without hesitation about risky situations and investment. This not only offers a competitive advantage to strategic businesses but also facilitates innovation among businesses, thereby boosting sustainable development and getting better investment and trading strategies.

This study also has some limitations. Although the main relationship between state ownership and risk-taking has been demonstrated, there are still potential factors that influence this relationship, such as monitoring roles, the business environment, and economic crisis. Therefore, future studies should expand the analytical framework for a comprehensive view. Furthermore, although the validity and reliability of the data have been determined, the number and time of data should be improved in subsequent studies to ensure robustness and avoid possible bias. Finally, this paper studies the profitability and risk-taking behavior in investment and trading strategies for state-owned enterprises. An extension of our paper could study other behaviors, other investments, and other trading strategies. This could include an extension of Tobin (1958), Pratt (1964), Kogan and Wallach (1964), Slovic (1964), Wong and Li (1999), Li and Wong (1999), Wong (2006, 2007), Wong and Ma (2007), Qiao et al. (2013), Guo and Wong (2019), and many others to study other types of risk-loving behavior; of Wong and Chan (2008), Lean et al. (2010), Qiao et al. (2012), Clark et al. (2015), and others to study a mixture of both risk-averse and risk-loving behavior; of Egozcue et al. (2015), Guo et al. (2017b), and Guo and Wong (2019) to study regret-aversion behavior; of Guo et al. (2020) to include the behavior of disappointment; of Munkh-Ulzii et al. (2018) to study herding behavior; and of Guo et al. (2017a), Chan et al. (2019), and Wong and Qiao (2020) to use other types of utility functions to study the behavior of risk loving. Scholars could also extend Lean et al. (2007), Chiang et al. (2008), Qiao and Wong (2015), Tsang et al. (2016), Guo et al. (2017b), and others to examine the existence of any arbitrage opportunity; extend Abid et al. (2014), Wong et al. (2008, 2018), Li et al. (2018), and others to study other investment behaviors; and extend Wong et al. (2001, 2003), Lam et al. (2007), Lam et al. (2010, 2012), Kung and Wong (2009a, 2009b), Egozcue and Wong (2010), Egozcue et al. (2011), Lean et al. (2012), Chan et al. (2012, 2014), Fabozzi et al. (2013), Hoang et al. (2015a, 2015b), Lozza et al. (2018), Lu et al. (2018), Hoang et al. (2019), and Guo et al. (2020) to study different trading strategies. In addition, academics and practitioners could extend Liao and Liao and Wong (2008), Liao et al. (2012, 2014), Moslehpour et al. (2017), Moslehpour et al. (2018a, 2018b) to study marketing behavior; extend Moslehpour et al. (2018a) to study management behavior; extend Mou et al. (2018) and Pham et al. (2018) to study corporate behavior; and extend Thompson and Thompson and Wong (1991, 1996), Fung et al. (2011), Wong and Chan (2006), Xu et al. (2017), and Ly et al. (2019a, 2019b) to study the handling of risk. There is much other work studying behavior, investment, and trading strategy. Readers may refer to Chang et al. (2018) and Woo et al. (2020) for more information.

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Trade-Offs in Competitive Transport Operations

Usman Akbar [1], Akash Kumar [2], Hameed Khan [3,4], Muhammad Asif Khan [5], Khansa Parvaiz [1] and Judit Oláh [6,7,*]

[1] School of Economics and Management, Yanshan University, Qinhuangdao 066004, China; usman.akbar@outlook.com (U.A.); khansapervaiz@outlook.com (K.P.)
[2] Department of Public Administration, Yanshan University, Qinhuangdao 066004, China; indulantian1@gmail.com
[3] School of Economics, Jilin University, Changchun, Jilin 130012, China; hameed.qec@gmail.com
[4] Department of Economics, Kohat University of Science & Technology, Kohat 26000, Pakistan
[5] Faculty of Management Sciences, University of Kotli, Azad Jammu and Kashmir, Kotli 11100, Pakistan; khanasif82@uokajk.edu.pk
[6] Faculty of Economics and Business, University of Debrecen, 4032 Debrecen, Hungary
[7] TRADE Research Entity, North-West University, Vanderbijlpark 1900, South Africa
* Correspondence: olah.judit@econ.unideb.hu

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Abstract: One of the goals of developing a transport corridor is to promote socio-economic development by improving connectivity and sustainable transport operations, which largely depends on the operational strategy. Trade-off policies can be important tools for gaining the competitive advantage of road transport corridors, and thus, help facilitate sustainable growth and welfare. This article uses a case-based approach to observe the trade-offs in the first phase of transport infrastructure development, and then, in the second stage, further explores the trade-off variables in the transport operations strategy under the China-Pakistan Economic Corridor (CPEC). The results from the three cases of the parallel route system of the CPEC indicate that trade-off is an easily understandable and applicable method, which can foresee the operational gains or compromises for significant welfare of the regions. The implications of the trade-off are two fold, first is the "importance" of the trade-off, which is related to its impact on operational competitiveness. The other is the "sensitivity" of the trade-off, in terms of the change that will be caused to one variable when changing the other. The trade-off concept can be used for several landlocked transport corridors to achieve a competitive edge in transit trade.

Keywords: trade-offs; transport operations; competitiveness; sustainability

1. Introduction

Over the last two decades, emerging markets have received much attention due to their substantial development relative to the rest of the world (Khan et al. 2020), while the concept of the trade-offs is not mysterious; in fact, it is potentially straightforward and adaptable. The trade-off is the balance among two variables for an optimal gain (Cheng et al. 2013). After being both praised and criticized, the importance of the trade-offs has increased in recent years. It is found to be a central approach in operations management and strategy. Since the 1970s (Skinner 1992), the trade-off strategy has been proposed primarily in processed manufacturing and productions, but the discussion of the trade-off requirements has recently continued in operational strategies (Akbar et al. 2019).

Critics argue that corporations cannot compete solely based on cost and production, but must moderately compete with multiple variables like cost, quality (Skinner 1969), variety, lead-time, delivery, and flexibility (Da Silveira and Slack 2001; Boyer and Lewis 2002). Numerous scholars have challenged the authenticity of the trade-off methods. Collins (Collins et al. 1998) discussed the trade-offs by providing empirical support to the models and suggests that there should be no trade-off between quality and delivery in any system designed to improve simplicity and level of discipline. Similarly, (Shahbazpour and Seidel 2007) consider trade-offs as constraints by arguing that trade-offs can be eliminated by applying the creative space-time problem-solving theories. The trade-offs are also associated with the paradigms in resources, which are challenged by one of the Searle Medical Instruments case studies. The case study suggested that, in reality, paradigms can improve many operations but cannot eliminate trade-offs (Clark 1996). Therefore, the concept of trade-offs has been perceived as wrong. Considering the trade-offs definition from an operations management perspective, it is the balance (between two expectations) which benefits the most, and, thus, there is no more room for trade-offs (Akbar et al. 2019).

In a broad-spectrum, by considering the road transport operations as the means to cope with a country's development challenges (i.e., welfare through regional integration), the trade-offs among prioritized operational variables (i.e., travel cost, travel time, routing flexibility, traffic information, and road capacity, etcetera) must emphasize consistent improvement. This research adds a valuable contribution to the existing literature of road transport operations management and opens the discussion for researchers by posing a question: "Can the competitive transportation factors, such as transport infrastructure, transport services, logistical technology, and transport policy, enable the trade-offs among operational variables?" The findings suggest that they can enable the trade-offs if the choices are made regarding critical competitive factors, e.g., to decide a factor that should receive the most significant investment of resources and infrastructure. The adjustable trade-offs, as the road transport operations technique, contributes to the consistent outcomes in the long run. Figure 1 shows the idea of the stage, where operational factors can enable trade-off among operational variables for sustainable growth.

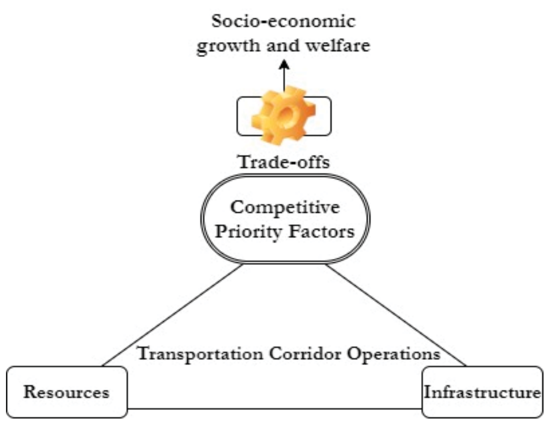

Figure 1. Operations strategy model for the transportation corridor.

We aim to find an answer to the question of whether trade-offs among competitive attributes in road transportation play roles in achieving sustainable socio-economic growth. We take the case of the China Pakistan Economic Corridor (CPEC), and it is momentous to know the pre-developed transportation infrastructure of the CPEC. In this study, the northern route of CPEC, which (at one end) connects with China, is considered as a series route system. The other end of the series route system is connected with the three highway road routes termed as a parallel route system, i.e., central route, western route, and eastern route. We collect official referenced data of the parallel highway route system of the CPEC. The trade-off decision made during the highway construction phase is observed. The second phase of the CPEC (i.e., road transportation during industrial development) was carried out to identify the trade-offs, which may help to obtain a competitive transport business, thereby promoting socio-economic growth. The findings may also be applicable to operations management in different landlocked countries, where road transport works as a backbone to their economies. The following sections of this paper include literature, methodology, case study, propositions, and conclusion.

2. Literature

2.1. Trade-Offs and Social Impacts of Transportation

A provincial report by Kaiser Bengali showed trade-offs of transport routes in the Balochistan province of Pakistan (Bengali 2015). There was a route controversy and much pressure faced by the federal government to start the operational trade with existing highways of Pakistan, which majorly consist of the eastern route. This was because of the huge investment required for the western route due to its high land-acquisition cost. The trade-offs considered for the western route of the CPEC had lessened the land acquisition cost and enabled the mutual consensus on building a new route; see more details in the provincial report (Mohmand and Wang 2014). This trade-off decision had not only reduced the cost but also enhanced social connectivity and opened doors to better education, employment, and businesses for the neglected backward regions of the Balochistan province. Similarly, (Heshmati et al. 2019) took the case of challenged trade-offs between welfare and economic growth and argued that there is a need for better understanding of the causes of income inequality.

Mohmand and Wang statistically proved the positive impact of transportation on social connectivity. Before CPEC, due to political conflicts, many land areas stayed unconnected. The improvement in the construction phase of highways won the hearts of the people from backward areas of Pakistan. Their findings pointed out that the transport infrastructure investment had improved not only accessibility but also enhanced opportunities for trade and investments (Mohmand et al. 2017). Ali and Mi showed a positive impact of transport connectivity on education and employment by providing easy access to basic services. In the following year, in 2018, they considered the crucial impact of road and transportation on society. They explained both favorable and adverse influence of transport on the local people by using factor analysis and structural equation. However, the overall impact of road and transportation on society and economy was still directly positive (Ali et al. 2018). In addition, Zhang used the concept of "vulnerability to assess the social impact of transportation, and showed that the integration of sourcing strategies with social impact assessment proved to be a better tool to benefit the local communities of development projects (Zhang et al. 2017).

Garlick, in 2018, points out that the overland connection is beset with challenges in the operational phase even after having the infrastructure developments, and hence, the positive impact of transport can be seen in the long run (Garlick 2018). The social impact of transportation is a broad subject where it is deemed to bring prosperity to the region. There are also many factors like insecurity, man-made disaster, and accidental rates that harm the image of the CPEC, and hence, deter investments (Black 2009). Mengsheng, a professor at Peking University, pointed out new challenges in the second phase of the CPEC, which is the phase of industrial development. Out of many challenges, there is a need for foreign capital inflows to cope with the serious fiscal deficit, and the most important, it demands the trusted commodities trade that is free of security and political conspiracy threats. The author elucidated that these are the internal factors that are affecting the CPEC (Zhang et al. 2017).

2.2. Recognizing Trade-Offs and Challenges

Trade-offs can be visualized in different ways. One way of picturing the trade-off is that it is a function of two variables, which can also be plotted graphically, and the other is related to multivariable. It helped to predict the performance of variables in routine processes (Hayes and Pisano 2009). An additional proposition defined a new element besides the trade-off function known as a pivot of the trade-off. The rise in the pivot helped to overcome the trade-off and hence led to the performance improvements. However, in this literature, the author did not describe which elements of an operational system represents this improvement, despite the bright ideas of attitudinal and technical constraints

(Slack 1991). This pivot was later explored by Silveria in 2001, where the author defined internal (the attributes) and external (competitive objectives) performance measures in trade-offs using the case-based studies. The author elaborates that the internal factors measures were the pivots in the trade-off model, whereas the external factors measures were their variables. Moreover, the role of internal variables are illustrated as a combination to improve pivot (whenever trade-offs overcome) (Da Silveira and Slack 2001). The trade-offs have also been identified with the help of mathematical support, such as, Akbar et al. (Akbar et al. 2020) use the data envelopment analysis (DEA) to calculate the efficiencies of nineteen countries along with the Belt and Road Initiative (BRI). They identify that the slacks show the due trade-offs in the form of excess values in bad outputs and inputs, whereas, shortages in the good outputs.

After the 1970s (with the introduction of the trade-offs), the 1990s (with facing challenges), and the mid-1990s onward had been majorly concerned with compromises between trade-off factors. All these years, the trade-off concept is used mainly as a tool to achieve an ambitious objective for improvement. Later, the significant progress in the subject is seen by the contributions of the Gibson trade-off rules, suggesting acceptable criteria to evaluate consistent trade-offs (Morrison-Saunders and Pope 2013). Gibson et al. presented a political tilting approach for decision processes in trade-offs, such as prioritized positioning of resources between two activities, and a decision on a priority action when to push a little further (Gibson et al. 2005). Skinner and Hayes, in their conceptual studies, suggested that conglomerates should focus on one priority at a time (Amit and Schoemaker 1993; Hayes and Pisano 2009). This implies that irrespective of the industry type (i.e., manufacturing plant or road trading corridor), the cost, flexibility, and delivery requires different and improved operational structures and infrastructures.

Given the unsuccessful efforts in proving the trade-off concept as wrong, the heated debate grew over the recognition of the relevant concept that was being misunderstood. The implication of this concept is the appropriate "positioning" of competitive factors as an initial task of an operations strategy, by focusing on a narrower set of objectives. Even the recent studies explored the ways that helped in recognition of the characterized positioning and the consistency of that positioning by the adoption of resources and procedures (Thomas et al. 1985).

2.3. Trade-Offs for Sustainability

In 2019, Quium elaborated that there can also be essential trade-offs among social welfare, financial system, and environmental quality (Quium 2019). Even with evolution in managerial practices due to IT (information technology) advancements, strong trade-offs are considered compulsory to realize sustainable e-commerce (Oláh et al. 2018). According to Blankespoor, if a transportation corridor generates balanced social well-being and economic growth in the corridor region (Blankespoor et al. 2018), then the trade-offs can become a tool to keep sustainable socioeconomic growth with consistent competitiveness. To the best of our knowledge, there is little noticeable writing that has discussed trade-off in the business conglomerate, but trade-off is not explicitly found in the transportation corridor operations, particularly for the contribution of sustainable socio-economic growth. It was mostly discussed as an influential factor, for instance, Skinner suggested that even the simple operations without the trade-offs cannot be sustained (Skinner 1992). This is because the level of consistency among the competitive priorities and decisions regarding the operational processes can better determine the efficiency of operations (Leong et al. 1990).

Zimm et al. found a holistic approach to assess the inherent synergies and trade-offs between sustainability gaps in business, environmental, and social goals. They recognized the potential for multiple trade-offs and synergies between the Sustainable Development Goals (SDG) and concluded that trade-offs should not be seen as permanent but as indicators of the need for transformation (Zimm et al. 2018). Saunders and Pope argued that for the right positioning of trade-offs, sustainability requires an explicit assessment during internal (development phase) and external (approval decision point) phases (Morrison-Saunders and Pope 2013). Utne took a slightly different approach and discussed the trade-off analysis of sustainable attributes for the fishing fleet along with decision-making methods (Utne 2008). This implies that, whether it is a manufacturing company, a transport company, or a transport corridor, sustainable growth is dependent on the prioritized decision among the competitive factors. The trade-offs involve not only the priority of the competitive dimensions but also the rate of improvement in them, which makes the trade-off a more balanced and harmonious approach towards sustainability. A question crops up that "what are important competitive factors in transport corridors' operations?"

2.4. Competitive Trade-Offs in Transport Operations

Considering the economic consequences of transport infrastructure (Rehman et al. 2020; Khan et al. 2020), the competitive trade-offs call for optimal balance between the factors, which also demands management focus, a thorough investigation before the trade-offs should take place. Though the standard framework for transport operations is already well known, the question over the relationship between competitive priority factors is continuous and evolving with technology. Three models, such as the cumulative, the integrative, and the trade-off model, are supporting this debate. However, the trade-off model seems to be the most established, but regardless of any of these models, the operational strategy is viewed as the correct positioning capability of competitive factors.

Strategic theories repeatedly stressed the four necessary capabilities (competitive factors), such as cost, quality, delivery, and flexibility (Ward et al. 1998; Hassan and Azman 2014). These factors help to ensure that the road transport network is linked to national growth at the micro and macro levels (i.e., national output, employment, income, production, wages, jobs, low inputs, and high outputs). To attract international industries, the most quoted examples for high-quality standards were investors' needs (flexibility), reliability (delivery), and efficiency (cost) (Szwejczewski et al. 1997). Ferdows and De Meyer further explained the same three factors with the help of the "sand cone model", to capture the advanced capabilities (Ferdows and Meyer 1990). There is limited literature that has taken trade-offs as a tool to gain sustainable growth in the business conglomerate; however, the extant literature is lacking the trade-offs for the transport operations.

3. Research Methodology

A case study approach is adopted because case-based research is found to be a suitable method to conduct empirical studies or to prolong exposed debates (Eisenhardt 1989). A qualitative approach is used for two reasons; first, this research aims to focus on "how" trade-off can play a role in transport operations for sustainable developments, which is mostly found appropriate for descriptive studies (Da Silveira and Slack 2001). Secondly, this research intends to establish the trade-off theory for competitive road transport operations, in the light of real facts and figures, rather than testing it.

The data collection for the parallel route system of the CPEC comprised of five actions:

1. Observation of the overall CPEC routes and the seaports connected to it (www.cpec.gov.pk). An informal discussion is performed with the CPEC officials and the major logistics operators in Pakistan i.e., Costa Logistics, MG Sky Cargo, Akurate Services, Agility, and Silk Goods Transportation.
2. To quantify the cost, safety, and profit of each highway route, we adopt the probability density function (PDF) and use the cumulative probability. This is to propose the effective trade-off types in the proposition section. The results are conducted using assistance from a website www.vertex42.com, simulation graphed by Witter in 2004. The results are shown in Appendix A.
3. Discussion and calculation on unsafe probabilities of each route are done by taking factors like natural disasters, terrorism (National Counter Terrorism Authority Pakistan, www.nacta.gov.pk), and accidents (National Highway Annual Performance Report, www.ntrc.gov.pk) using Microsoft Excel between the years 2010–2018. These factors were chosen to know the current investment atmosphere after the infrastructure development of the CPEC.

4. The important transport factors, such as infrastructure, transport services, logistical technology, and transport policy, are selected from the related literature (Akbar et al. 2019; Rehman et al. 2020). Moreover, the important transport variables (i.e., transport cost, reliability, information, capacity, and route insecurity) are also selected from citations (Mohmand et al. 2017; Ali et al. 2018). The importance of each route of the parallel route system is judged by using three factors, i.e., population density, the total area of cultivation, and the production of four major crops (Bengali 2015).
5. Follow up emails, real-time news, and latest updates were kept align to authenticate the interpretations (www.cpecinfo.com).

Since specific provincial governments dominate each highway route, i.e., the western route majorly comes under the Balochistan, most of the eastern route is under the Punjab control, and the central route crisscrosses the boundaries of two provinces, the above activities are intentionally carried out for each highway route. We combine the CPEC road transport factors, transport operating variables, and trade-offs with the help of three detailed case studies of CPEC's road routes. This study is meant to explore trade-off strategies that can be practiced by operational managers. The specific trade-offs variables in this study are limited to five. They are transportation cost (C), reliability (R), information systems (I), capacity (V), and insecurity (S). Transportation costs (C) consist of travel time, travel costs, and travel safety; reliability (R) is quality, flexibility, and speed. The information systems (I) include e-commerce and logistics, while capacity (V) is the ability to adapt to the volume of road traffic and types of goods. The fifth and final factor is road insecurity (S), which takes into account accidents, natural disasters, and terrorism. So, for example, the trade-off between cost and capacity is termed as a CV. By this, we are limiting this study not to involve the trade-offs, such as operational expenditure or transportation modes, but rather to match the frequently cited competitive objectives.

4. Case Study

Considering the case of Pakistan, a large amount of foreign exchange is needed to rein in colossal capital spending. The most effective way to improve the country's foreign exchange is to attract foreign direct investments for better resource utilization and financial development within the sound institutional framework (Khan et al. 2019, 2020; Abdulahi et al. 2019; Nawaz et al. 2014), which also demands both the route efficiency and effectiveness, see the report of Mengsheng and Jingfeng (Tang and Li 2019). Therefore, the three cases of highway route systems are investigated, and related data are calculated to have a better understanding of the trade-off technique for road operational efficiency and effectiveness (see Appendix A). The parallel road route cases are termed here as central case, western case, and eastern case, see Figure 2. All the information and data are official and have been fetched from the ministries' official website for the national highway authority and the CPEC authorities (Highway 2019; Bengali 2015).

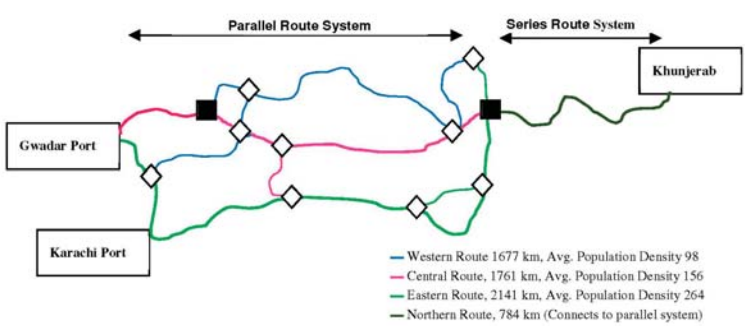

Figure 2. The parallel route system of the CPEC in Pakistan.

4.1. Central Case

The central route passes through the Balochistan province and parts of the Punjab province of Pakistan. This long-term construction of highways and bridges has opened economic opportunities for the vast number of backward regions of Pakistan. It passes through undeveloped and unindustrialized major urban nodes, namely Basima, Khuzdar, Sukkur, Rajanpur, Layyah, Muzaffargarh, and terminating in Dera Ismail Khan, and leads to Karakoram Highway through the Brahma Bahtar–Yarik Motorway. This alignment is narrow, with 2 to 4 lanes only.

It is 2423 km long and facilitates more road connections with the highways, which means it is found to be a more cost-effective and flexible route in road transportation. The total travel time is 62 h (including possible delay time) with the probability rate of 91 percent, which makes this route relatively reliable in transportation. The total traveling cost of this route (from Gwadar port to Khunjerab border) is 760 USD with a probability rate of 46 percent. The terrain along the alignment is mostly hilly; moreover, this alignment crosses the Indus River and contains a major bridge. The probability of overall insecurity, which includes natural disasters, accidents, and terrorist incidents, is 11 percent. Thus, this alignment also does not require significant diversions due to environmental and military reasons. On the other hand, the central route region entails higher land leveling costs because the average population density around the central route is 156 (per sq. km of land), which is not much. However, due to insurgencies in Balochistan and FATA (Federally Administrated Tribal Areas), the security cost is likely to be higher. Moreover, the total area under cultivation is 5829 (in million hectares), and the production of major crops—wheat, rice, cotton, and sugarcane—is 13,754 (in million tones).

4.2. Eastern Case

The length of eastern route is of 2692 km. This longest route of the CPEC passes through the Sindh and the Punjab province of Pakistan before it connects with the northern corridor. The highway routes connect the two largest cities of Pakistan (i.e., Lahore and Karachi) and consist of 4 to 6 lanes. The total traveling cost of the eastern route (from Gwadar port to Khunjerab border) is 984 USD with a probability rate of 61 percent. This route is divided into four sections, Karachi to Hydrabad, Hydrabad to Sukkur, Sukkar to Multan, and Multan to Lahore. Considering the Gwadar port as a departing place, by avoiding the Sindh highway, it goes along the shared M-8 motorway between the Turbat and the Khuzdar regions. The travel time on the eastern route is 113 h (including possible delay time) with the probability of 41 percent, indicating less reliability.

Except for the backward areas of the south Balochistan, the southern Punjab and the northern Sindh (provinces), more than half of the distance passes through developed areas of the central Punjab, which increases the convenience level of traveling on this route. The re-routing flexibility of this route is manifold and hence considered the most efficient route under the CPEC. The essential city nodes in the eastern route are Multan, Faisalabad, Pindi Bhatia, Rawalpindi, Hasanabdal, and onwards to the northern alignment. Thus, this route has a big border with India. The probability of insecurity, considering the aforementioned factors, is calculated as 64 percent. The security and safety cost is much higher on the eastern route. The average population density in the regions around this route is 264 (per sq. km of land), which is higher than the other two cases. The overall area under cultivation is 10,332 (in million hectares), and the production of major crops is 30,928 (in million tons). The eastern route is mostly plain and is likely to entail low land-leveling costs. On the contrary, the land around this route is also considered the most fertile in the country, which may lead to higher substitution costs.

4.3. Western Case

The western route of the CPEC is crisscrossing the Khyber Pakhtunkhwa, the Balochistan, and the western Punjab Province. The alignment is 2492 km long, which is shorter than the eastern route but longer than central alignment. The highway lane capacity is 2 to 4 lanes; thus, the capacity is not consistent along the route. It consists of eleven interchanges, seventy-four culverts, and three major bridges crossing the Indus, Soan, and Kurram rivers. The total travel time on this route is 56.29 h, including possible delay time on toll plazas and interchanges. The probability of this travel time including the delay time is 34 percent. The total traveling cost (from Gwadar port to Khunjerab) is 723 USD with a probability rate of 46 percent. The rapid land development around this route has enabled the benefits of serving landlocked countries like Afghanistan, Kyrgyzstan, and Kazakhstan, etc. The newly developed special economic zones around this route are rapidly developing, but security threat is still a big hurdle in that region. This region has faced the most earthquakes in the country, and it has extreme temperature i.e., extremely hot in summer and extremely cold in winter. The unsafe probability in this case, which includes accidental rate, natural disasters, and terrorism, is 41 percent (higher than central route but much lower than eastern alignment); the security cost is still expected to be higher due to insurgencies in a neighboring province, namely "Balochistan and FATA".

The terrain along the alignment is hilly, and land leveling cost is high, as it passes through the key city nodes, namely Brahma Bahtar, Burhan, and Hasan Abdal. The Karakoram highway connects to the western highway at Burhan. The average population density in this region is 98 (per sq. km of land), the overall area under cultivation is 2933 (000 ha), and the production of major crops is 7430 (000 tons), which shows that the domain is relatively unproductive. On the other hand, there are two special economic zones (SEZ) under the development stage, which will enable further road transport trade-off opportunities.

The selection of these three cases is because of their parallel nature, and the current trading stage of the CPEC, and also, because it is considered a major concern regarding Pakistan's sovereignty (Abbas et al. 2019). There are few points noteworthy for the overall corridor routes.

- The custom posts on seaports or routes are linked with WeBOC (under Pakistan Revenue Automation Private Limited) electronically without any compliance or connectivity issues (Rana 2018). This platform will facilitate the fast movement of cargos across the country (www.weboc.gov.pk).
- The trucking business and transport industry need to be updated by introducing technologies like auto transmission and higher axle load, etc. Pakistan is one of those countries where the ministry for logistics does not exist, and the delay time problem occurs when logistic industry seeks approvals of different ministries. On the other hand, considering the CPEC developments, Pakistan is likely to become a hub of transshipment trade. Hence, the central authority for logistics becomes a need.
- The CPEC routes go through the hilly, mountainous, and hazardous terrains, and thus likely to face driving safety challenges (www.cpec.gov.pk). Hence, there is a need for logistic technologies. The improved Early Warning System (EWS) under the Pakistan Meteorological Department (PMD) (www.pmd.gov.pk) is not as yet installed, which is necessary to the trade and overall sustainable socioeconomic development.

The propositions based on the above case studies are in the following section that can help managers identify the trade-offs for a competitive road transport corridor. However, the above cases deliberately focus on infrastructure resources (highways, bridges, and safety), road capacities (number of road lanes, travel time, delay time), and land acquisition status (cultivation area, major crop production, and population density). This is to explore whether the trade-offs can be achieved through infrastructure and resources. Although the land acquisition has already taken place and infrastructure is developed, still the information is gathered to witness the previous trade-off during the development phase.

5. Propositions Based on Case Study

This section deals with the proposed categories of trade-offs and consists of nine propositions. The first three propositions are the validation of the trade-offs, the next three are the natural trade-offs found in the parallel route system, and the rest of the three propositions are related to the differences in the trade-offs.

Proposition 1. *Trade-off in operational management.*

The trade-off concept is considered as opportunistic and simplistic. It is, in our case, to let go of some of the benefits to gain better or similar benefits with comparative advantage to keep balanced and sustainable road trading. However, it is not the continuous benefited method but always beneficial in finding the optimal balance between two factors. For example, in some cases, trade-offs are impossible because the other factors that are meant to be ignored are essential and cannot be overlooked. The authentication of the trade-off concept is to consider it as a central operational policy or strategy, even if it requires a structural modification (as in our route cases).

Proposition 2. *Trade-offs role as effectiveness.*

The usefulness of the trade-offs enabled us to form another element for the improved operational trade-off. This element, which increases the trade-off opportunity without losing much, is termed as "effectiveness." For a valuable trade-off, we associate it with the assumptions that can be relaxed to gain benefits. For instance, the trade-off between cost and reliability of the CPEC routes depend on the attributes, such as volume and variety of trade commodity. Pakistan has significant textile and agricultural expertise; hence, the growth opportunity can be gained by improving the relative elasticity of demand using trade-offs as a tool.

Proposition 3. *Easier to understand.*

The trade-off is easier to understand on the process-based day to day operations. It is found difficult in operations when managers have to meet the targets and to prepare the batches to dispatch. For an understanding of the trade-offs, we can consider reducing road transits by reducing the accidental rate, customizing the inspections, or eliminating the security checkpoints to improve the total effort. This can also improve the trade-off between travel cost and time (the best fit in the eastern route and better for the rest of the two routes), and this will be helpful to overcome the trade-offs. Another example can be the trade-offs between reliability and capacity, i.e., the more the area is deprived of economic activities, the less consumption there will be. Therefore, there will be less demand for production and distribution; hence the trade-off between reliability and capacity may play an important role (considering the central route case). The aforementioned is similar to the finding of another study by suggesting better trade-offs between manufacturing companies (Da Silveira and Slack 2001).

Proposition 4. *Observed Trade-offs Gain.*

The trade-off nature of all three cases of the parallel route system had already changed due to China's investment in highways infrastructure in the first phase of the CPEC development. For example, the route controversy between the provincial government and the federal government on the western route had created an unjust situation by considering the immediate CPEC operations in the eastern route (with the help of already developed industrial zones and highways). However, this could have neglected the less developed western regions in the country. On the contrary, the trade-off of a route path, considering factors as population and crops, has created possibilities to connect with landlocked countries on the eastern border. Further trade-off is observed when the western route is being redesigned considering less land acquisition cost, see Table 1. It also did not neglect the compromise of the eastern route through implicit and explicit changes, mainly because the new Gwadar port connected to the western route is forcing developed companies to expand or reposition.

For example, the mature industries around the eastern route may now find it feasible to relocate their extended branch near the new seaport, e.g., Gwadar. Hence, better trade-off dynamics are already seen, and now, in the second phase, the CPEC is more in a position to work for better gains in terms of internal and external connectivity.

Table 1. Observed trade-offs of alternate routes with less land acquisition cost.

Factors	Western Route	Western Reroute [1]
Cultivated area (000 ha)	98	76
Production [2] (000 tons)	2938	1838
Population density (per sq. km of land)	7430	1485

[1] Route decided at an all-party conference (APC). [2] Production of wheat, rice, cotton, and sugar-cane. Source: Report by Kaiser Bengali (Bengali 2015).

On the other hand, road safety also contributes to international trade competitiveness and hence affects the overall trade. Therefore, it implies that the trade-off design strategy may be a solution for economic growth, even if it demands the development of more alternate routes or to integrate the processes. Figure 3 shows the trade-offs based on resources. The more the resources are increased, the better the trade-off level is to take place. For example, with improved highway infrastructure, we are now able to use the transportation trade-offs for better international trade competitiveness. Likewise, when the resources are increased, we shall be able to control the volume of trade more effectively, and hence the trade-off between cost and volume plays a more vital role in transit trade growth.

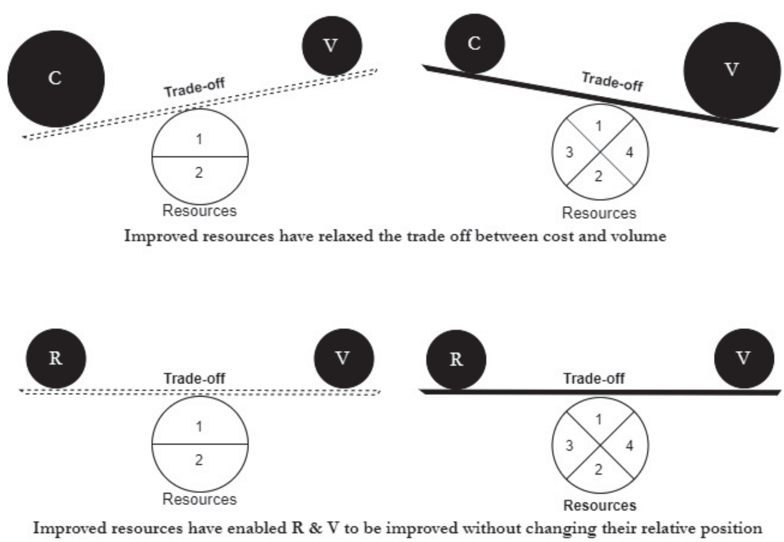

Figure 3. Categorized trade-offs. The dotted and the filled lever shows the week and strong stage of pivot respectively.

In some cases, improved trade-offs can be made without losing the relative position; in fact, it causes the other factors to grow. It is seen habitually in the provincial transaction but can also be done in international trade transportation. For example, the trade-off of RV (transport reliability versus capacity) is already improved in complying with the policy of ease of doing business or transit procedures, which is used to attract the business firms (both domestic and foreign), and this has also improved the trade-off factor of "transport cost". There are cases when trade-offs are to be made traditionally, that is, to achieve a competitive objective at the expense of the other. For instance, the trade-off between road transport reliability (R) and road transport safety (s) to gain the process integrity, where more travel safety can be a competitive advantage, but it may cause the indirect cost to increase. Lastly, a few examples are found where improvements can be made by trading-off one or more assumptions together for higher gains. This paper does not explore these assumptions because it is possible that each trade-off assumption has to wait for its related sequence of actions before it can take place.

Proposition 5. *Trade-offs Conflicts.*

In the trade-off literature, there is no evidence that trade-offs conflict with growth and improvement for any reason. The implementation of the trade-off concept must stress the acceptance of trade-off as continuous improvement and should never conflict with the idea of constant development. For example, to gain a competitive advantage among the belt and road countries (BRI countries), the level of trade cost minimization should not deteriorate the quality process of the CPEC. On the other hand, the trade-off can be applied as partial or can be ignored. For example, the trading commodity on western route demands high safety while the western case has insecurity probability 41 percent. In this scenario, ignoring route trade-offs and putting the commodity on the safest route may be a solution but also may result in an extra trading cost.

Proposition 6. *Overcoming different trade-offs or trade-offs with similar effects.*

It is essential to know how the resource investment can enable many trade-offs to overcome. Once the relative gains have been achieved to a certain maturity level, then there may not be a need for further trade-off assumptions. It implies that overcoming a trade-off requires an assessed investment in the light of the selected essential trade-off assumptions that may have a significant effect on the operations strategy. For example, in central and eastern cases, the speed of learning and innovation through logistic technology may enable the RV (transport reliability and capacity), which is improving transport reliability at the cost of allowing limited capacity. Otherwise, opening to the variety of commodity trade may require the investment in docking warehouses. In the eastern case, the investment in the range of route segments (improved infrastructure) can improve its connectivity with the western case (which has a nearest and direct connection with Gwadar port), which reduces the cost and increases the reliability. Hence, the trade-off between transport cost and transport reliability (CR) can rise to the maturity level. On the other side, trade-offs may have similar effects on investments in all cases. For example, assuming trade-offs with relaxed taxes (transport cost 'C') and an increased variety of commodity trades (capacity 'V') will have a similar effect of gaining inclusion (socio-economic welfare). So, asking the question "what investments are essential to overcome trade-offs?" may equally be necessary to know how peculiar investments can overcome many trade-off factors.

Proposition 7. *The trade-offs types will vary from case to case.*

The degree of impact due to trade-offs is termed here as the "importance" of a trade-off (Sarmiento 2011). Each of the three cases has different nature of trade-offs that impacts its overall performance. The central case is mostly barren and has the least economic activities, so the change in the trade-off assumptions may hardly make visible performance. This makes the trade-offs in the central case less important, and hence the central case may require more investments' trade-offs rather than transportation trade-offs. The traditional trade-off (which is to achieve one competitive objective at the cost of the other) may work well with the eastern and western cases, while the trade-offs without losing the relative positions/status of its assumptions fit for all cases (i.e., not to ignore it completely but rather trading it off partially for a balanced trade-off). Since it is not intended to opine further on the importance of the individual trade-off factor concerning the rate of impact, it is worth mentioning that the trade-offs with strong influence are related to "benefits" and hence are essential in transport operations, especially the CR (transportation cost and transport reliability).

Proposition 8. *Importance determined by important factors.*

Logically, the significance of a trade-off always determined by factors that are influential for welfare gains from international trade. In the CPEC road trading, the selected factors are linked to the behavior in which Pakistan chooses to constitute its trading strategy as a comeback to the international market. As prioritized, these factors consist of infrastructure, assisting services, logistic technologies, and policy/regulations for the growth of integration, cooperation, welfare, and industrial growth. These factors are further explained as follows:

- The infrastructure allows imports of much-needed capital goods to enhance economic activity. It allows the small cities and rural regions around the corridor to be well connected, and thus, it will increase job opportunities, education, and ease of doing business.
- The number of services is the logistics services to dominate internationally in the core comparative transportation. It allows the rural and urban regions to involve in learning innovation and technological developments.
- Logistic technology brings ease of doing trade on the CPEC routes. Lower price distortion is one of the viable factors that has an adverse effect. The technology will help in preventing corruption and improve the process by bringing equity among rich and poor people.
- Policy/regulations work in two ways in our case. Pakistan, by trading with comparatively small countries, can enhance transit trade. On the other hand, Pakistan can benefit more while trading with big countries due to comparative small export surplus. The policies of ease of doing business can help industrial growth, and it will also contribute to economic growth. For example, in China, the labor cost is increasing, and manufacturing companies may find it feasible to relocate for more profit.

The trade-offs and competitive factors used are exemplary and can be changed, increased, or decreased as per the needs and gains. Table 2 shows the perceived logical trade-offs considering road trading on the parallel route system of the CPEC. The adopted trade-off variables are found most cited and considered as "important" in road trading when the main goal is to create ease of doing business. The critical trade-off variables are the road transportation cost (C), the transport reliability (R), transport information system (I), capacity (V), and safety services (S). The road transport cost (C) consists of travel time, travel cost, and safety cost. Transport reliability (R) includes speed and routing flexibility. The transportation information systems (I) is meant to be e-commerce and logistical updates, capacity (V) is the volume and variety of trade (that a highway can allow), and transport safety (S) are the probabilities of accidents (fatal and non-fatal), natural disasters (includes temperature, earthquakes, land sidings, etc.), terrorism (man-made insecurities), because these factors effects majorly on the exchange rate and it becomes major obstacle for regional growth (Maitah et al. 2017).

Table 2. Essential factors, route cases trade-offs, and sustainable outcomes.

Important Factors	Western	Central	Eastern	Outcomes
Infrastructure	CV, CI	CV, CI	CV, RV	Integration
Transport services	CR, CV	CR, RV, CV	CR, CV	Cooperation
Logistical technology	CI, RV, RS	CI, RV, RS	CI, RV, RS	Welfare
Policies/regulations	ALL	ALL	ALL	Growth

Note the competitive trade-offs: C = Transportation cost (travel time, operational cost and security cost). R = Transportation reliability (Quality, flexibility, and speed). I = Information systems (ecommerce and logistics). V = Capacity (volume and variety of trade). S = Transport safety (safety from accidents, natural disasters, and terrorism).

The important factors are the result of the investments and policies, which enable the trade-offs to take place at different levels. For instance, in the central case, the construction of the new highway decreased the traveling cost (C) dramatically, but it is still higher than the western route. The construction of the new central route has enabled the trade-offs with a variety of commodities (V) and facilitates the smooth transport process. Moreover, it can accommodate a transport volume (V) with the least transits, but the insecurity rate is high. Hence, the CV (cost and capacity) and CI (cost and information systems) trade-offs can make the central region integrated for smooth operations. Conversely, the eastern case with road infrastructure allows us to increase the reliability (R), due to its pre-established industrial areas, without compromising the capacity of trade (V). Although the infrastructure achieves the RV trade-offs at a higher level, the RV still exists independently of the infrastructure, which allows the balanced volume to ensure transportation safety. On the other hand, CI (cost versus information) trade-offs, in the eastern route, play a more vital role than in the central and western routes. This is since the eastern route is more affected by the terrorism and natural disasters than the central and western routes which has high facilitation rate of social welfare (i.e., insecurity probability 64%). The information system can reduce the cost; however, the better the information system is employed the more cost it may demand.

Similarly, the number of services facilitates the business cooperation with the help of tradeoffs like the CR (cost versus reliability), while logistic technologies bring integrity by enabling tradeoffs like the RS, i.e., to find the trade-off of transport safety (S) and transport reliability (R). Now, we discuss in detail the conceptual design of the trade-off in the next proposition. In many pieces of literature, the trade-offs are mentioned as problems because of their traditional behavior in causing a change to other elements when action is taken to improve one. It is termed in many pieces of literature as "sensitivity". Whereas, insensitive factors are the one where one competitive achievement can be gained with little change in the other, which we termed here as an "improved trade-off".

Proposition 9. *The internal variables determining sensitivity.*

The internal variables of transport corridors determine the sensitivity of essential competitive factors. These internal variables include resource, capacity, and attribute. The competitive factors are dependent on the sources of internal variables, i.e., trade specialization and national-international trade policy. Likewise, the parallel route system of the CPEC passes through different provinces with different local government control, and every province, in Pakistan, has different competencies of selected resources, see Table 3.

1. Resources are the available factors owned by an operating authority (Amit and Schoemaker 1993). In our cases, they are the present fertile cultivatable area, production of four major crops (wheat, rice, cotton, and sugarcane), and population density of the western, central, and eastern cases, see Table 3. Please note that the mentioned resources are selected based on regions around the CPEC routes. The total provincial capacity is not taken because our study aims to find out the role of the trade-offs in the road transport routes resourced by the aforementioned factors. It is essential to know why cultivation area, crop production, and population are selected as resources in gaining a competitive edge. For example, the relative elasticity of demand can be improved with the help of trading with competitive agricultural products, which can increase the impact on the CV (cost and variety) trade-off. Whereas, the provincial governments (as in the western case) can accomplish their development objectives by offering their low-cost labor and by improving the trade-off assumption of the RV (reliability and volume). This is possible with an increase in the road segments connecting the deprived areas, as it will save time, money, and improve accessibility. However, making more roads can affect the cultivation areas (which are the assets of a country), so one has to see if it can give vital gains in return and the higher level the RV trade-off.
2. Capacities are the total agricultural production, routing flexibility, and highway capacities in terms of the number of available road lanes. Resources and capacities are equally important to

each other. For example, in the central case, chances of competitive advantage are increased with the help of the trade-offs, enabled by its up-gradation as the shortest highway path. In addition, due to its central location, it has more capacity of route segments to connect with the western and eastern route, which gives a strong trade-off relation among the CR (cost and reliability), the RV (reliability and capacity), and the CV (cost and capacity) to achieve competitive objectives. On the other hand, the eastern case can enhance trade with the big countries by using agricultural expertise and to gain benefits in return, which creates the need to relax the assumption of the RV trade-off (reliability and capacity).

3. Attributes are defined as the rerouting flexibility and trading reliability on the central, eastern, and western routes (the parallel route system). The attributes can be improved with the combination of capacities and resources. For example, the central case, due to its central location, can have more routing flexibility due to route segments connected to eastern and western cases, whereas the eastern and western cases will be less flexible with each other during road transportation. Similarly, the reliability also majorly depends on the route safety, Pakistan has been a hub of terrorist attacks which has been improved manifold but not eliminated, see Table A1 in Appendix A. The more the routing reliability can be increased, the more chances there will be to improve the CR in the long run. Another option is to upgrade the roads with more lanes which may pay back sooner or later, but one cannot increase the transport reliability by the existence of road insecurities, since it may increase the permanent indirect cost. In the western case, CR can be positively affected by close coordination between trade policy and route extensions to landlocked countries on its western border. It does not mean that CR will not be positively affected on other routes, but it is rather not a priority need on other routes. In all the cases, it is suggested that the sensitivity of the trade-off, such as RV, can be improved by improving core competency, i.e., production of major crops and delivery flexibility.

Table 3. Internal variables to determine sensitive roles.

Variables	Eastern Route	Central Route	Western Route
Cultivated area (000 ha)	264	156	98
Production [1] (000 tones)	10,322	5829	2993
Population density (per sq. km of land)	30,928	13,754	7430
Highway capacity (lanes) [2]	6	2	4
Routing flexibility (percentage) [3]	62	68	43

[1] Production of wheat, rice, cotton, and sugar-cane are considered (Bengali 2015). [2] The number of lanes is as per the official record of the National Highway Authority (Highway 2019). [3] Routing flexibility is measured by the average cost and time of each route. See Appendix A.

Figure 4 shows the sensitive role of internal variables (i.e., resource, capacity, and attribute). They are used to improve the pivot of trade-offs and allow one or more pairs to make trade-offs at a higher level to achieve high-level performance.

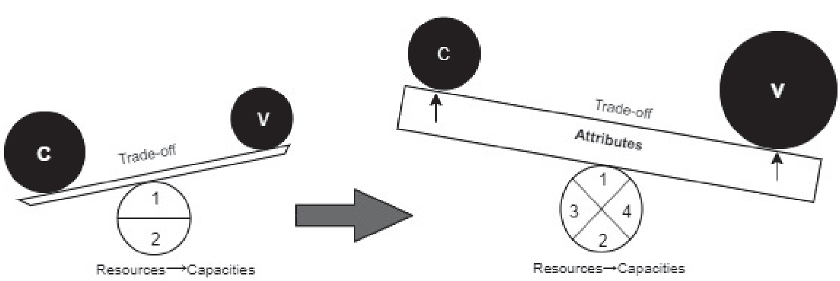

Figure 4. Trade-offs improvement by resources, capacities, and attributes.

6. Conclusions

The particular cases of a transport corridor unfold that the trade-offs are real, and they do exist; even more, they are the central approach for improving the operational processes. The much-argued questions "whether the trade-offs exist or which of them are more real and beneficial", are directly relevant to operations management practices and hence missing the point here. It is more useful to pose questions "How trade-off factors should be perceived in transport operations for a consistent competitive edge?", "What are the trade-off factors that can benefit more for specific sub-operations?", and "How many ways can be adopted to overcome the trade-offs". This paper does not adequately address these questions; instead, it provides an insight for operational managers in the transport corridors, who handle the process every day. The trade-off method can be an operational management technique, so that decision-makers do not have to invest in infrastructure to improve road reliability and traffic capacity, but can use alternative technologies for intelligent management.

Furthermore, it put forward the most useful ideas, which provide the foundation for the trade-off concept in transport operations, for far-reaching socio-economic benefits. They are as follows:

- Trade-offs are easily adaptable for practicing operational managers.
- The trade-offs, for consistent competitive advantages, are comparatively understandable and straightforward, which foresee the expected compromises for more consistent trade growth.
- Trade-offs must always be seen as a tool towards improvement in operations strategy. Otherwise, we must consider that the trade-offs have been overcome, and there is no room for further trade-offs. At this stage, further investment in resources and capacities may enable the trade-offs again at a higher level of performance.
- Among the corridors' operations, many sub-operations may find trade-offs as an easier approach than some other operations. For example, the series route system may have less capacity to accommodate trade-offs because of its less re-routing flexibility.
- The recognized trade-offs can be improved or raised using pivot by improving the resources and capacities in the transport corridor, but cannot be eliminated, because it helps to improve the related performance attribute.
- A trade-off in road transport operations differs in two aspects. First is the degree of importance that impacts the operational competitiveness, and the second is the degree of sensitivity that the change in one factor of operation may have a less or more significant effect on the other factors, where the optimal balance among trade-offs play the role.
- In the transportation corridor, some trade-offs are more apparent and strongly governed by recognized resources and capacities than other critical trade-offs.

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Appendix A

The figures and information on CPEC routes have been fetched from the national highway authority of Pakistan and Google maps (Highway 2019). Calculations are computed using Microsoft Excel.

Table A1. Cost, time, and safety insecurity on city nodes among parallel route system.

Sr	Major City Nodes under CPEC	Time Including Delay Time				Un-Safe Factors Disaster, Accidents, Terrorism			Cost			
		(h)	Prob	Mean	Var	Prob	Mean	Var	($)	Prob	Mean	Var
	WESTERN ROUTE	56.29	0.41			0.32			723	0.55		
1	Burhan-D.I.Khan	11	0.34	0.34	0	0.46	0.41	0.01	125	0.49	0.46	0.05
2	D.I.Khan-Zhob	9.4	0.31			0.48			89	0.28		
3	Zhob-Quetta	11.92	0.35			0.42			144	0.6		
4	Quetta-Surab	9.58	0.32			0.41			93	0.3		
5	Surab-Hoshab	14.28	0.39			0.24			194	0.86		
6	Hoshab-Gwadar	9.16	0.31			0.44			84	0.25		
	CENTRAL ROUTE	61.5	0.91			0.11			760	0.6		
1	Burhan-D.I.Khan (Partial Western Route)	11.06	0.34	0.34	0	0.4	0.36	0.01	125	0.49	0.46	0.1
2	D.I.Khan-Jampur	10.3	0.33			0.47			109	0.39		
3	Jampur-Wangu Hills	12.56	0.36			0.49			157	0.68		
4	Wangu Hills-Khuzdar	7.46	0.29			0.22			48	0.11		
5	Khuzdar-Basima	7.5	0.29			0.22			49	0.11		
6	Basima-Gwadar (Partial Western Route)	18.14	0.44			0.33			277	0.99		
	EASTERN ROUTE	112.58	0.41			0.64			948	0.84		
1	Peshawar-Islamabad	50.8	0.88	0.69	0.07	0.48	0.52	0.01	112	0.41	0.61	0.06
2	Islamabad-Pindi Bhattian	73.6	0.98			0.3			150	0.64		
3	Pindi Bhattian-Multan	106.66	1			0.49			161	0.7		
4	Multan-Sukkur	13.14	0.37			0.55			176	0.78		
5	Sukkur-Hyderabad	11.22	0.34			0.55			136	0.56		
6	Hyderabad-Karachi	45.12	0.83			0.63			65	0.17		
7	Karachi-Gwadar	17.9	0.45			0.63			272	0.99		

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Impact of Khartoum Stock Exchange Market Performance on Economic Growth: An Autoregressive Distributed Lag ARDL Bounds Testing Model

Tomader Elhassan [1,*] and Bakhita Braima [2,*]

1 Department of Administrative Sciences and Humanities, Jouf University, Qurayyat 77451, Saudi Arabia
2 Department of Finance & Investment, Tabuk University, Tabuk 47315, Saudi Arabia
* Correspondence: tomadurgaber@gmail.com (T.E.); bgadkreem@yahoo.com (B.B.); Tel.: +966-531039087 (T.E.); +966-538769915 (B.B.)

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Abstract: This study examines the impact of the Khartoum Stock Exchange market performance on economic growth in Sudan from Q1 1995 to Q4 2018. The data were collected from the Central Bank of Sudan (CBS) and Khartoum Stock Exchange (KSE). The autoregressive distributed lag (ARDL) bounds test was applied to estimate the impact of the Khartoum Stock Exchange market performance on economic growth. The results show that the Khartoum Stock Exchange market performance has a limited impact on economic growth. The results of the ARDL test reveal that the speed of adjustment towards long-run equilibrium after a short-term shock, which confirms the stability of Sudanese economic system through stock market performance, equals 24% only. Although market capitalization has a positive and significant impact on economic growth in the long term, the turnover ratio and stocks traded value showed insignificant negative impacts on economic growth. We recommend that suitable investment policies should be developed by policy makers for the Sudanese economy to allow the Khartoum securities market to attract foreign investors and encourage local investors in order to improve the efficiency and effectiveness of the stock market, thus, leading to a boost in securities exchanges as well as economic growth.

Keywords: growth; ARDL; stock exchange; capitalization; turnover; value traded

JEL Classification: C22; C57; G20; E44

1. Introduction

The stock exchange market plays a critical role as a financial intermediary in the economy by mobilizing saving units, subsequently handling them as deficit units which require capital to produce goods and services. Thus, the market contributes to economic growth by effectively allocating financial resources to mitigate the creditors' risks and enhance profitability by increasing the efficiency of financial intermediaries. Several literature reviews have explained the impact of stock markets on economic growth, as developed by Goldsmith (1969), Levine (1991), and Levine and Zervos (1998). By contrast, other authors have argued that stock market development measures explained part of the variation in economic growth, including Osamwonyi and Kasimu (2013), Adjasi and Biekpe (2006), Nguyen and Bui (2019), Rezina et al. (2017), Bayar et al. (2014), and Abdalla (2011). On the other hand, Pan and Mishra (2018) found a negative impact in the long term.

The stock market provides an indispensable centerpiece for the growth of economic sectors such as industries, firms, and trade, ultimately fostering a reasonable degree of economic growth in the country. Therefore, local government authorities—represented by the central banks—and the international monetary system track and control stock market activities closely. There are numerous avenues by which the impact of the stock market is conveyed to the economy. These avenues include liquidity on the stock market, real market capitalization, the value traded, and stock exchange turnover on the market, among other factors.

The stock exchange market is expected to promote savings by providing financial instruments for individuals that may better meet their risk preferences and liquidity needs. The mobilization of better savings would increase the savings rate (Abdalla 2011). Moreover, economic growth is perhaps encouraging for stock market development (Osamwonyi and Kasimu 2013). The stock market gives investors an opportunity to raise capital at reasonable costs. A fully fledged stock exchange market decreases credit risk to investors by providing market—rather than bank-based financing and, thus, is able to positively influence economic growth, as a perfect securities market helps investors to escape asymmetric information. This encourages companies to make investment decisions, therefore improving the efficiency of resource allocation and thereby increasing economic growth (Mamun et al. 2018).

The Khartoum Stock Exchange was launched in 1994. In 1995, a secondary market was launched with 34 listed companies. The market capitalization increased in 1997 to 139 dollars compared to 31 million dollars in 1995. The Financial Investment Bank was established to support the market. In 1999, the parallel market system was launched; furthermore, the issuance of Sukuk investment funds began in this year. In 2001, government participation certificates (Shahama) began to be issued. In 2003, the Khartoum index was announced as KSE30. The market witnessed an increase in trading indicators, the trading volume increased to 1.21 billion dollars, and the Khartoum KSE30 index increased with a growth of over 97.3% and a market value of 470 billion dollars. In 2007, the market was part of the African Stock Exchanges Union; in 2008, the share deposit of all listed companies was completed. In 2012, the electronic trading platform was launched. The market joined the Federation of Deposit Centers in Africa and the Middle East in 2014. In 2015, the market had an active role in combating money laundering. It received several international and regional awards, including the Capital Finance International Magazine Award in 2017. In 2018, market capitalization increased by SDG 48 million and the general index of the market increased by 13,317.48 points (KSE 2018).

Sudan's economy, particularly in recent years, has suffered from high inflation, fluctuations in exchange rates, supply shortages, and other economic problems. These problems, especially high inflation and fluctuations in exchange rates, negatively affect the Khartoum Stock market returns as much as stock prices (Omer and Ahmed 2020; Mohamed and Elmahgop 2020).

In addition, there is no clear consensus in the last studies in Sudan investigated the impact of Khartoum Stock Exchange Market performance as a financial development indicator on real economic growth. However, some studies examined the relation between financial development and economic growth in Sudan using bank credit as financial development indicator such as: Abdel-Gadir (2012) he demonstrated that a weak relationship between financial development and economic growth in Sudan (Sirag et al. 2018) their findings revealed that Foreign Direct Investment (FDI) leads to better economic performance through financial development;

As we know, Sudan is ones of sub-Sahara African countries there are some studied conducted in this geographic area such as Enisan and Olufisayo (2009), and Ngare et al. (2014). However, they did not include the Khartoum stock exchange market as a developing African country market, to demonstrate its role in economic growth.

2. Research Design

2.1. Problem

There is no clear consensus in previous studies on Sudan, which investigated the impact of the Khartoum stock exchange market performance as a financial development indicator on real economic growth.

2.2. Objectives

The main objective of this study is to fill the gap in Sudanese studies, because there is no clear consensus about the impact of the Khartoum stock exchange market on real economic growth as such as. Thus, we add new knowledge to African and worldwide studies by investigating the impact of the Khartoum stock exchange market performance on economic growth over 23 years (1995–2018). Because this period covers the age of this market from it establishment until the end of last government period, this period covers all Sudanese economic conditions witnessed by the Khartoum stock exchange market (KSEM) but we consider 2019 as the beginning of Sudan's temporary government period and excluded it from our study.

2.3. Methodology

The data were collected from the Central Bank of Sudan (CBS 2019) and the Khartoum stock exchange market (KSE 2018) for the period Q1 1995 to Q4 2018. Following some literature, we employed an autoregressive distributed lag (ARDL) approach to estimate the long run and the short run coefficients.

We employed the quarterly time series data of real GDP growth rate (RGDP), the turnover ratio of stocks traded (TR), the stocks traded value as a percentage of GDP (STV), and the market capitalization as a percentage of GDP (MC) to measure the impact of the Khartoum stock exchange market performance on economic growth in Sudan. The autoregressive distributed lag (ARDL) bounds test was applied to estimate the impact of the Khartoum stock exchange market performance on economic growth. The suggested hypotheses of this study are as follows:

The Khartoum stock exchange market performance has a significant positive impact on economic growth;

- Capitalization has a significant positive impact on economic growth;
- Turnover ratio has a significant positive impact on economic growth;
- Stocks traded value has a significant positive impact on economic growth.

The results show that the Khartoum stock exchange market performance has a limited impact on economic growth, his weak relationship between KSEM performance and real GDP is attributed usually to the prevailing situations of political instability, and prolonged civil wars (Sufi an Abdel-Gadir (2012)).

2.4. Organization

The paper proceeds as follows: Section 2 provides research design, Section 3 briefly reviews the literature on the growth–stock market nexus. Section 4 specifies the model and indicates the sources of data and setting up the econometric methodology use in the study. Section 5, contains the main findings of the study, their analyses and assessments. The Section 6 contains conclusions and policy implications, recommendation, and limitations.

2.5. The Significant of the Study

This study fills the gap because there is no clear consensus about the impact of Khartoum stock exchange market on real economic growth and as such, this study adds new knowledge to African and worldwide studies. The results of the ARDL test reveals the speed of adjustment towards the long-run equilibrium after a short-term shock, which confirms the stability of the Sudanese economic system through stock market performance, equaling 24%.

2.6. Implications

One of the most obvious implications of our results is that if Sudan is to realize its target growth rate, it needs to create a stable political and economic climate conducive to increase real sector investment through the Khartoum stock exchange market. In addition to policies designated to raise local investment awareness and encourage foreign direct investment in the Khartoum stock market and adopting modern technology in the Sudanese financial system are preconditions for Sudan's economic success. Thus, economic policy makers, Khartoum stock exchange market management, technology supplier companies, as well as economic and finance researchers are going to benefit from reading this paper.

2.7. The Limitations of This Study

This study focuses on financial development using Khartoum stock exchange market (KSEM) performance proxies as supply side only, following the suggestion that the existence of units relate to deficit units, thereby promoting efficient allocation of resources and thus leading other economic sectors in the growth process. Therefore, further studies should examine the bidirectional relationship between financial development, stock exchange market performance and economic growth in Sudan and other African countries.

3. Literature Review

The literature review conducted in the present study was crucial and allowed for the definition of the following model variables by which the impact of the stock market was measured: market capitalization, turnover ratio, and total value of stocks traded. The literature review differed in terms of the analysis methods used from other works. Some studies have found that the impact of the stock market was on economic growth, and some found otherwise. The most significant study was carried out by Goldsmith (1969). Therefore, the stock market could provide an effective investment channel for investors and increase long-term capital sources for companies, additionally boosting economic growth.

Firstly, this study is based on the Modigliani hypothesis, which refers to the increase in securities prices that lead to increases in individuals' possession of wealth to a high permanent income level. Therefore, the consumption level increases, leading to increased investment, and the resulting increase in the investment multiplier, in turn, results in increased economic growth (Modigliani 1971).

Secondly, the literature review covered the following topics.

In the study by Osaseri and Osamwonyi (2019), the authors used quarterly data for the period 1994–2015. Moreover, they used the panel least squares approach based on a fixed estimation model. Their work showed that stock market development has a significant impact on economic growth. In addition, a positive correlation exists between stock market development indicators and BRICS's economic growth.

Nyasha and Odhiambo (2019) used the autoregressive distributed lag approach to examine the period 1980–2012. They found that market-based financial developments have a positive effect on economic growth in the United States in both the long and the short term.

Tekin (2019) employed a Toda–Yamamoto Granger causality test to estimate quarterly data for the period 1998–2017. The results showed one-way causality from the stock market to economic growth in the USA, BRICS countries, and Turkey. However, the results for Germany indicated a two-way relationship.

Nguyen and Bui (2019) employed the ARDL approach estimation technique for the analysis of data. They revealed that economic growth was more strongly correlated with stock market efficiency than foreign investors' net trading interest.

Mamun et al. (2018) employed the ARDL bounds testing approach to obtain estimations for the period 1993–2016. The study found a direct impact of the stock market on economic growth both in the short and long term along with the spread of interest rates, financial support, and real effective exchange rate.

Pan and Mishra (2018) used annual data over the period 2007–2012 and employed the ARDL bounds testing approach. They found no relationship between the stock market and the real economy in the short term. In addition, there was a negative relationship between the Shanghai A share stock market and the real sector in the long term.

Sirag et al. (2018) they have used fully modified ordinary least squares and the dynamic ordinary least squares techniques to estimate the long-run model, and analyzed annual data from 1970 to 2014. They have demonstrated that financial development and FDI are positive and significant in explaining economic growth in Sudan. Moreover, their findings revealed that FDI leads to better economic performance through financial development; they have use banks' credit to the private sector as financial development proxy.

Rezina et al. (2017) employed the Granger causality test for estimations for the period 1994–2015. Their results showed that there is a long-term relationship between economic growth and the factors of stock market and that there is unidirectional causality from the factors of stock market capitalization, the total value of stocks traded, and the turnover ratio of stocks traded to economic growth.

Dimic et al. (2015) investigated how determinants of the political risk factor affect the stock returns of developed, emerging and frontier markets. They found that political risk influences the stock return of developed, emerging and frontier markets, which is different according to the market category. However, government stability is a unique source of political risk in frontier markets.

Bayar et al. (2014) employed the Granger causality test for the period 1999–2013. The results showed that the factors of stock market capitalization, total value of stocks traded, and turnover ratio of stocks traded had significant influences on economic growth in the long and short term.

Rajabi and Muhammad (2014) employed the dynamic panel pooled mean-group technique. They found that the stock market showed a significant effect on economic growth. Furthermore, the turnover ratio had a positive effect on economic growth.

Ngare et al. (2014) used annual data over the period 1980–2010 and employed the panel data econometrics technique. They found countries have stock markets that grow faster than countries that without stock markets, they demonstrated that, stock market development have a positive effect on economic growth, moreover, countries that were politically stable and less corrupt tend to grow faster.

Ishioro (2013) applied the Granger non-causality estimation technique proposed by Toda and Yamamoto. He found that there was a causality between economic growth and real stock market volatility, market capitalization, and the value traded ratio.

Masoud (2013) used causality testing and demonstrated that the stock market has a positive relationship on economic growth in the short and long term.

Osamwonyi and Kasimu (2013) adopted the Granger causality test for the period 1989–2009. Their results showed that there was causality between stock market development and economic growth in Kenya, while no causality was found in Ghana and Nigeria; however, their causality test showed the presence of causality between stock market capitalizations and the number of listed securities and bidirectional causality between stock turnover ratio and economic growth. Additionally, the stock traded value had a strong negative impact on economic growth.

Abdel-Gadir (2012) over the period (1970–2007) by using the autoregressive distributed lag (ARDL) approach to co-integration. He used M3/GDP and he value of credit offers by the commercial banks to the private sector divided by GDP as financial development proxies in addition to inflation rate and government spending (GOV) as a percentage to GDP proxies as macroeconomic in stability indicators, his results demonstrated that a weak relationship between financial development and economic growth in Sudan.

Abdalla (2011) used the Granger causality test. He demonstrated that economic growth is sensitive to the stock market and that there is a bidirectional causal relationship between market capitalization and economic growth; on the other hand, there was a unidirectional causal relationship from economic growth to stock market liquidity.

Kaya et al. (2011) employed the Granger causality test to estimate quarterly data for the period 1988 to 2004. The study concluded that stock market development did not lead to economic growth.

Enisan and Olufisayo (2009) employed the autoregressive distributed lag bounds test. Their results showed that the stock market development was co integrated with economic growth in Egypt and South Africa. Moreover, this test suggests that stock market development has a significant positive long run impact on economic growth. The Granger causality test based on vector error correction model (VECM) further showed that stock market development Granger causes economic growth in Egypt and South Africa. However, Granger causality, in the context of Vector AutoRegressionVAR shows evidence of bidirectional relationship between stock market development and economic growth for Cote D'Ivoire, Kenya, Morocco and Zimbabwe. In Nigeria, there is a weak evidence of growth-led finance using market size as indicator of stock market development. Based on these results, the paper argued that stock markets could help promote growth in Africa. However, to achieve this goal, African stock markets need to be further developed through appropriate regulatory and macroeconomic policies.

Adjasi and Biekpe (2006) used the dynamic panel data model. Their results showed a positive impact between the stock market and economic growth. Additionally, a significantly positive impact of the stock market was found in upper and middle-income countries, while the stock markets of low-income countries were shown to require development.

4. Materials and Methods

4.1. Data Sources

The study employs the quarterly time series data of real GDP growth rate (RGDP), the turnover ratio of stocks traded (TR), the stocks traded value as a percentage of GDP (STV), and the market capitalization as a percentage of GDP (MC) to measure the impact of the Khartoum stock exchange market performance on economic growth in Sudan. The data were collected from the Central Bank of Sudan (CBS 2019) and the Khartoum stock exchange market (KSE 2018) for the period Q1 1995 to Q4 2018.

4.2. Model Specification

The study was based on the Modigliani hypothesis and previous models, allowing us to build the following model:

$$\mathrm{RGDP} = \mathrm{f}(\mathrm{MC}, \mathrm{STV}, \mathrm{TR})$$

where RGDP is economic growth, MC is market capitalization as a percentage of GDP (the value of listed shares of real GDP (Mamun et al. 2018), STV is the stocks traded value as a percentage of GDP (the value of the trades of domestic shares of real GDP (Ishioro 2013)), and TR is turnover ratio of stocks traded (total value of stocks traded/market capitalization) (Bayar et al. 2014).

4.3. Econometric Analysis Methods

4.3.1. Unit Root Test

The study employed Augmented Dickey–Fuller and Phillip–Perron stationary tests to examine the stationarity of the series. The results for the series are listed in Tables 1 and 2.

Table 1. Augmented Dickey–Fuller (ADF) stationary test. RGDP: real GDP growth rate; MC: market capitalization; STV: stocks traded value; TR: turnover ratio.

Unit Root Test Results Table (ADF)					
Null Hypothesis: The Variable Has a Unit Root					
	At Level				
		RGDP	**MC**	**STV**	**TR**
With Constant	*t*-Statistic	−1.9175	−2.5775	−1.4089	−1.9416
	Prob.	0.3229	0.1014	0.5747	0.3120
		no	no	no	no
With Constant and Trend	*t*-Statistic	−2.2542	−2.5589	−0.2717	−1.1806
	Prob.	0.4538	0.3000	0.9904	0.9078
		no	no	no	no
Without Constant and Trend	*t*-Statistic	−0.8878	−0.6555	−0.6302	−0.7333
	Prob.	0.3287	0.4306	0.4417	0.3961
		no	no	no	no
	At First Difference				
		d(RGDP)	d(MC)	d(STV)	d(TR)
With Constant	*t*-Statistic	−3.0848	−2.3194	−5.2510	−1.8133
	Prob.	0.0314	0.1682	0.0000	0.3718
		**	no	***	no
With Constant and Trend	*t*-Statistic	−3.0791	−2.3047	−5.4981	−1.7198
	Prob.	0.1179	0.4269	0.0001	0.7340
		no	no	***	no
Without Constant and Trend	*t*-Statistic	−3.0898	−2.2751	−5.3006	−1.7949
	Prob.	0.0024	0.0229	0.0000	0.0692
		***	**	***	*

Notes: a: (*) Significant at 10%; (**) significant at 5%; (***) significant at 1% and (no) not significant; b: lag length based on Schwarz Info Criteron SIC; c: probability based on MacKinnon (1996) one-sided *p*-values; source: authors' analysis using EViews 10, 2020.

The stationary test results show that RGDP, MC, TR and STV variables are stationary at the first level of difference. According to the ADF results in Table 1, the null hypothesis of non-stationary is rejected for all the variables at the 1%, 5%, 10% significance levels. The stability of the variables at the first level of difference enables the use of the ARDL bounds test.

The stationary test results show that RGDP, MC, TR and STV variables are stationary at the first level of difference. According to PP results in Table 2, the null hypothesis of non-stationarity is rejected for all the variables at 1%, 5%, and 10% significance levels. The stability of the variables at the first level of difference enables the use of the ARDL bounds test.

Table 2. Phillip–Perron (PP) stationary test.

Unit Root Test Results Table (PP)					
Null Hypothesis: The Variable Has a Unit Root					
	At Level				
		RGDP	**MC**	**STV**	**TR**
With Constant	*t*-Statistic	−2.9828	−1.5729	−1.5865	−1.8247
	Prob.	0.0401	0.4924	0.4855	0.3666
		**	no	no	no
With Constant and Trend	*t*-Statistic	−3.9008	−1.4984	−0.8996	−1.9022
	Prob.	0.0157	0.8236	0.9512	0.6456
		**	no	no	no
Without Constant and Trend	*t*-Statistic	−0.8838	−0.4596	−0.8874	−1.2666
	Prob.	0.3307	0.5136	0.3292	0.1879
		no	no	no	no
	At First Difference				
		d(RGDP)	d(MC)	d(STV)	d(TR)
With Constant	*t*-Statistic	−6.0204	−3.7612	−4.2412	−3.4290
	Prob.	0.0000	0.0046	0.0010	0.0123
		***	***	***	**
With Constant and Trend	*t*-Statistic	−5.9429	−3.7583	−4.4010	−3.4840
	Prob.	0.0000	0.0232	0.0035	0.0470
		***	**	***	**
Without Constant and Trend	*t*-Statistic	−6.0644	−3.7386	−4.2749	−3.4440
	Prob.	0.0000	0.0003	0.0000	0.0007
		***	***	***	***

Notes: a: (**) significant at 5%; (***) significant at 1% and (no) not significant; b: lag length based on SIC; c: probability based on MacKinnon (1996) one-sided *p*-values; source: authors' analysis using EViews 10, 2020.

4.3.2. ARDL Bounds Test

The study employs the autoregressive distributed lag (ARDL) approach; it introduced originally by Pesaran (1997) and redeveloped ARDL bounds testing approach by Pesaran et al. (1999, 2001). The ARDL approach is distinguished from other co-integration approaches such as Engle and Granger (1987), Johansen and Juselius (1990), and Johansen (1992, 1995), it can be used if the variables are integrated of order one [I(1)], order zero [I(0)], or a combination of both. In addition, not assumed is an equal lag length in the model (Duasa 2007). Moreover, the ARDL approach provides unbiased estimates and statistically significant *t*-statistics in the long term even when some of the regressors are endogenous (Odhiambo 2011). It is suitable for small samples size ranging over 30 observations. The ARDL approach is applied as follows: test unit roots and ensure that the all variables are integrated of order one [I(1)], order zero [I(0)], or a combination of both, then the long and short term models are estimated by way of cointegration Wald test. The decision is that if the computed Ward test *F*-statistic is the upper bound critical value, therefore, we can reject the null hypothesis of cointegration. If the computed Ward test *F*-statistics is less than the lower bound critical value, this means that we don't reject the null hypothesis of cointegration. Furthermore, the decision is inconclusive if the computed Wald test F-statistics value falls within the lower and upper bound critical values.

Finally, the diagnostic and stability analysis (Menegaki 2019). Therefore, the ARDL approach is very suitable to our study. It has been widely used in empirical studies in recent years.

An autoregressive distributed lag (ARDL) bounds test is specified as follows

$$\Delta(RGDP_t) = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta RGDP_{t-1} + \sum_{i=1}^{n} \alpha_2 \Delta MC_{t-1} + \sum_{i=1}^{n} \alpha_3 \Delta STV_{t-1} + \sum_{i=1}^{n} \alpha_4 \Delta TR_{t-1} + \alpha_5 RGDP_{t-1}$$
$$+ \alpha_6 MC_{t-1} + \alpha_7 STV_{t-1} + \alpha_8 TR_{t-1} + e$$

4.3.3. ECM Model

After confirmation of the long term association, the error correction model (ECM) is applied to estimate short term relationships among underlying variables. The sign of ECT must be negative and statistically significant, with a coefficient (η) ranging between zero and one, which represents the speed of adjustment towards long-run equilibrium after a short-term shock that confirms the stability of the system. We estimate the following equation:

$$\Delta(RGDP_t) = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta RGDP_{t-1} + \sum_{i=1}^{n} \alpha_2 \Delta MC_{t-1} + \sum_{i=1}^{n} \alpha_3 \Delta STV_{t-1} + \sum_{i=1}^{n} \alpha_4 \Delta TR_{t-1} + \alpha_5 ECT_{t-1} + e$$

Bounds testing for co-integration analysis:

$$H_0 = \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$$
$$H_1 = \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq 0$$

The Table 3 provides test results demonstrating that all variables have long-term relationships (an *F*-statistic above the critical upper bound value at the 1% significance level indicates that there is a long-term co-integration relationship among the RGDP and its independent variables).

Table 3. Wald test for long-term cointegration.

Wald Test				
	F-statistic Value	Signif.	I(1)	I(0)
$f_{RGDP}(RGDP/MC, STV, TR)$	6.862741	10%	2.37	3.2
		5%	2.79	3.67
		2.50%	3.15	4.08
		1%	3.65	4.66

Source: authors' analysis using EViews 10, 2020.

4.3.4. Diagnostic Check for Serial Correlation

Table 4 indicates that the Breusch–Godfrey serial correlation LM test shows no problem with serial correlation, because the *p*-value is greater than 0.05.

Table 4. Diagnostic check for serial correlation.

Breusch–Godfrey Serial Correlation LM Test	
F-statistic	0.085333
Prob. F(1,81)	0.7709

Source: authors' analysis using EViews 10, 2020.

5. Results

5.1. Estimation of Long-Term Coefficients

The long-term results in Table 5 allow and Figure A1 allow us to create the estimated long-term model shown above. The MC coefficient has statistical significance at the 0.01 level; in the long term, a 1% increase in MC would increase economic growth by 1.16%. The result shows that market capitalization has a positive impact on economic growth in Sudan, supporting the previous findings by Osaseri and Osamwonyi (2019), Mamun et al. (2018), Bayar et al. (2014), Abdalla (2011), Ishioro (2013), Ngare et al. (2014) and Enisan and Olufisayo (2009). The Enisan and Olufisayo (2009) study supports our study in the relationship between stock market and growth, as in the case of Nigeria. STV is statistically significant at the 10% level, but its impact on economic growth is negative. This result indicates that, in the long term, a 1% increase in STV would reduce economic growth by 4.52%.

This result supports the previous findings by Pan and Mishra (2018) and Osamwonyi and Kasimu (2013) and is in contrast with those made by Osaseri and Osamwonyi (2019), Rezina et al. (2017) and Ishioro (2013). TR doesn't affect significantly on economic growth. This result go in contrast of Osaseri and Osamwonyi (2019), Pan and Mishra (2018), Osamwonyi and Kasimu (2013), and Ishioro (2013).

Table 5. Estimation of long-term coefficients.

Estimation of Long-Term Coefficients				
Variable	**Coefficient**	**Std. Error**	***t*-Statistic**	**Prob**
MC	1.160328	0.442268	2.623583	0.0104
STV	−4.515979	2.438455	−1.851984	0.0676
TR	0.072632	0.067485	1.076261	0.285
C	5.82237	1.089981	5.341717	0
EC = RGDP − (1.1603 × MC − 4.5160 × STV + 0.0726 × TR + 5.8224)				

Source: authors' analysis using EViews 10, 2020.

5.2. Short-Term Error Correction

The short-term results in Table 6 and Figure A2 indicate the value of the ECM (−1) coefficient was found to be negative and statistically significant, as expected. This indicates that a shock in the economy will be adjusted by 0.24 in the next year. This indicates that any shock in the Sudanese economy will be corrected in the next year by 24%, only through the stock exchange market. Thus, we can say that the stock exchange market can affect slightly the Sudanese economy. The short-term parameters are significantly different from the long-term results: MC has a negative impact on economic growth in Sudan and TR is statistically significant at the 0.05 level, but its impact on RGDP is negative, supporting the previous findings by Enisan and Olufisayo (2009). STV is statistically significant at the 0.05 level, and its impact on RGDP is positive. These results are in contrast to those of Sheilla Nyasha and Nicholas M Odhiambo, Nyasha and Odhiambo (2019) and Ngare et al. (2014), who demonstrated that market-based financial development has a positive impact on economic growth in the long and short term.

Table 6. Short-term error correction.

Short-Term Error Correction Result				
Variable	**Coefficient**	**Std. Error**	***t*-Statistic**	**Prob.**
D(RGDP(−1))	0.393362	0.086324	4.556792	0
D(RGDP(−2))	0.23669	0.087387	2.708523	0.0082
D(MC)	−1.065073	0.30511	−3.490785	0.0008
D(STV)	2.854943	1.317073	2.167643	0.0331
D(TR)	−0.098007	0.037431	−2.618295	0.0105
@AFTER("2007")	−0.624119	0.14412	−4.330553	0
CointEq(−1) *	−0.235444	0.039247	−5.998962	0

* means the result is significant all levels (1, 5, 10). Source: authors' analysis using EViews 10, 2020.

5.3. Stability Analysis

Figures 1 and 2 show that the cumulative sum and cumulative sum of squares graphs are within the critical limits at a significant level of 0.05; this means that the model has stability and validity.

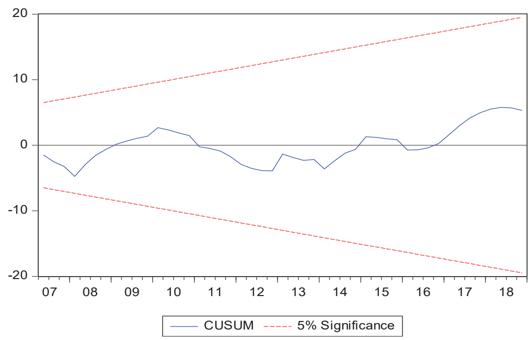

Figure 1. Plot of cumulative sum of recursive residual.

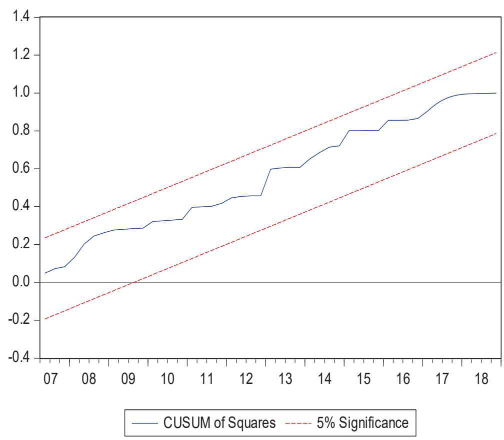

Figure 2. Plot of cumulative sum of squares. Source: authors' analysis using EViews 10, 2020.

5.4. Diagnostic and Stability Analysis

Table 7 indicates that the LM test shows no problem in terms of serial correlation, since the *p*-value (0.77) is higher than 0.05. The results of the heteroskedasticity test indicate no issues since the *p*-value (0.45) is higher than 0.05. The Ramsey Regression Equation Specification Error testRESET test probability value (0.79) is higher than 0.05, which means the model is valid (i.e., it does not suffer from omitted variables).

Table 7. Diagnostic and stability analysis.

Statistics	Estimated Value	Prob
Breusch–Godfrey Serial Correlation LM Test	0.085333	0.7709
ARCH Test	0.584675	0.4465
Ramsey RESET Test	0.26835	0.7891

Source: authors' analysis using EViews 10, 2020.

6. Conlusions, Policy Implications, Recommendationand Limitations

6.1. Conclusions and Policy Implications

In this study, we examined the impact of the Khartoum stock exchange market performance on economic growth in Sudan; for this, the data for Q 1 1995 to Q4 2018 were used. The empirical results of the study and the stationary test results show that all variables are stationary at the first level of difference. The stability of the variables at the first level of difference enables the use of the ARDL bounds testing approach. Market capitalization (MC) measures the ability of the market to provide capital, and it was found to be has positive and statistically significant impact on economic growth in the long term, (coefficient = 1.160328, p value = 0.0104), see (Table 5). Therefore, this result indicates the ability of the market to mobilize capital. However, it has negative and significant impact on economic growth in short-term (coefficient = −1.065073, p = 0.0008), see (Table 6). The liquidity, represented by stock turnover ratio (TR), the result showed that it does not affect significantly on economic growth in the long term (coefficient = 0.072632, but, p value = 0.285) see Table 5. However, it affects negatively, and significantly on economic growth in the short-run (coefficient = −0.098, p value = 0.0105), see Table 6. This negative impact is observed through the investment efficiency of the stock exchange market, as well as the increasing in the transactions cost. Although the stocks traded value (STV) does not affect significantly on economic growth in the long-term, it affects positively and significantly on economic growth in the short-term.

The ECM (−1) coefficient was found to be negative and statistically significant, as expected. This indicates that a shock in the economy will be adjusted by 0.24 in the next year. This result indicates that any shock in the Sudanese economy will be corrected in the next year by 24% only through stock exchange market. Thus, we can say stock exchange market can affect slightly on the Sudan economy.

One of the most obvious implications of our results is that if Sudan is to realize its target growth rate it needs to create a stable political and economic climate conducive to increase in real sector investment through Khartoum stock exchange market. In addition to policies designated to raise local investment awareness and encourage foreign direct investment in the Khartoum stock market, and adopting modern technology in the Sudanese financial system, these are preconditions for Sudan's economic success. Thus economic policy makers, Khartoum stock exchange market management, technology supplier companies, and economics and finance researchers are going to benefit from reading this paper.

6.2. Recommendations

This study recommends that suitable investment policies should be developed by policy makers for the Sudanese economy, allowing the Khartoum securities market to attract foreign investors and encourage local investors in order to improve the efficiency and effectiveness of the stock market, thus leading to securities exchanges as well as economic growth being boosted. Further studies should focus on the impact of bank credits and human capital on the model. In addition, we recommend further studies should examine the bidirectional relationship between financial development, stock exchange market performance and economic growth in Sudan and other African countries.

6.3. Limitations

The study was limited by a lack of financial and economic data for the recent years of 2019 and 2020. The study focuses on financial development using Khartoum stock exchange market (KSEM) performance proxies as supply side only, following the suggestion that the existence of units relates to the deficit units, thereby promoting efficient allocation of resources and thus leading other economic sectors in the growth process. Therefore, further investigation of (KSEM) as a financial development indicator in terms of demand side (to test how growth in the real sector of the economy can facilitate KSEM performance development) will complete our work.

Author Contributions: T.E. and B.B. prepared the study and were responsible for the design, development of the data analysis, and discussion results. All authors have read and agree to the published version of the manuscript.

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Appendix A

ARDL Long Run Form and Bounds Test
Dependent Variable: D(RGDP)
Selected Model: ARDL(3, 1, 1, 1)
Case 2: Restricted Constant and No Trend
Date: 07/06/20 Time: 16:10
Sample: 1995Q1 2018Q4
Included observations: 93

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.370840	0.387996	3.533133	0.0007
RGDP(-1)*	-0.235444	0.042290	-5.567338	0.0000
MC(-1)	0.273192	0.103744	2.633334	0.0101
STV(-1)	-1.063258	0.553742	-1.920133	0.0583
TR(-1)	0.017101	0.015242	1.121948	0.2652
D(RGDP(-1))	0.393362	0.088482	4.445650	0.0000
D(RGDP(-2))	0.236690	0.090312	2.620822	0.0105
D(MC)	-1.065073	0.330606	-3.221575	0.0018
D(STV)	2.854943	1.400187	2.038973	0.0447
D(TR)	-0.098007	0.039321	-2.492484	0.0147
@AFTER("2007")	-0.624119	0.311141	-2.005903	0.0482

* p-value incompatible with t-Bounds distribution.

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MC	1.160328	0.442268	2.623583	0.0104
STV	-4.515979	2.438455	-1.851984	0.0676
TR	0.072632	0.067485	1.076261	0.2850
C	5.822370	1.089981	5.341717	0.0000

EC = RGDP - (1.1603*MC -4.5160*STV + 0.0726*TR + 5.8224)

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	6.862741	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	93		Finite Sample: n=80	
		10%	2.474	3.312
		5%	2.92	3.838
		1%	3.908	5.044

Figure A1. Estimation of long-term coefficients. Source: authors' analysis using EViews 10, 2020.

ARDL Error Correction Regression
Dependent Variable: D(RGDP)
Selected Model: ARDL(3, 1, 1, 1)
Case 2: Restricted Constant and No Trend
Date: 07/06/20 Time: 16:10
Sample: 1995Q1 2018Q4
Included observations: 93

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RGDP(-1))	0.393362	0.086324	4.556792	0.0000
D(RGDP(-2))	0.236690	0.087387	2.708523	0.0082
D(MC)	-1.065073	0.305110	-3.490785	0.0008
D(STV)	2.854943	1.317073	2.167643	0.0331
D(TR)	-0.098007	0.037431	-2.618295	0.0105
@AFTER("2007")	-0.624119	0.144120	-4.330553	0.0000
CointEq(-1)*	-0.235444	0.039247	-5.998962	0.0000

R-squared	0.505958	Mean dependent var	-0.018985
Adjusted R-squared	0.471490	S.D. dependent var	0.990145
S.E. of regression	0.719822	Akaike info criterion	2.252660
Sum squared resid	44.56036	Schwarz criterion	2.443286
Log likelihood	-97.74869	Hannan-Quinn criter.	2.329629
Durbin-Watson stat	2.026837		

* p-value incompatible with t-Bounds distribution.

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	6.862741	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Figure A2. Short-term error correction result. Source: authors' analysis using EViews 10, 2020.

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Article

The Optimization of Bayesian Extreme Value: Empirical Evidence for the Agricultural Commodities in the US

Jittima Singvejsakul [1,*], Chukiat Chaiboonsri [2] and Songsak Sriboonchitta [2,3]

[1] Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[2] Faculty of Economics, Chiang Mai University, Chiang Mai 50200, Thailand; chukiat1973@gmail.com (C.C.); songsakecon@gmail.com (S.S.)
[3] Puey Ungphakorn Center of Excellence in Econometrics, Chiang Mai University, Chiang Mai 50200, Thailand
* Correspondence: jittima.s@cmu.ac.th

Abstract: Bayesian extreme value analysis was used to forecast the optimal point in agricultural commodity futures prices in the United States for cocoa, coffee, corn, soybeans and wheat. Data were collected daily between 2000 and 2020. The estimation of extreme value can be empirically interpreted as representing crises or unusual time series trends, while the extreme optimal point is useful for investors and agriculturists to make decisions and better understand agricultural commodities future prices warning levels. Results from the Non-stationary Extreme Value Analysis (NEVA) software package using Bayesian inference and the Newton-optimal methods provided optimal interval values. These indicated extreme maximum points of future prices to inform investors and agriculturists to sell the contract and product before the commodity prices dropped to the next local minimum values. Thus, agriculturists can use this information as an advanced warming of alarming points of agricultural commodity prices to predict the efficient quantity of their agricultural product to sell, with better ways to manage this risk.

Keywords: agricultural commodity future prices; extreme value; NON-stationary Extreme Value Analysis (NEVA); Newton-optimal method

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1. Introduction

Commodity futures are one of the most important asset classes. Investors are now increasingly investing their portfolios into commodity futures after the equity market crash in 2000. Investment in commodities is attractive in terms of diversification with respect to fixed income from equities that follows changes in inflation rates. The large changes in commodity prices that occurred in late 2008 have attracted considerable research attention. The financial crisis in 2008, caused by the subprime crisis in the United States, played a very important role in the economic system. Agricultural commodities are an influential group in the futures market and also impact economic productive growth in every country. Food price volatility is a critical problem for governments and regulators worldwide as most nations trade in food. High food prices can lead to poverty and malnourishment, especially in developing countries. The United Stated performs best farming practices and is the world's richest agricultural nation. The largest crops grown in the United States are corn and soybeans, with wheat, coffee and cocoa as the second rank of production. The agricultural industry in the United States contributes more than 100 USD billion to the economy, but agricultural exports remained depressed in 2019. Extreme price changes have become increasingly interesting in financial markets for many agricultural commodities. Commodity markets are widely used for risk management by producers and by the federal crop insurance program that has revenue protection. Extreme price events can have major implications on producer profitability. Consequently, futures prices for cocoa, coffee, corn, soybeans and wheat, as a broad range of agricultural commodities, are employed to statistically investigate the optimal point in future prices to try to understand what could trigger the next global crisis and when. Two types of maximum points are defined as the global maximum and local maximum. The global maximum is the absolute maximum for the overall number of sets across the entire domain of the function, while the local maximum is the relative maximum from a particular neighborhood and might have many points for one set.

This paper focused on the estimation of the local maximum which, using the Non-stationary Extreme Value Analysis (NEVA) software package with Bayesian inference and the Newton-optimal methods, provided optimal interval values. Estimation of the optimal local maximum point is useful for investors and agriculturists to plan their investments and initiate product sales before the agricultural commodity future prices drop to the next local minimum point. The study of early warning points would be useful in a global financial crisis and commodity prices, especially in the agriculture sector. This study consists of five sections. After the introduction, Section 2 provides an overview as a literature review that includes Bayesian and other extreme value applications. Section 3 details the research methodology used to quantify the Bayesian extreme values for agricultural commodities, with results of our empirical analysis presented in Section 4, while key conclusions are drawn in Section 5.

2. Literature Review

This section provides an overview of previous research on extreme value applications. Historically, several studies have considered and investigated extreme value theory in an economic system. Gilli and Këllezi (2006) studied the measurement of financial risk using extreme values, focusing on the computation of tail risk measures and confidence intervals in the stock market index. Estimations showed a 0.01 probability that the loss value would be 2.397%, with the confidence interval finite at 1/0.671 > 1. Peruvian stock market returns were studied by Gabriel in 2017 (Gabriel 2017) by investigating daily data to obtain 'value at risk' and 'expected shortfall' using the generalized Pareto distribution (GPD). Results showed a negative return from the stock market at 12.44% in 2011 and instability for the negative stock market from estimation of the Hill tail index. Oordt, Stork and Vries (Oordt et al. 2013) studied agricultural commodities extreme price risk. They showed that the agricultural price had a fat tail and occurred endogenously as a result of productivity shock for commodities futures in the United States as corn, oats, soybeans, wheat, cotton, sugar, orange juice, live cattle and lean hogs. Estimation of the extreme value of commodities in agriculture was also undertaken by Fretheim and Kristiansen (2015). They applied the extreme value theory approach to commodity market risk from 1995 to 2013 using commodity prices of corn, wheat, soybeans, soy oil, cocoa, orange juice, lean hogs and feeder cattle. Their contribution as an empirical analysis confirmed a well-established fact, namely, that the distribution of commodity price returns is fat-tailed relative to the Gaussian distribution. An analysis of the estimated shape parameters of the generalized extreme value (GEV) distribution further substantiated no systematic change in the extreme risk associated with commodity investments. They concluded that commodity return distributions had heavy tails during the period 1995 to 2013.

One statistical analysis is called the Bayesian extreme value approach. This method is proposed as an alternative analysis using Bayesian extreme values that can provide accurate results using random parameters, while the extreme value approach presents only fixed parameters. Several studies have investigated this method. For instance, Merwe, Steven and Pretorius (Merwe et al. 2018) explored the Bayesian extreme value analysis of stock exchange data, focusing on the fitting of the GPD beyond a threshold and improved the Bayesian methods with parameter estimation, while Wannapan, Chaiboonsri and Sriboonchitta (Wannapan et al. 2018) considered extreme values for macro-econometric forecasting of the gross domestic product (GDP), consumer price index (CPI) and foreign direct investment (FDI) using Non-stationary Extreme Value Analysis (NEVA) by applying Bayesian inference. Results showed extreme points of macroeconomic data that presented as the interval value and optimal point. Park and Maples (2018) studied extreme events and the serial dependence of agricultural commodity prices. They used the daily price of five agricultural commodities as corn, soybeans, wheat, cotton and live cattle. Results revealed that the prediction accuracy of the Bayesian hierarchical model for serially dependent extremes outperformed the other candidates in measuring extreme risks in the agricultural commodity markets. The model captured the changes in the shape of a heavy-tailed distribution when calculating risk measures such as the expected price shortfall and value at risk (VaR).

However, limited studies exist concerning Non-stationary Extreme Value Analysis (NEVA) that apply Bayesian inference with financial data and commodity prices, especially agricultural commodities. Therefore, in this paper, we proposed the Bayesian extreme value using the Newton optimization processing method to study the extreme value point in five major agricultural commodities future prices in the United States including cocoa, coffee, corn, soybeans and wheat.

3. Research Methodology

In this study, several methods were employed to determine the forecast of Bayesian extreme value optimization in agricultural commodity future prices. Firstly, the augmented Dickey–Fuller (ADF) unit root test, based on Bayesian inference, was used to classify the stationary data and non-stationary data. Second, the Non-stationary Extreme Value Analysis (NEVA) method was employed to determine the extreme interval for both the non-stationary and stationary data. Lastly, the results from the NEVA were plugged into the random variable method to obtain a finite random set, before estimation using the Newton-optimal processing method to determine the optimal extreme point.

3.1. The Unit Root Test Using Bayesian

The unit root test is investigated by using the ADF test, which shows the ratio between the stationary data and non-stationary data of the null hypothesis (Said and Dickey 1984). The significant statistical issues associated with the autoregressive unit root test (AR) are defined as

$$x_t = c + \rho x_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2), \tag{1}$$

The prior density of ρ is formulated and expressed as following:

$$p(\theta) = p(\phi) p(a^* | \phi), \tag{2}$$

The marginal likelihood for ϕ is

$$l(\phi \Big| D) \alpha \int l(\rho | D) \phi(a^* | \phi) da^*, \tag{3}$$

The consideration of the hypotheses of Bayesian is combined with the Bayes factor to interpret the hypothesis of stationary data. The null hypothesis is defined by N_i and the alternative hypothesis is denoted by N_j. The ratio of posterior odds of N_i and N_j is

$$\frac{p(N_i|y)}{p(N_j|y)} = \frac{p(y|N_i)}{p(y|N_j)} \times \frac{\pi(N_i)}{N_j}, \tag{4}$$

The interpretation in the Bayes factor can be interpreted in Table 1.

Table 1. The explanation of Bayes factor of Jeffrey Guideline model.

Items	The Interpretation
BF < 1/10	Strong evidence for N_j
1/10 < BF < 1/3	Moderate evidence for N_j
1/3 < BF < 1	Weak evidence for N_j
1 < BF < 3	Weak evidence for N_i
3 < BF < 10	Moderate evidence for N_i
10 < BF	Strong evidence for N_i

3.2. The Generalized Pareto Distributions (GPD)

The extreme event distributions for the threshold under condition (Pickands 1975) sing GPD to estimate the distribution as

$$G(x|\zeta,\sigma,u) = \begin{cases} 1-\left(1+\frac{\zeta(x-u)}{\sigma}\right)-1/\zeta, \text{ if } \zeta \neq 0 \\ 1-\exp\left[-\frac{(x-u)}{\sigma}\right], \text{ if } \zeta = 0 \end{cases}, \tag{5}$$

where $\sigma > 0$ and ζ are the scale and shape parameter, respectively.

Then, the threshold from the GPD equation is assumed to be the observations under the threshold u. Thus, the model $H(.|\eta)$from the generation of u from a certain distribution with parameters η is shown as

$$F(x|\eta,\zeta,\sigma,u) = \begin{cases} H(x|\eta), \text{ if } x < u \\ H(x|\eta) + [1-H(x|\eta)]G(x|\zeta,\sigma,u), \text{ if } x \geq u \end{cases} \tag{6}$$

The likelihood function can be expressed as

$$L(\theta;x) = \prod_A h(x|\eta)\prod_B(1-H(u|\eta))\left\{\frac{1}{\sigma}\left[1+\frac{\zeta(x_i-u)}{\sigma}\right]_+^{-(1+\zeta)/\zeta}\right\}, \text{ for } \zeta \neq 0,$$

and

$$L(\theta;x) = \prod_A h(x|\eta)\prod_B(1-H(u|\eta))[(1/\sigma)\exp\{(x_i-u)/\sigma\}], \text{ for } \zeta = 0, \tag{7}$$

The threshold (u) is the discontinuous density that depends on jumped density. The jumped distribution consists of small and large jumped density, of which the large jumps are more favorable than small jumps in terms of parameter estimation.

3.3. The Non-Stationary Extreme Value Theory

The Non-Stationary Extreme Value Analysis (NEVA), is proposed by Cheng et al. in 2014 (Cheng et al. 2014). This method uses Bayesian inference for the GPD of the distribution for both stationary and non-stationary conditions from which the posterior distribution of parameters is obtained by the Bayesian technical. The Markov chain Monte Carlo (MCMC) approach is used in several investigations of extremes for the arbitrary distribution. Thus, the GPD parameters of Bayes' theorem under the non-stationary assumption can be shown as

$$p\left(\beta|\vec{y},x\right) = \prod_{N_t,t=1} p\left(\vec{y}|\beta,x(t)\right) = \prod_{N_t,t=1} p\left(\vec{y}|\mu(t),\sigma,\zeta,\right) \tag{8}$$

where $\beta = (\mu_1,\mu_0,\sigma,\zeta)$.

The stationary term can be shown as

$$p\left(\theta|\vec{y}\right)\alpha p\left(\vec{y}|\theta\right)p|(\theta) = \prod_{N_t,t=1} p(y_t|\theta)p(\theta) \tag{9}$$

where $\theta = (\mu, \sigma, \zeta)$.

The estimation of NEVA from the joint posterior distribution creates the number of realization using the differential evolution Monte Carlo Metropolis transitions (DE-MCMC). The individual C_i can be described as s_i for the non-dominated and s_j for the dominated as

$$\text{fit}(C_i) = \begin{cases} s_i \\ 1 + \sum_i^{i=j} s_j \end{cases}, \tag{10}$$

The MCMC is employed to create new samples with probabilities based on the variation of the $\text{fit}(C_i)$ value as

$$w\left(C_i \to C_t^i\right) = e\frac{-(\text{fit}(c_t')\text{fit}(c_t))}{T} \tag{11}$$

where T is the simulation of the future prices, of which the generated values from C_t' are accepted with the probability as

$$\min(1, w(c_i \to c_t')) \tag{12}$$

3.4. Random Sets

The estimation from the NEVA is provided as an interval number. Then, the interval number is used to generate the random number before applying the Newton method to find the optimal point. The sampling random number is generated from the power set of 2^U, which is interested in which U is a finite number (Polyak 2007). The set of 2^U is chosen by a probability density function $f : 2^U$ is $[0, 1], \sum_{A \subseteq U} f(A) = 1$. The coverage function is used to define the degree of separation as

$$\pi_s : U \to [0, 1],\ \pi_s(u) = P(u \in S) = \sum_{u \in A} f(A) \tag{13}$$

3.5. The Newton Optimization Approach

This approach finds the extreme value point, which is the process after investigating the sampling number. Thus, Newton's method, theorized by Newton in 1669, is used to estimate the optimal point of agricultural commodity future prices in the US. The function of the Newton method can be written as

$$F(x) = x_0 \tag{14}$$

where x_0 is the initial point or made to be the starting point, and to assemble the linearapproximation of $F(x)$ in the neighbor of x_0:$F(x_0) + F(x_0)h = 0$.

Then the calculation of the linear equation can be shown as

$$x_{k+1} = x_k F'(x_k)^{-1} F(x_k), k = 0, 1, \ldots\ldots \tag{15}$$

Newton's method proposes two approaches—the continuously differentiable and twice differentiable on the data—that can be expressed as follows:

$$|x_k - x^*| \leq \frac{\eta}{h2^k}(2h)^{2^k} \tag{16}$$

and

$$|x_k - x^*| \leq \frac{\beta\eta \pm h/2^{2^k - 1}}{1 - h/2^{2^k}} \tag{17}$$

The calculation of Newton's method $F'(x)$ provides the tangent line at $x^{(0)}$ and root $x^{(1)}$, to show the calculation of the true x^*. Then, the next calculation of $x^{(2)}$ is produced following the same step as before and shows the root at x^* that can be seen in Figure 1.

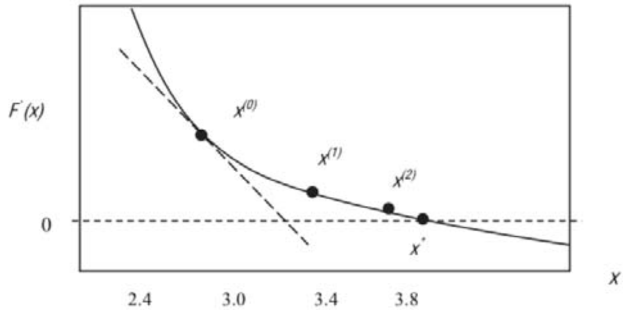

Figure 1. The Newton method of convergence.

4. Empirical Results

4.1. Data Description

The future prices data considered in this study consisted of five agricultural commodities including cocoa, coffee, corn, soybeans and wheat. Daily data were collected as 5000 observations between 2000 and 2020. Basic information consisted of the mean value, maximum and minimum value and standard deviation, as displayed in Table 2.

Table 2. Descriptive data of future prices for five agricultural commodities.

	Cocoa	Coffee	Corn	Soybeans	Wheat
Mean	2167.789	122.8145	382.1173	930.8092	502.5286
Median	2205.000	118.6000	361.7500	945.1900	480.6300
Max.	3774.000	304.9000	831.2500	1764.750	1280.000
Min.	674.0000	41.50000	174.7500	418.0000	233.5000
Std.Dev.	701.7960	48.84470	160.7520	326.3169	183.2688
Sum	10,838,947	614,072	1,910,587	4,654,046	2,512,643
Obs.	5000	5000	5000	5000	5000

4.2. Stationary Testing

Empirically, the data from agricultural future prices are the time series data. Thus, the data should be tested for the stationary data. In this paper, the unit root test based on the Bayesian method is used to investigate the stationary data which is shown in Table 3. The null hypothesis (H0) is non-stationary and the alternative hypothesis (H1) is stationary. The results show that all of the time-series data from agricultural future prices are non-stationary or (I(1)).

Table 3. The unit root test relies on the Bayesian inference in daily data of five agricultural commodity future prices.

Agricultural Commodities	Bayesian Factor Ratios (M1/M2)	Interpretation	Result
Cocoa	1005	Strong evidence for Ni	I(1)
Coffee	1076	Strong evidence for Ni	I(1)
Corn	1048	Strong evidence for Ni	I(1)
Soybeans	1031	Strong evidence for Ni	I(1)
Wheat	1114	Strong evidence for Ni	I(1)

4.3. Estimation of Extreme Value Using Bayesian Inference and the Newton Method

From the result of Table 4, the extreme value estimation from the Bayesian inference estimation by using Non-stationary Extreme Value Analysis (NEVA) can be used to estimate both the non-stationary and stationary data. In this paper, all of the agricultural future prices data are non-stationary, which the results deduced from this approach as shown in the interval value. Empirically, the interval of the extreme value from the Cocoa future prices is 2500 to 3500 USD/MT. For coffee future prices, the extreme value interval is between 180 and 220 USD/lb. Additionally, For the length of the interval extreme value for corn, soybeans and wheat future prices, the non-stationary estimated outcomes are shown as 440 to 480, 1300 to 1800, and 700 to 900, respectively. This is displayed in detail in Table 4.

Table 4. The optimally extreme value calculation of five agricultural commodity future prices.

Agricultural Commodity	Bayesian Extreme Estimation as Interval Value	General Mean	The Newton Method
Cocoa	2500–3500	2908.6	3040.053
Coffee	180–220	204.6	197.0472
Corn	440–480	446.5	466.0243
Soybeans	1300–1800	1606.5	1684.319
Wheat	700–900	816.9	853.9703

The Newton optimization method is the efficiently computational tool that extends the details of the results from the NEVA to provide the optimal point at which an extreme value should be considered to be alarming. Empirically, in this paper, the general mean and Newton optimization method are employed; the Newton method can investigate the results with more detail and reliability than the general mean method. From the details in Table 4, the estimation of the general mean shows that the optimal point for cocoa, coffee, corn, soybeans and wheat future prices are 2908.6, 204.6, 446.5, 1606.5, and 816.9, respectively. However, the results from the Newton optimization method differ from the general mean method, which can be described as follows: the optimal point of the cocoa future price is 3040.053, the coffee future price is 197.0472, the corn future price is 1684.319, the soybeans future price is 1684.319 and the wheat future price is 853.9703. Additionally, the results of the Bayesian extreme estimation and Newton optimization method are shown in Table 4, Figures 2 and 3 below.

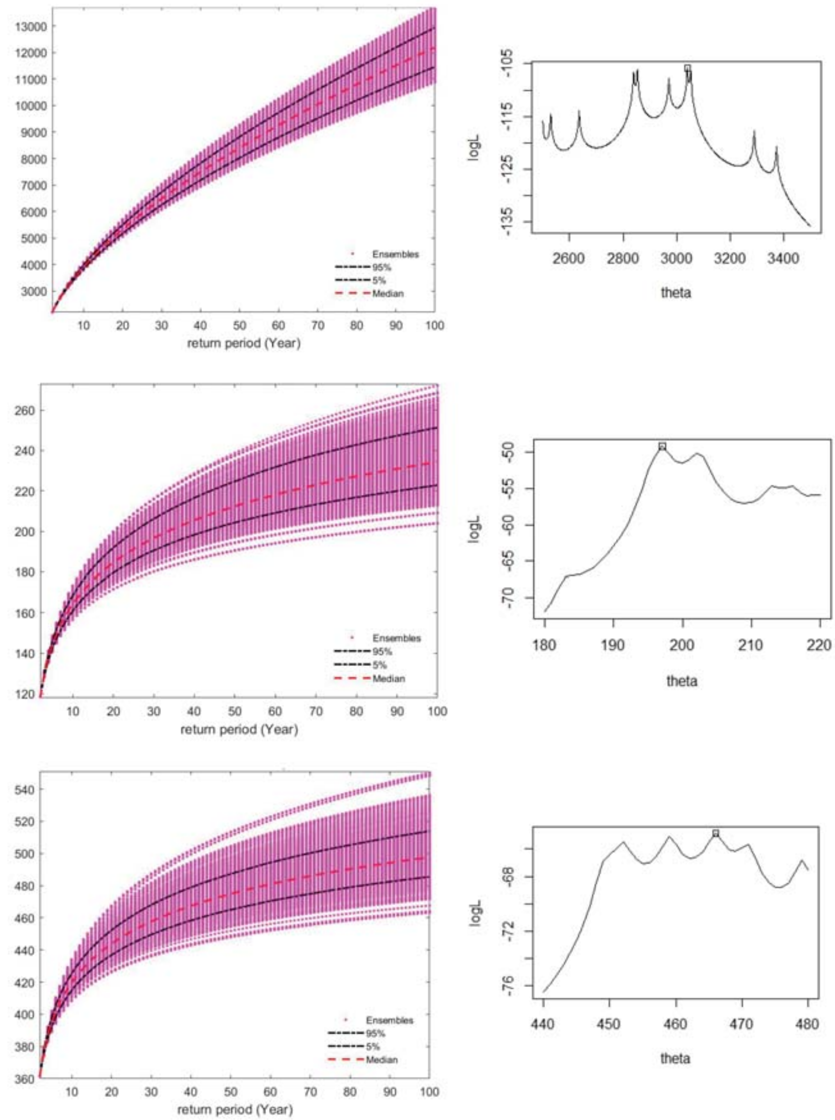

Figure 2. Presentation the Bayesian extreme results and the Newton-optimal point regarding cocoa, coffee, and corn.

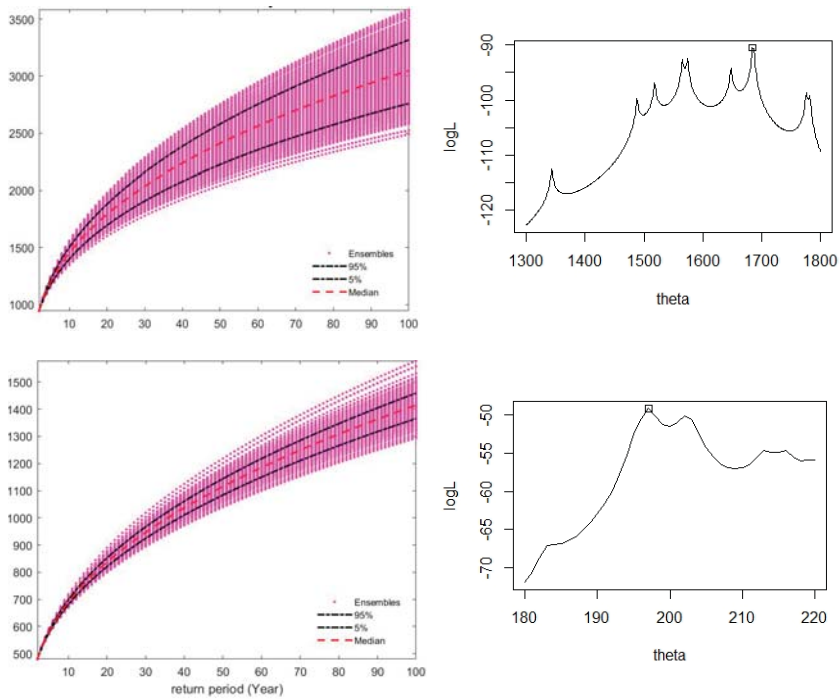

Figure 3. Presentation the Bayesian extreme results and the Newton-optimal point regarding soybeans and wheat.

5. Conclusions

Extreme events of five agricultural commodity future prices including cocoa, coffee, corn, soybeans and wheat as the most crucial major commodities in the United States are undergoing major changes and impacting other commodities in terms of agricultural markets and the economy. Here, time-series data were collected daily from 2000 to 2020 (5000 observations). Non-stationary Extreme Value Analysis (NEVA) using Bayesian inference, random variable processing and the Newton-optimal method were employed to determine the optimal point of extreme events. The NEVA method showed the interval value of extreme events from the measurement of agricultural commodity future prices. Results can be used to forecast the alarming interval value before the crisis or extreme event occurs. Furthermore, random variable processing and the Newton-optimal method were used to clarify more precise details of the optimal position exact point to define the highest value of agricultural commodity prices. Results from the Newton optimization can be used to forecast warning prices for farmers and investors as follows: the optimal point of cocoa future price was determined as 3040.053, coffee 197.0472, corn 1684.319, soybeans future price is 1684.319 and wheat 853.9703. Investors should prepare to sell their contract before the future prices of these agricultural commodities decrease. Agriculturists can use this information as advanced warning of alarming points of agricultural commodity prices to predict the most efficient quantity of their agricultural product to sell, with better ways to manage this risk.

The estimation of results using the Non-stationary Extreme Value Analysis (NEVA) method with Bayesian inference and the Newton-optimal method can support policy-makers to make decisions to prevent a crisis in the agricultural market and prepare solutions to solve this problem. Our results, showing computed interval values and optimal points, can provide useful additional information about extreme events. Bayesian interference is an important computational statistical method for econometrics research.

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Liquidity Spill-Overs in Sovereign Bond Market: An Intra-Day Study of Trade Shocks in Calm and Stressful Market Conditions

Linas Jurksas, Deimante Teresiene * and Rasa Kanapickiene

Finance Department, Faculty of Economics and Business Administration, Vilnius University, Sauletekio av. 9, 10222 Vilnius, Lithuania; linas.jurksas@evaf.vu.lt (L.J.); rasa.kanapickiene@evaf.vu.lt (R.K.)
* Correspondence: deimante.teresiene@evaf.vu.lt

Abstract: The purpose of this paper is to determine the liquidity spillover effects of trades executed in European sovereign bond markets and to assess the driving factors behind the magnitude of the spill-overs between different markets. The one minute-frequency limit order-book dataset is constructed from mid-2011 until end-2017 for sovereign bonds from the six largest euro area countries. It is used for the event study and panel regression model. The event study results revealed that liquidity spill-over effects of trades exist and vary highly across different order types, direction and size of the trade, the maturity of traded bonds, and various markets. The panel regression model showed that less liquid bonds and bonds whose issuer is closer by distance to the country of the traded bond have more substantial spillover effects and, at the same time, are also more affected by trades executed in another market. These results should be of interest to bond market participants who want to limit the exposure to the liquidity spillover risk in bond markets.

Keywords: high-frequency data; market liquidity; sovereign bonds; spillover

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1. Introduction

While fixed income market traders and analysts do not pay much attention to the liquidity situation when markets are sufficiently liquid, it becomes a critical issue when market liquidity suddenly evaporates. These tail risk events of liquidity shocks are mainly characterized by the sharp reduction in the number of traders who stand ready to buy and sell particular bonds and become a real concern to fixed income investors who base their decisions on the available bid and ask prices in the market. Alongside the period of increasing connectedness in asset markets, it is often a case that spill-overs, when (il-)liquidity spreads across different bonds or even markets, become a risk to the orderly functioning of the whole fixed income market. Besides, as "investors" trading returns are increasingly shaped by several basis points margin in a low-interest-rate environment, liquidity shocks could highly increase liquidity premium embedded in bond prices—this would have a significant impact on the valuations of bonds. Because market liquidity, i.e., the ease and speed of trading, is crucial to the functioning of financial markets, there has been a surge of interest in the topic of market (il)liquidity in recent years. This has been mostly the case after the European sovereign debt crisis when market participants witnessed deprived liquidity conditions (European System of Financial Supervision 2016). Nevertheless, there are still many unanswered questions. What causes these sudden liquidity shocks in fixed income markets? Do these events affect only some particular bonds or the whole market? Is there a contagion effect that reverberates among different bonds? This study tries (at least to some extent) to shed light on this topic by analyzing the impact of sovereign bond trade shocks and how they spillover to other bonds and markets.

The novelty of this paper is several-fold. To start with, we employ the large intraday sovereign bond quoting and trading dataset that contains multi-year information of trade shocks and quoting activity. To be specific, we derive minute-frequency limit order-book from tick-by-tick sovereign bond market data of Mercato dei Titoli di Stato (MTS) from June

2011 until December 2017. This relatively long sample period lets us analyze how trade shocks affect liquidity in distinct market periods: exceptionally stressful market conditions from end-2011 until start-2012 (i.e., peak of European sovereign debt crisis), relatively calm market period of 2013–2014, the “Bund-Tantrum” in mid-2015, the spikes of market tensions after “Brexit” vote and US presidential elections in 2016, and etc. To compare the results among different sovereign bond issuers, many markets are selected: Germany, France, Italy, Spain, the Netherlands, and Belgium. The event study method is employed to analyze the spillover of trade effect because this method is less prone to variable selection bias and reverse causality issues common with more complex econometrical models when analyzing spill-over effects between many different bonds with high-frequency data. Additionally, panel regression model is used to answer the question of what factors affect the strength of liquidity spillover effect among markets. Rigobon (2019) made a significant research on the empirical literature about international spillovers and contagion and made a conclusion that there was no single technique that could help to give the answer to the full-fledged problem. The author pointed that empirical studies of spill-overs and contagion were quite complicated applied issues. Glosten and Milgrom (1985) analyzed the spread of bid and ask prices, paid the most attention to insiders and liquidity traders, and used the approach that a bid-ask spread can be an informative factor. Other authors focused more on critical moments, which are especially important at a government level, attracting more funds or making suitable monetary policy. Dungey et al. (2006), using a latent factor model, analyzed the emerging and developed markets focusing more on the Russian crisis. The results showed that both markets experienced a contagion effect. Brière et al. (2012) made a research with a considerable database to investigate the stability of correlation matrices in different asset segments with the contagion tests, which were neutralized with respect to the globalization effects. Liquidity contagion effect analyzed by (Macchiati et al. 2020); Macchiati et al. (2020) and Cifuentes et al. (2005) while gravity model issues were investigated by Zhu and Yang (2008). Overall, the topic is very relevant and quite complicated, so it is essential to research this field from different perspectives. This study is focused on a vital market microstructure subject: how shocks of sovereign bond trades affect the prices and quantities of the limit order book. In the wake of the rapid increase of automated trading, there are relatively fewer transactions than the number of buy and sell orders submitted to the market, so an execution of a trade has more informational value for traders. Simultaneously, larger transactions are less suitable for trading on such increasingly automated markets as prices. Thus liquidity can instantly be moved against the participant who wants to trade. The trade execution should lead to an immediate liquidity spillover effect to the quoted prices and quantities of this bond because the trade can be executed only inside the central limit order book of the MTS market. Moreover, the sovereign bond markets are much more decentralized and fragmented than equity markets, so it is important to understand if a shock—trade of a particular bond—affects the liquidity situation only of the traded bond or does it also reverberate to other bonds of the same issuer, or maybe it even spill-overs to the sovereign bonds from other markets. In fact, the sudden liquidity dry-up for one bond might lead to a contagion effect that could become a severe threat to the functioning of the whole sovereign bond market and is critical to the financial stability. As a result, the liquidity spillover effect of trades is a rarely examined but increasingly important topic for investors, analysts, regulators, policymakers, and issuers of sovereign bonds.

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This paper consists of four main parts: the review of relevant literature; the description and examination of the data and methods that are used in this analysis; the results of event studies and discussion of liquidity spillover effects; findings from a panel regression model of possible factors that explain the magnitude of spillover effects between different European markets.

2. Literature Review

Although there is no analogous event study of liquidity spillover of trades with high-frequency European sovereign bond data, this chapter reviews the several strands of academic literature that is relevant for conducting this study: the microstructure of fixed income market, liquidity indicators of bonds, contagion effects among different asset markets, and liquidity spillover of sovereign bonds. It should be noted that while there are many studies on intraday market liquidity, most of them still concentrate on equity markets and particularly on US markets He et al. (2020); Rappoport and Tuzun (2020); Honkanen and Schmidt (2017); Rindi and Werner (2017); Sheng et al. (2017); Shaikh (2018); Righi and Vieira (2014); Bein (2017); Diebold and Yilmaz (2009), given its size and the availability of high-frequency data. Some research papers are focused on the future market. Fassas and Siriopoulos (2019) studied the Greek market using the high-frequency data and tried to identify the relationships between spot and future prices. The authors revealed strong bi-directional dependence in the intraday volatility and pointed to the improvement of futures' pricing efficiency in the Athens financial market. But there is still relatively little research specific to liquidity spillover effects, especially on European sovereign bond markets.

Before analyzing the liquidity spill-over effects, it is important to analyze the liquidity spill-over effects. It is important to analyze the liquidity spill-over effects, and it is essential to understand the microstructure of the whole fixed income market. Bank for International Settlements (2016a) gives a comprehensive overview of the evolution of fixed income markets. For instance, it documents that the share of electronic trading in sovereign bond and other fixed-income markets is gradually increasing (mainly due to the rise of automated and high-frequency trading). However, the market structure is still fragmented between inter-dealer and dealer-to-client segments. Bond trading still lags development compared to other asset classes due to, more significant heterogeneity and complexity. Nevertheless, while the impact of automated trading on market liquidity is highly debatable, technological improvements enabled dealers to better monitor how the flow of orders changes in response to news and other shocks. Regarding European sovereign bond markets, a pan-European trading protocol of the central limit order-book has become a dominant feature (e.g., MTS market). However, it is still less technologically advanced and less liquid than the US sovereign bond market.

Market liquidity in different asset markets has been analyzed from various perspectives. One of the first inclusive studies is the paper of Kyle (1985), who states that there are three main liquidity dimensions: (1) tightness (cost of buying and selling a position); (2) depth (the size of order-book or amount of quotes); (3) resiliency (the speed of recovery of tightness and depth). While these three dimensions vary significantly depending on the size and type of trade, all measurements are essential for frequent traders. Tsuchida et al. (2016) also group metrics to these three categories, and distinguish volume, i.e., the trade size and turnover of each transaction. These authors find that the shock of economic indicator announcement has a negative effect on all liquidity dimensions. In contrast, the shock of monetary policy announcement has a positive impact on the volume indicators. Albagli et al. (2015) found significant monetary policy effects on developed and emerging bond markets.

Other import studies describing various liquidity metrics and dimensions are Sarr and Lybek (2002); Fleming (2003); Goyenko et al. (2009); International Monetary Fund (2015); Diaz and Escribano (2017); Broto and Lamas (2020); O'Sullivan and Papavassiliou (2019); Clancy et al. (2019); Barth and Kahn (2020); Jiang et al. (2020); Gupta et al. (2018); Kandil (2018) and White et al. (2018).

An overview of various liquidity indicators as well as microstructure of the European sovereign bond market is provided by Pellizon et al. (2013); Mahanti et al. (2008); Brunnermeier and Pedersen (2008); Chordia et al. (2007); Dunne et al. (2015); Galliani et al. (2014); Han and Pan (2017); Holden et al. (2014); MTS (2017); Kurosaki et al. (2015). By employing MTS tick-by-tick data, authors compose three types of indicators that they include in econometric models: (1) Bond-specific characteristics: coupon type, time-to-maturity, issued amount; (2) activity variables: number of trades and volumes, revisions per single order, quantities at the best bid and ask; (3) liquidity measures: bid-ask spread, a measure developed by Amihud (2002), measure composed by Roll (1985), and etc. With the help of an event-type method, Pellizon et al. (2013) found that dealers still withdraw from the bond market during periods of stress despite contractual agreements with market operators, especially for the longer-term and less liquid bonds. Besides, the liquidity of less liquid bonds has a contagion effect on the broader market, while rapid increase of automated trading (proxied by order revisions) has not led to market resiliency improvement. In a similar study, Darbha and Dufour (2015) describe the European government bond market's microstructure and analyze how liquidity measures evolve during stressful and normal market conditions.

Regarding the studies about spillover effects in fixed income markets, the critical distinguishing feature is the determination of the impulse factor that reverberates through the markets. While liquidity spillover is quite a rare research topic, spillover of bond yields or prices has been well documented. Dufour and Nguyen (2011) analyze sovereign bond markets of the euro area countries for the pre-crisis period to assess the price responses to trades in different markets. They reveal that investors indeed require higher yields for bonds that exhibit more enormous trading impacts. Claeys and Vašíček (2014), using the variance decompositions of vector auto-regression model, studied bilateral linkages between EU sovereign bond spreads and tried to determine the origins of the shock, i.e., the specific sovereign bond market from which the spillover emanates to other markets. Their results indicate that the spillover effect increases substantially during stressful market periods. This effect varies highly across countries, e.g., financially stronger countries, such as the UK, Sweden, and Denmark, are much less affected by shocks from other EU countries. Bowman et al. (2015) examine the effects of FED's unconventional monetary policies on sovereign yields in seventeen emerging markets. Their event study findings suggest that the US monetary policy shocks significantly affect the sovereign yields in other countries. However, the strength and persistence of the effect vary significantly across the emerging markets. Papadamou et al. (2020) also investigated unconventional monetary policy effects, but they focused more on the economic variables and financial markets. The authors revealed a unified positive impact of quantitative easing (QE) on bond prices across different studies. The other interesting aspect was that a contagion effect from US QE to emerging markets was identified.

Levisauskaite et al. (2015) studied the relationships between EU government bond markets and found that the common currency and geographic proximity influence the correlations in different markets. Another study by Bank for International Settlements (2016b) reveals that price impact from large incoming orders have increased for US and Italian sovereign bonds. Still, the more significant price sensitivity has no clear sign of contagion effect.

The spill-overs of liquidity have been mostly studied between different types of assets. For instance, Tang and Yan (2008) use data from the US corporate bond, stock, option, and credit default swap (CDS) markets for computing correlations between liquidity measures. Their central finding is that the role of a common liquidity factor across the markets is more important than generally assumed. In particular, the illiquidity emanating from the CDS markets is found to spillover to other markets and leads to a statistically significant increase in credit spreads. In a relatively similar study, Calice et al. (2013) analyzed the spillover effects between the credit and liquidity spreads in nine Eurozone sovereign bond markets and the sovereign CDS market. They found significant variation in the spillover effect between maturities and among countries, e.g., in several markets (Greece, Ireland, and Portugal), the sovereign CDS market's liquidity has a substantial time-varying influence on sovereign bond credit spreads. Lin et al. (2013) investigated the liquidity risk spillover from equities to bond markets and found that the spillover of liquidity risk exists. International Monetary Fund (2015), relying mostly on the event studies, reveals that liquidity shocks spillover across different asset classes and that this effect has increased over time. Besides, the commonality of liquidity of different assets has increased due to widespread index investors' growth index. Moshirian et al. (2017) add that liquidity commonality is in weaker and riskier markets with poorer investor protection and less transparency. Smimou and Khallouli (2017) found that liquidity often spill-overs from smaller to larger more extensive German, French, and Italian markets in a similar vein.

Despite the increase of high-frequency bond data availability, still very few empirical papers analyze the liquidity spill-overs among different bonds and, especially on an intraday basis. One notable exception is the study by Schneider et al. (2016), which focuses on illiquidity risks, i.e., liquidity dry-ups, and how they spillover across Italian government bonds of different residual maturities. These authors use mainly three liquidity indicators at one-minute frequency: bid-ask spread, price impact of particular trade, and depth across the limit order book. They find, for instance, that shorter-term bonds are increasingly affected by the liquidity spill-overs from the long-term bonds and that market liquidity is less resilient and predictable when the bonds are less liquid.

To conclude the relevant studies review, it is clear that the literature is scarce on the topic of liquidity spill-overs in sovereign bond markets. Besides, liquidity spill-overs of trades, especially on an intraday basis, has been almost an unexplored research area, possibly due to the limited availability of high-frequency trade and order-book data that is a prerequisite for the robust spillover analysis in the financial markets where prices and liquidity conditions adjust instantly after the trade is executed.

3. Data and Methodology

This chapter defines the data, derived dependent and explanatory variables, and liquidity indicators that will be used in the empirical analysis. Two research methods that will be employed in the analytical part—the event study and the panel regression model—are briefly described afterward.

3.1. Data

Two different datasets from MTS are used to study liquidity spill-overs of trades in European sovereign bond markets: inter-dealer tick-by-tick trade and limit order book data. Sovereign bonds can be traded over-the counter or on the electronic exchanges; the latter can be further divided into dealer-to-dealer (inter-dealer) and dealer-to-customer platforms (Bank for International Settlements 2016a). MTS is the largest interdealer platform for European sovereign bonds with the central limit order-book mechanism (MTS 2017). While relatively fewer trades are executed on the MTS interdealer market, the number of orders submitted to the central limit order-book is much higher. Order revisions outnumber trades so vastly that trade-based indicators considerably underperform order-based indicators (Pellizon et al. 2013).

The preparation for the minute frequency order book closely follows the Darbha and Dufour (2015). To analyze the spillover effects on a discrete and high frequency period, limit orders for each bond are sampled to one-minute intervals. At the same time, all trade stamps are assigned to the nearest minute interval, and traded quantities are summed for each bond. Gkillas et al. (2020) forecasted realized volatility of the oil market using high frequency data as well but those authors used different types of Heterogeneous Autoregressive models of realized volatility (HAR-RV) and focused more on indexes of financial stress as a proper tool for more accurate forecasting.

The study covers the period from June 2011 until December 2017 for six major European sovereign bond markets. This time period encompasses heightened market conditions during the euro area sovereign debt crisis in end-2011—start-2012, environment of very low or even negative bond rates, central bank asset purchases, important political events (e.g., US and French presidential elections, "Brexit" vote) and various significant financial events (e.g., the "Bund-Tantrum"). During this period, the outstanding nominal value of -area sovereign bonds increased from around 6.1 tn EUR in June 2011 to 7.3 tn EUR in December 2017 (ECB 2017). Six European sovereign bond markets are chosen for the analysis: Germany, France, Italy, Spain, the Netherlands, and Belgium. Although these markets have the highest market capitalization in the euro area, they still have a lot of heterogeneity regarding credit risk, market depth, economic and financial developments, political events, etc.

The most frequently used liquidity indicator in this study is calculated accordingly (Jurkšas et al. 2018):

$$Order - Book\ Illiquidity\ Score\ _{t,5} = \frac{Spread_{t,5}}{Quantity_{t,5}} = \frac{\frac{1}{5}\sum_{j=1}^{5} P_{t,Ask(J)} - \frac{1}{5}\sum_{j=1}^{5} P_{t,Bid(J)}}{\sum_{j=1}^{5} Q_{t,Ask(J)} + \sum_{j=1}^{5} Q_{t,Bid(J)}} \quad (1)$$

where:

t—the time in minutes at which the limit order-book is calculated (e.g., before, at, and after the trade is executed);
P—the price of the limit order book, i.e., the mid-point of ask and bid price;
Q—the quantity that can be traded at a given quoted price;
"Ask" and "Bid"—the side of the limit order-book;
j—number of the priority of the offers in the limit order book (from 1st to 5th best Ask/Bid price and its corresponding quantity).

The order-book illiquidity score encompasses two main liquidity dimensions: cost and depth. The numerator is the average bid-ask spread of five best (i.e., closest to the mid-price) quotes. The denominator is the sum of quoted quantities corresponding to the five best ask and bid prices. In general, the lower the order-book illiquidity score and the average bid-ask spread, and the higher the corresponding quoted quantities, the more liquid the bond is. The order-book illiquidity score principally indicates the average transaction costs of the five best buy and sell orders, relative to their quantities, i.e., how, on average, the average bid-ask spread would be impacted if the amounts of the five best bids and five best asks would be transacted. So order-book illiquidity score positively represents a widely used price impact indicator created by Amihud (2002), although the latter indicator is calculated with trade and not limit order data. Five best bid/ask prices are chosen because dealers can observe in real-time the five best prices (with corresponding quantities) on each side of the limit order book in the MTS trading platform. Besides, Bank for International Settlements (2016b) states that simple bid-ask spreads and quantities at the best bid and ask price are no longer a representative indicator of liquidity conditions due to increased automated trading. However, the limit orders with prices that are far away from the mid-price have a very low probability of being hit by another incoming order, so the prices and, especially, quantities might also not reflect true "dealers" intentions.

3.2. Research Methods

The event-type study is the primary method used in this paper to analyze the liquidity spillover effect of sovereign bond trades. The execution of trade acts as a shock to the market because relatively fewer trades are executed during the day, and the transaction directly affects the limit order book. A trade is executed when a standing limit order is crossed by incoming market-order (that is immediately filled or killed) or another limit order. So a buy-side transaction results in the removal of the limit order with the lowest bid price, while a sell-side transaction leads to the elimination of the limit order with the highest ask price. As a result, bid-ask spread widens and illiquidity-score increases immediately after the trade is executed. So the event-type study is an appropriate method to analyze how the execution of the trade immediately reverberates to the quoted prices and quantities of this bond and helps to determine the average spillover effect across different bonds from the same or another country.

The results of this relatively simple statistical analysis method can be noticeably analyzed graphically. Besides, this method is less prone to possible errors and variable selection bias, which is often a case in more sophisticated econometrical models. International Monetary Fund (2015) argues that the event studies often help overcome the problem of reverse causality. The event studies are carried out by many authors, including Pellizon et al. (2013); Andrulytė and Jurkšas (2015); Blasi (2016); Tsuchida et al. (2016), etc.

The average value of a particular liquidity indicator (e.g., illiquidity score, bid-ask spread, quoted quantity) is calculated on a minute frequency from 15-min before until

15-min after a transaction of sovereign bond is executed. This time period is long enough to assess if the transaction resulted in a temporary or permanent liquidity spillover effect and if there was a particular dynamic of liquidity indicator even before the trade was executed. The average cumulative change (C_t) of a particular liquidity indicator before and after the transaction is calculated according to this formula:

$$C_{t,k} = \frac{1}{K}\sum_{k=1}^{K}(M_{t,k} - M_{0,k}) \tag{2}$$

where:

t—minutes after (+)/before (−) a trade is executed,
M_0—the value of bond liquidity indicator at the time of the trade,
M_t—the value of bond liquidity indicator at time t,
k—the number of observations at time t.

Several other critical computational transformations were performed. First, the cumulative changes of liquidity indicator at t minute before/after the trade were at first averaged across all observations on a monthly basis. This was done due to the computational efficiency (as it was not possible to calculate the limit order-book for the full sample period from 2011 at once). In this way, it was easier to compare the results during the time. Second, to reduce the effect of spurious outliers, winsorizing procedure was employed: 10% lowest and highest values were set to the value of the respectively 10 and 90 percentile of the liquidity indicator values among the bonds from the same country. Third, a simple mean of monthly winsorized cumulative liquidity changes was computed.

The average cumulative liquidity change was calculated for several different dimensions: the direction of the transaction, the buckets of bonds with different residual maturities, the size, and type of trade; across various markets. This distinction helps to comprehensively determine the bonds with the strongest spillover effects that emerge after the trades are executed.

In Section 5, a panel regression model is employed to assess the underlying reasons for the strength of trade liquidity spillover effects among different markets. This model is used to understand why after a transaction is executed in one market, the liquidity shock reverberates more strongly to some markets while less so, to others. So the dependent variable is the change of order-book illiquidity score in the market where no trades have been executed. Country-specific fixed effects were included in the panel regression model because fixing the group means (in this study—among bonds from various countries) helps in controlling the unobserved heterogeneity (Stock and Watson 2011) because bonds from different countries might be correlated with the level of the illiquidity score and the overall spillover effect.

4. Results of the Event Studies on Spillover Effects of Trades

This chapter presents four different graphical event studies of the spillover effects of trades: buy and sell-side of the transactions; bonds with different maturity (a term structure of liquidity spillover effect), various sizes of trades; across six euro area sovereign bond markets.

4.1. Direction of Trade

Before analyzing the liquidity spillover of trade, it is important to understand how different types of trades affect sovereign "bonds" prices and how this effect differs for the traded (direct impact) and non-traded (spillover effect) bonds. As market intelligence would confirm, buy-side transactions lead to the increase of the traded sovereign bond's mid-point price, while sell-side trades—to the decrease of the price up to several basis points (Figure 1). This effect seems to be permanent as the average price does not reverse even 15 min after the trade's execution. Importantly, the change of other bonds' prices from the same country as the traded bond is on average around five times smaller than the price change of the traded bond. However, the prices of other (non-traded) bonds change much more (and with different sign) before the trade is executed than the price of the traded bond, meaning that the change of bond prices enters the endogenous "investors" decision process of selecting particular bonds that should be traded, i.e., the bonds whose price decrease has a higher probability of being bought.

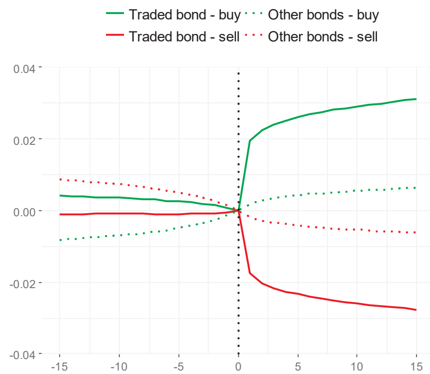

Figure 1. The trade effect on sovereign bond mid-point price 15 min before and after the trade was executed.

Although the trade effect on bond prices is opposite for buy and sell-side transactions (Figure 1), the impact is much more homogenous on liquidity. The liquidity diminishes only slightly after the sell-side trade rather than the buy-side transaction, and this difference becomes more evident in time (Figure 2). Notably, while the liquidity spillover from the prices of the traded to other bonds of the same country is noticeable, it is around ten times smaller than the effect on the traded bond's liquidity. The spillover effect is mostly visible on the first minute after the transaction is executed and entirely dissipates after around 5 min for the buy-side transaction and after about 15 min for the sell-side transaction, leaving the liquidity situation broadly unchanged. It is also worth stressing that before the transaction, the liquidity situation improves for the traded bond and deteriorates a bit for all other bonds. This observation again indicates that investors trade bonds whose liquidity is improving until the bond becomes sufficiently liquid for the trader.

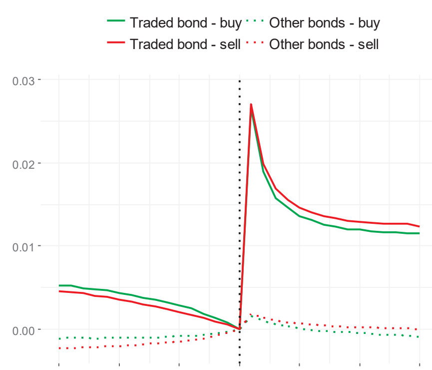

Figure 2. The trade effect on illiquidity-score 15 min before and after the trade was executed.

To a large extent, the bid-ask spread follows the pattern of illiquidity score. The average bid-ask spread of the traded bond increases most severely immediately after the trade is executed and decreases somewhat afterward. Still, the negative effect does not disappear even after 15 min (Figure 3). The spillover to the bid-ask spreads of other bonds is also visible but comparatively much smaller (around 15 times) than for the traded bond. Still, the spillover effect does not dissipate even after 15 min.

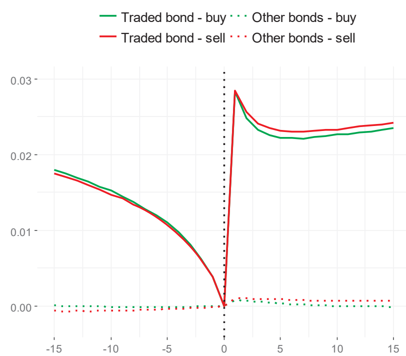

Figure 3. The trade effect on sovereign bond bid-ask spread (15 min before and after the trade is executed.

The impact of a trade shock on liquidity is also visible for the quoted quantities component of the illiquidity score. Quoted quantities of the traded bond decreased by almost eight million units on the first minute after the buy and sell-side transaction is executed (Figure 4). However, this effect completely disappears after several minutes and even attracts new traders to quote additional quantities. Interestingly, the quantities are decreasing sharply, while the bid-ask spread is tightening before the transaction is executed, possibly meaning that there is some kind of front-running behavior of market participants (e.g., leakage of information of incoming "clients" orders) that materialize in diminished quantities, especially before the sell-side transaction. A very similar pattern is visible for quantities of non-traded bonds from the same country as the traded bond, but around five times smaller in magnitude both before and after the transaction is executed.

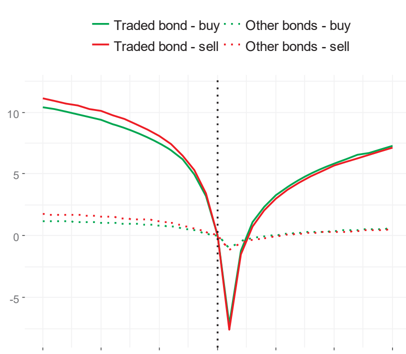

Figure 4. The trade effect on quoted quantities 15 min before and after the trade is executed.

4.2. Maturity Buckets

While the liquidity spillover effect seems to be relatively quiet small (i.e., on average, ten times smaller than the impact on the liquidity of the traded bond), there is a lot of heterogeneity across bonds with different residual maturities. The liquidity of bonds from the same country and residual maturity closer to the traded "bonds" maturity is affected most detrimentally (Figure 5). This effect is strongest the first minute after the trade is executed; afterward, this negative effect gradually dissipates. Meanwhile, the liquidity of bonds with very different residual maturity than the traded bond is almost unaffected, i.e., around five times less than the liquidity of bonds with similar maturity as the traded bond on the first minute after the trade.

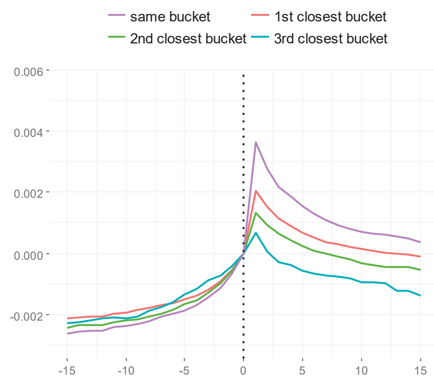

Figure 5. The spill-over effect on illiquidity score of different by residual maturity sovereign bonds 15 min before and after the trade is executed.

The liquidity spillover to non-traded bonds varies notably during time. The spill-over effect on the first minute after the trade is strongest during turbulent times (e.g., European sovereign debt crisis in 2011–2012, the "Bund-Tantrum" in mid-2015) and is almost negligible during calm market periods, e.g., 2013–2014 (Figure 6). The peak of spillover effect in end-2011 is almost ten times higher than at the beginning of 2014. Importantly, the liquidity of bonds with closer residual maturity to the traded "bonds" maturity is affected most significantly during the whole analyzed period, while the effect on the furthest by maturity bonds was even a bit negative for a couple of months in 2015. This probably speaks for the tight relationship between the spillover effect and the market risk sentiment (and therefore the magnitude of illiquidity score).

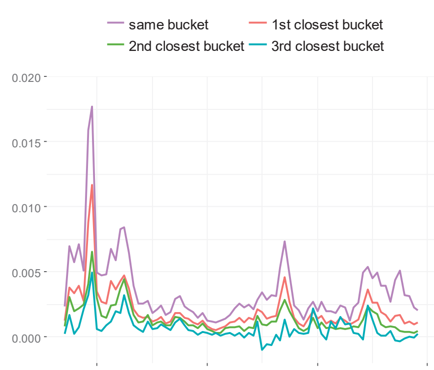

Figure 6. The spill-over effect on illiquidity score during time.

Both components of the illiquidity score of the non-traded sovereign bonds are negatively affected by the trade's execution, although this effect varies highly for bonds with different maturities. The quoted quantities (Figure 7) and the bid-ask spreads (Figure 8) are more severely affected for the bonds with similar residual maturity as the traded bond.

This is probably since bonds with similar maturity are regarded as close substitutes. In contrast, bonds with different maturity might have quite unlike characteristics and features that attract distinct types of investors (so-called "preferred habitat" investors). Notably, the magnitude of spillover effect on bid-ask spreads varies more than on quantities among different maturity bonds, i.e., the quantities of bonds with different maturities change relatively more homogenously than the bid-ask spreads. Also, quoted quantities return to the pre-trade state in around five minutes, while the spillover effect for spreads decreases much more gradually.

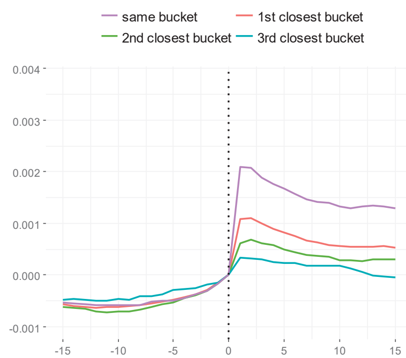

Figure 7. The spillover effect on bid-ask spreads of different by residual maturity sovereign bonds 15 min before and after the trade is executed.

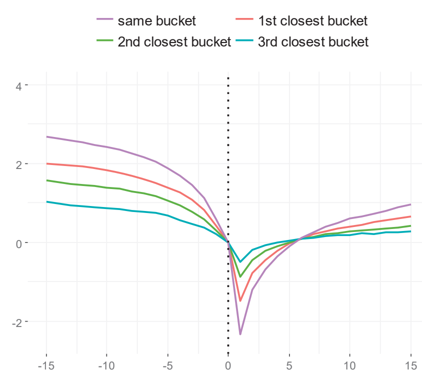

Figure 8. The spill-over effect quoted quantities of different by residual maturity sovereign bonds 15 min before and after the trade is executed.

4.3. Size of Transaction

The trade size of sovereign bonds also explains the difference in magnitudes of the liquidity spillover effect. The smallest value transactions have almost no liquidity spillover effect, while the largest transactions lead to a considerable detrimental effect (Figure 9). The differences of spillover effects between various sizes of transactions are also notable for both illiquidity score components: quoted quantities and spreads (not plotted here). The much higher spillover effect of the largest transactions holds during the whole review period, especially during stressful market conditions (Figure 10). As a result, the observed liquidity spillover effect should mainly be related to the largest transactions, while the smaller trades do not considerably affect liquidity. This result also implies that investors should deter from executing larger orders at once and divide them into smaller trades across longer time periods to reduce liquidity shocks.

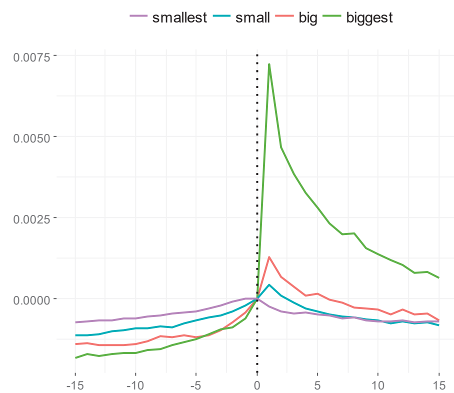

Figure 9. The spillover effect of different trade size on the illiquidity score of sovereign bonds 15 min before and after the trade is executed.

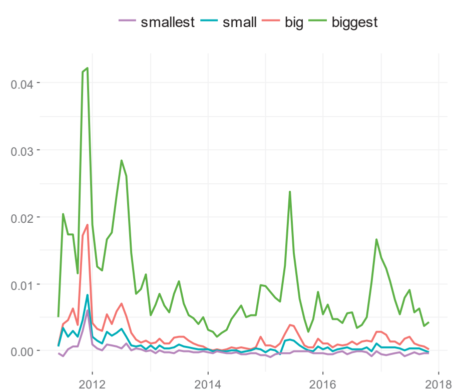

Figure 10. The spill-over effect of different trade size on the illiquidity score of sovereign bonds during time.

4.4. Issuing Country

The liquidity spillover effect varies highly among different markets. There are two notable country groups: the spillover is relatively small in sovereign bond markets from Germany, France, and Italy, while it is much more noticeable in smaller countries—Belgium, the Netherlands, and Spain (Figure 11). This segregation into two country blocks persists for both liquidity dimensions—the bid-ask spreads and quoted quantities (not plotted here)—as well as through time (Figure 12). The only notable exception is the more pronounced liquidity spillover in the Italian market during the European sovereign debt crisis. It is also important to note that the return of liquidity indicator to the pre-trade state is also very different among countries, i.e., the liquidity spillover effect is more permanent in Germany, France, and Spain, but seems to be temporary in Italy, Belgium, and the Netherlands.

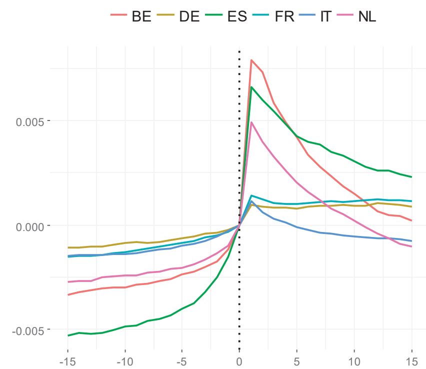

Figure 11. The spillover effect on illiquidity score of sovereign bonds in different countries 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

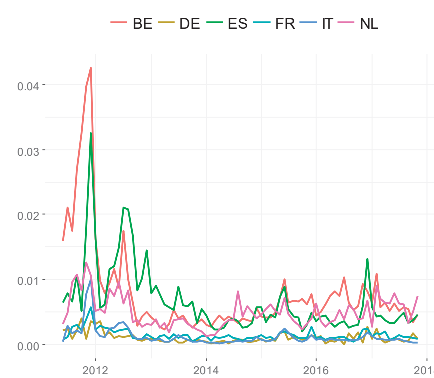

Figure 12. The spill-over effect on illiquidity score of sovereign bonds in different countries during time. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

5. Results of the Liquidity Spillover Effect from One Market to Another

This chapter focuses on the bilateral linkages among countries of the liquidity spillover effect. The first part reports the results of an event study of liquidity spillover from one market to, on average, all other markets. In the second part, the panel regression model results try to bring more light onto the possible determinants of these bilateral cross-country linkages.

5.1. Event Study of the Liquidity Spillover Effect from One Market to Another

Intuitively, a liquidity spillover effect of particular trade should be strongest for the bonds from the same market as the traded bond. It is the case with the spill-over effect of German trades (Figure 13) and French (Figure 14) sovereign bonds. This is especially evident immediately after the trade execution, because afterward the picture is potentially blurred by market-specific factors, e.g., the liquidity trend of Spanish bonds. The liquidity spillover effect to bonds from other countries is also visible, but this effect is around three times smaller than for the bonds from the same country. Interestingly, only Italian bonds seem to remain unaffected by the trades of German or French sovereign bonds, possibly because Italian bonds are the most traded bonds in the MTS market.

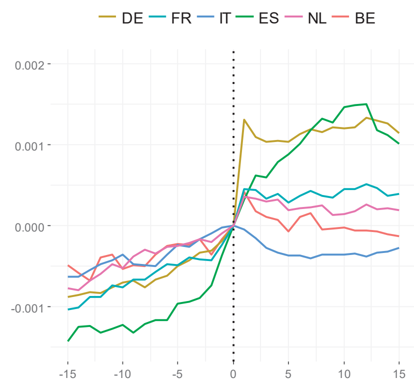

Figure 13. The liquidity shock spillover effect of trades of German sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

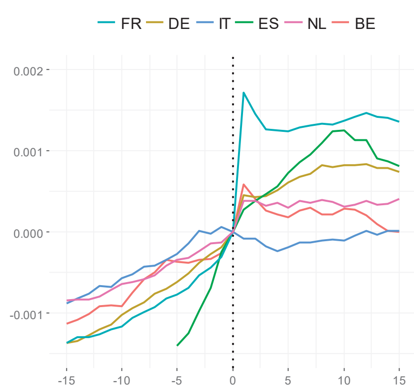

Figure 14. The liquidity shock spill-over effect of trades of French sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

Similar conclusions can be reached regarding the spill-overs emanating from Italian trades (Figure 15) and Spanish (Figure 16) sovereign bonds. However, the liquidity spillover from Spanish bonds trades to all other markets is comparatively much smaller (only Italian bonds are somewhat affected), meaning that trades of Spanish sovereign bonds have little informational value for traders from other countries. Interestingly, the liquidity of Spanish bonds is also highly affected by Italian bonds' trades, while there is limited effect on the bonds from other markets.

The spillover effect emanating from Belgium sovereign bonds trades (Figure 17) also seems to be comparatively small. In contrast, the spillover effect is a bit higher from the Netherlands sovereign bonds (Figure 18). After the trade is executed of the Netherlands sovereign bonds, the liquidity of German, French, and Belgian sovereign bonds are most negatively affected. At the same time, no effect is visible in Italian and Spanish markets. Meanwhile, the trades of Belgian sovereign bonds has only a marginal effect of bonds from all other markets; only the effect on own Belgian bonds is significant.

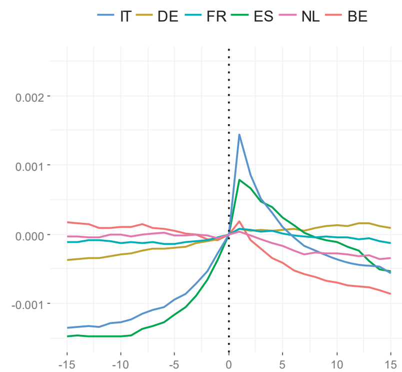

Figure 15. The liquidity shock spillover effect of trades of Italian sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

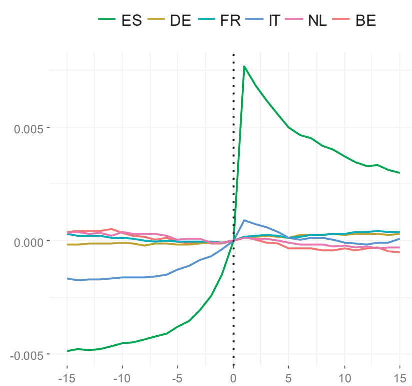

Figure 16. The liquidity shock spill-over effect of trades of Spanish sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

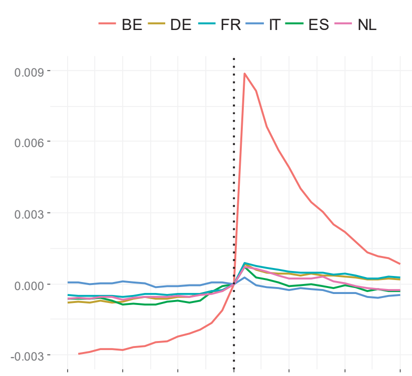

Figure 17. The liquidity shock spillover effect of trades of Belgian sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

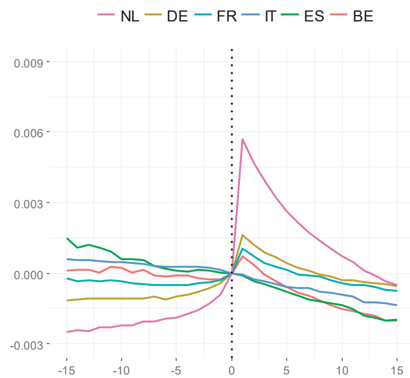

Figure 18. The liquidity shock spill-over effect of trades of Netherlands sovereign bonds to different markets 15 min before and after the trade is executed. Notes: BE—Belgium; DE—Germany; ES—Spain; FR—France; IT—Italy; NL—Netherlands.

5.2. Panel Regression Model of the Underlying Factors of Liquidity Spillover Effect from One Market to Another

To determine the underlying reasons for the strength of liquidity shock spillover effect among markets, a panel regression model was employed. The dependent variable is the monthly average of the changes of order-book illiquidity score immediately after the transaction is executed. As the analysis was carried out with monthly data from June 2011 until December 2017, 79 monthly averages for bilateral linkages in 6 markets led to overall 2370 bilateral observations. Country-specific fixed effects were included in the model, and the standard errors were clustered because the panel consists of different markets with heterogeneous liquidity levels.

As the spillover effect is related to bilateral linkages (i.e., the traded bond which is transmitting liquidity shock and the non-traded bond that is responding to the shock), two models with different explanatory variables were constructed. The first model focuses on the spill-over effect emanating from the trades of sovereign bonds of a particular market ("spill-over from", i.e., analyzing why the trade signal emanating from some markets is stronger, while from others—weaker. Most of the model's variables were constructed from the transactional data because this model concentrates on the sovereign bonds from which the spillover effect reverberates, i.e., from the traded bonds. The second model focuses on the strength of the spill-over effect to the bonds from another market than the traded bond ("spill-over to"). As this model is related to the sovereign bonds that are "receiving" spill-over effect, most of the variables were constructed from the limit order book data.

The first model results reveal that the strongest liquidity shock spillover effect arises from sovereign bonds that are less liquid and whose issuer is closer by distance to the country of another—non-traded—bond (Table 1). As transactions affect more severely the liquidity of the relatively less liquid and therefore more sensitive traded bonds, the spillover effect from such transactions is also stronger. This result directly relates to the Bank for International Settlements (2016a) and Pellizon et al. (2013) that risks of information leakage from illiquid securities are often much higher. Intuitively, the liquidity spillover effect is stronger when it emanates from the traded bond whose issuer is closer by distance to another sovereign bond issuer. However, other variables—number of transactions, average trade size, and residual maturity of the traded bond—has no statistically significant explanatory power (Table 1).

Table 1. Explanation of variables and results.

Variable	Description	Results
Spill-over FROM	Average monthly spill-over effect from the country of the traded bond (from which spill-over impact is measured) to non-traded bond from another country	Dependent variable
distance	The distance between the country of the traded bond and the country of another bond (in 1000 km)	−0.00028 ** (−8.55)
num_trades	The number of trades from which the spill-over effect is measured during a month	−0.018 (−1.41)
trade_size	The average trade size of bonds from which spill-over effect is measured during a month (in millions)	−0.0000195 (−0.9)
illiq_score	The average illiquidity score of bonds from which spill-over effect is measured at the time of the trade	0.0015 ** (12.02)
res_maturity	The average residual maturity of traded bonds at the time of the trade (in years)	−0.000017 (−1.68)

Note: The number in parentheses is the heteroscedasticity robust *t* value, ** indicates statistically significant variables at 5% level.

The second model results (i.e., spillover effect to another market) are quite similar to the results of the first model (Table 2). The closer the two countries are, the higher the liquidity shock spill-over effect to the bonds from another market than the traded bond. Also, the less liquid bonds are affected more severely. Nevertheless, this model reveals that the number of quoted bonds also matters: the higher the number of bonds from a particular issuer that is quoted in the particular market, the weaker is the liquidity shock spillover effect, possibly due to the dilution of the impact among different bonds. Interestingly, bonds with a higher number of limit order revisions are more affected, meaning that such bonds quickly incorporate new information transmitted by trades of bonds from another market—though this effect is significant only at the 10% significance level. This result is also confirmed by other studies that state that rapid technological changes enable dealers to quickly incorporate incoming information in the central order book. Only the residual maturity of the non-traded bond is not statistically significant, contrary to Schneider et al. (2016) (Table 2).

Table 2. Explanation of variables and results.

Variable	Description	Results
Spill-over TO	The average monthly spill-over effect to the bonds from the country of the non-traded bond (to which spill-over effect is measured)	Dependent variable
distance	The distance between the country of the traded bond and the country of another bond (in 1000 km)	–0.00038 ** (−8.51)
num_bonds	The number of bonds with standing limit orders at the time of the trade	−0.000026 ** (−4.35)
num_updates	The number of limit order revisions in the central limit order book	0.0000012 * 1.75
illiq_score	The average illiquidity score of bonds to which spill-over effect is measured at the time of trade	0.0024 ** (13.79)
res_maturity	The average residual maturity of non-traded bonds from another country than the traded-bond (in years)	−0.00003 (−0.77)

Note: The number in parentheses is the heteroscedasticity robust *t* value, ** indicates statistically significant variables at 5% level, *—at 10% level.

The main takeaway from the two-panel regression models is that it is difficult to relate particular bond-specific factors to the size of the liquidity shock spillover effect both from and to another market. Only the distance between the countries and the relative liquidity of bonds help explain the spillover effect in both models. Possibly, other variables that are not directly related to the MTS bond market might be useful to explain these cross-country differences, e.g., the trading and quoting activity in other (including over-the-counter and futures) markets, linkages between different markets, and et cetera.

6. Conclusions

In our research, we tried identifying the liquidity spill-over effect. We wanted to reveal how different trades can influence sovereign bonds' prices and how this effect differs for the traded (direct impact) and non-traded (spill-over effect) bonds. Our event studies of spill-over effects of trades were carried out with minute frequency bond data from mid-2011 until the end-2017 for the six largest euro area markets. We determined that the outcome was permanent as the average price does not reverse even 15 min after the trade's execution. We would also like to point out that the change of other bonds' prices from the same country as the traded bond was smaller than the traded bond price change. However, the prices of other (non-traded) bonds change much more before the trade was executed than the price of the traded bond. The latter results mean that the change of bond prices entered the endogenous investors' decision process of selecting particular bonds that had been traded. Finally, we can conclude that the liquidity spill-over effect was relatively small. In the next step, we try to analyze maturity buckets. The liquidity of bonds from the same country and residual maturity closer to the traded "bonds" maturity was affected most detrimentally. Both components of illiquidity score—quoted quantities and bid-ask spreads—were more severely affected for the bonds with similar residual maturity as the traded bond.

The other interesting fact that we want to point is that the liquidity spill-over to non-traded bonds varies notably during time. The spill-over effect on the first minute after the trade was most robust during turbulent times and was almost negligible during calm market periods. We want to stress that the liquidity of bonds with closer residual maturity to the traded bonds' maturity was affected most significantly during the whole analyzed period. Such a tendency could be explained by the tight relationship between the spill-over effect and the market risk tolerance.

Because the trade size of sovereign bonds can also be used to explain the differences in magnitudes of the liquidity spillover effect, we included that factor. We have noticed that the smallest value transactions have almost no liquidity spillover effect, while the largest transactions lead to a considerable detrimental effect. So because of that, investors split the orders across more extended periods to avoid liquidity shocks.

Issuing country is also a significant factor for liquidity spill-over effects. We determined that the spill-over is relatively small in sovereign bond markets from Germany, France, and Italy. At the same time, it is much more noticeable in smaller countries—Belgium, the Netherlands, and Spain.

Finally, in our study, we tried to investigate the liquidity spill-over effects from one market to another. We revealed that the liquidity shock spill-overs are most robust for the bonds from the same issuing country as the traded bond rather than on the bonds from other countries. Regarding the strength of bilateral spill-over effects among different markets, the panel regression model results revealed that few liquid bonds and bonds whose issuer is closer by distance to the country of the traded bond has a more substantial reactive spillover effect. Such bonds are also affected more by the trades executed in another market. Also, the higher the number of bonds (mostly if they are less actively quoted) that are being listed in the particular market, the weaker is the liquidity spillover effect.

Results of this research should be of particular interest to the sovereign bond traders, analysts, market supervisors who actively monitor the dynamics of bond markets and try to understand the underlying reasons for market movements and liquidity dry-ups. Market liquidity can quickly evaporate after trades are executed even in another market.

Market participants should pay increasing attention to the cross-country effects and have a pre-emptive strategy to cope with the spillover shocks. Otherwise, increasing liquidity premium might reduce the efficiency of the trading strategies and negatively affect trading returns.

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Can Economic Factors Improve Momentum Trading Strategies? The Case of Managed Futures during the COVID-19 Pandemic

Renata Guobužaitė and Deimantė Teresienė *

Finance Department, Faculty of Economics and Business Administration, Vilnius University, LT-10223 Vilnius, Lithuania; renata.guobuzaite@evaf.stud.vu.lt
* Correspondence: deimante.teresiene@evaf.vu.lt

Abstract: Systematic momentum trading is a prevalent risk premium strategy in different portfolios. This paper focuses on the performance of the managed futures strategy based on the momentum signal across different economic regimes, focusing on the COVID-19 pandemic period. COVID-19 had a solid but short-lived impact on financial markets, and therefore gives a unique insight into momentum strategies' performance during such critical moments of market stress. We offer a new approach to implementing momentum strategies by adding macroeconomic variables to the model. We test a managed futures strategy's performance with a well-diversified futures portfolio across different asset classes. The research concludes that constructing a portfolio based on academically/economically sound momentum signals with its allocation timing based on broader economic factors significantly improves managed futures strategies and adds significant diversification benefits to the investors' portfolios.

Keywords: backwardation; economic regimes; momentum strategy; systematic trading

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1. Introduction

From difficult lessons learned in 2008, the traditional "suspects" in institutional investors' portfolios (i.e., equity, fixed income) face a significant problem. In a period of crisis, their prices tend to move together. Therefore, opportunities to diversify the portfolio become very limited. As investors seek to diversify into other asset classes, many turn to alternative assets as a solution, with managed futures strategies firmly in focus. In this study, we test the performance of managed futures strategies based on a theoretically proven momentum effect across different asset classes. This research aims to identify if the construction of a portfolio, based on academically/economically sound momentum signals, and its allocation timing based on broader economic factors, can significantly improve the performance of managed futures strategies and add significant diversification to investors' portfolios. The particular focus is placed on the recent COVID-19 period as a natural experiment of increased market uncertainty.

The managed futures are a sub-class of alternative investment strategies that take long/short positions across various futures markets (commodity, equity indices, foreign currency, bonds) globally. Some studies showed that tactical trading in futures markets had generated abnormal returns in the past (Gorton and Rouwenhorst 2006; Erb and Harvey 2006; Shen et al. 2007; Fuertes et al. 2010; Szymanowska et al. 2014). However, considering that managed futures strategies only trade in financial instruments listed on the exchanges, their positions are transparent, highly liquid (exchange trading, no asymmetry between short/long positions), with the minimum counterparty or credit risk. Thus, such strategies offer access to leverage, high liquidity, low transaction costs, and complete transparency. The studies also suggest that managed futures have performed exceptionally well during down markets and still delivered positive results during the up periods in equity markets.

Systematic momentum trading is a very popular risk premium strategy in different portfolios, where, according to a BarclayHedge report (2020), more than 70% of managed futures funds are estimated to follow momentum signals.

In this study, we selected to test the performance of managed futures strategies based on a theoretically proven momentum effect across various (i.e., equity index, foreign exchange, bonds, and commodity futures) markets. Our contribution to the current stream of literature on momentum strategies is twofold: (1) we estimate, compare, and analyze strategies based on long- and short-term momentum signals, respectively; (2) we offer a new approach to implementing momentum strategies by adding macroeconomic variables to the analysis. Our theoretical model for estimating a momentum strategy's returns is based on Elaut and Erdős's (2019) proposed asset-based factor that aggregates time-series momentum signals over different time horizons. Due to this model flexibility, it is possible to construct a momentum portfolio strategy with the selected lookback period length. Therefore, we can separate the momentum signal into "short-term" and "long-term" effects and separately assess their impact on portfolio performance. Furthermore, considering that the momentum strategy is highly dynamic and depends on the broader market, we also add some macroeconomic indicators to the model. To distinguish between different economic states, we use the Markov regime-switching model and test for the existence of one, two, and three different market states. Furthermore, we use an economic sentiment indicator (ESI) series available from Eurostat to confirm periods of economic recession and add the VIX index series to measure the increased uncertainty in the market. In addition, we assess the benefits of adding a managed futures' exposure to institutional investors' portfolios. A "traditional" institutional portfolio, in this case, is approximated by a 60% investment in equity and 40% in fixed income; then, considering this portfolio as a benchmark, we test what effect an increasing managed futures' position has on the overall performance of the portfolio.

We thoroughly compare the results across the portfolios and find that separating "short-term" and "long-term" momentum effects as two distinct factors in portfolio construction adds value by increasing returns and reducing the standard deviation of returns. We agree with Barroso and Santa-Clara (2012) that momentum strategies can increase the profitability and Sharpe ratio of a portfolio. Given their performance, the "long-term" momentum seems to capture a general trend in the market, and "short-term" momentum refers to the reversal effect due to market overreaction, liquidity, or trading issues. The results also show that the performance of each factor largely depends on the general economic conditions. Therefore, market timing is an essential component of a successful momentum strategy and can positively affect both risks and return on the portfolio. As expected, portfolios with combined long exposure to both "long-term" and "short-term" momentum factors performed exceptionally well during the COVID-19 financial crisis and can be considered a hedging instrument for improving the overall portfolio's performance during periods of financial distress.

In summary, our paper focuses on the performance of the managed futures strategy based on two "long-term" and "short-term" momentum signals across different economic regimes, with a particular focus on the COVID-19 pandemic period. The performance of each of the momentum series largely depends on the general economic conditions of the market. We offer a new approach to momentum strategies because we found that the momentum strategy's performance could be improved if broader macroeconomic variables were added to the analysis. We also address the critical characteristics of momentum strategies that can benefit institutional investors and highlight the potential advantages of including managed futures in a diversified portfolio. In particular, managed futures can be helpful as a hedging tool during a financial crisis.

The rest of the paper is organized as follows. Firstly, we discuss the main theoretical issues and academic literature related to managed futures portfolio management strategies. Secondly, we present the methodologies used and give our insights on each topic. We also add Markov regime-switching model to identify different types of decisions required, depending on the economic cycle. Finally, we present our results, discuss the main findings, and conclude.

2. Literature Review

The presence of profound economic reasons is a comforting indicator of the robustness of the expected managed futures' returns. Keynes (1930) explained two types of participants in futures markets: hedgers and speculators. The hedgers (producers and issuers) buy insurance for a price risk and pay a premium to the market. Speculators (traders and investors) assume price risk, provide liquidity, and are rewarded by collecting this insurance premium.

In more recent studies, the risk premium can be modeled via different observable factors in futures markets. Two major factors discussed in academic literature include momentum (Erb and Harvey 2006; Miffre and Rallis 2007; Shen et al. 2007; Szakmary et al. 2010; Moskowitz et al. 2012) and the slope of a futures' term-structure (Erb and Harvey 2006; Gorton and Rouwenhorst 2006; Fuertes et al. 2010). The momentum strategy attempts to capture significant directional moves across a diversified portfolio of assets. The model that generates buy or sell signals can be as straightforward as a price-moving average or exiting the price channel. The term structure strategy exploits the signals from a managed futures' price curve—it buys most backwardated contracts (with a downward sloping term structure) and shorts most contangoed ones (with an upward-sloping term structure). Some alternative strategies can also be based on other factors such as value (Asness et al. 2013), market volatility (Frazzini and Pedersen 2014), liquidity/open interest (Szymanowska et al. 2014), inflation (Erb and Harvey 2006), skewness (Fernández-Pérez et al. 2015), and idiosyncratic risk (Miffre et al. 2015).

Another part of the research tries to combine different strategies, including momentum. Baz et al. (2015) made an analysis using three different strategies: carry, momentum, and value using different ways of implementation (directional and cross-asset). Bender et al. (2013) focused on factor investing, stressing that value, low size, and momentum strategies traditionally offered excess long-term returns. Those authors expanded the group of systematic factors and conducted research with MSCI indices. Momentum strategies were analyzed by Chabot et al. (2008); Chabot et al. (2014); Campbell (2004); Vogel and Gray (2015); Elias et al. (2014); Foltice and Langer (2015); Hong and Stein (1998); Hurst et al. (2014); Yu and Chen (2012); Krauss et al. (2015); Martin (2021); Martins et al. (2016); Menkhoff et al. (2012); Roncalli (2017); (Shen et al. 2007); and Tauseef and Nishat (2018). Some authors even focused on modern machine learning ranking algorithms for cross-sectional momentum strategies (Poh et al. 2020). Fong et al. (2005) analyzed international momentum strategies using a stochastic dominance approach and identified that momentum could be found globally. However, models considering investors' mood are non-satiated, and that risk-averse models could not explain momentum.

Our study focuses on the time-series momentum factor that was first introduced by Moskowitz et al. (2012). Their paper offers one of the most comprehensive time-series momentum studies across various futures markets (equity index, commodity, foreign exchange, and fixed income). Baltas and Kosowski (2012) contribute by suggesting several alternative estimates for a time series momentum: return sign, moving average, trend extraction, time-series t-statistics, and statistically meaningful trend, with the last alternative being referred to as the most efficient. We use the model proposed by Elaut and Erdős (2019), which is based on Moskowitz et al. (2012), and allow for estimating and comparing time-series momentum signals over selected lookback periods.

Because of significant returns and a low correlation with traditional asset classes, managed futures can also be successfully used for strategic asset allocation (Jensen et al. 2000; Erb and Harvey 2006). In her paper, Kaminski (2016) notes that managed futures seem to be an excellent instrument for risk hedging during a financial crisis. For example, in the 2018 financial crisis, managed futures benefited from the distressed market and were recorded as the most profitable investment category. We also test this property by assessing the impact of adding a managed futures momentum exposure to the broader portfolio performance.

3. Methodology

For an investment strategy to be sustainable over a more extended period, there must be an underlying structural property in the market for a risk premium to exist and conditions for the trading strategy to capture it. Till (2016) suggests that there are some solid, economically grounded reasons for consistent returns in futures' markets to exist due to:

- Momentum;
- Term-structure; and
- Portfolio rebalancing.

Momentum is simply a "bet" that the past performance contains valuable information for estimating expected returns in the future. Indeed, securities with high average returns in the past can outperform equities with the worst performance up to 12 months ahead. Erb and Harvey (2006), Gorton and Rouwenhorst (2006), and Miffre and Rallis (2007) confirm that the momentum strategy works well in the futures markets. A momentum portfolio systematically longs futures with the best performance and shorts futures with the worst performance in these studies. This momentum estimate is typically referred to as a cross-sectional momentum, as it picks the best- and worst-performing contracts out of a cross-section of selected futures. An alternative method is a time-series momentum (Szakmary et al. 2010; Moskowitz et al. 2012). It focuses on each futures' past returns—buys if its past performance is positive and sells if the performance is negative. An aggregated time-series momentum strategy is, then, a weighted portfolio of these individual positions. This method allows for easy comparison and use of various asset classes with very different return distributions.

The term-structure of individual futures' contracts can also be considered a structural source of returns, especially over a more extended period. It is specific to the futures market, as a futures contract price today is paid for delivering an underlying asset at a pre-specified date in the future. When a futures' contract trades at a discount to a spot price, we call this futures' price curve slope a backwardation, and when a deferred futures' contract trades at a premium to a spot price, we refer to it as a contango. As maturity approaches, the futures' price of a backwardated (contangoed) contract is expected to increase (decrease) towards the expected spot price, enabling long (short) speculators to earn positive returns (Erb and Harvey 2006; Gorton and Rouwenhorst 2006; Gorton et al. 2013). Feldman and Till (2006) show that the deeper the futures market is in backwardation (or contango), the stronger the performance. When the futures' contract is in backwardation, an investor faces two potential return sources: an increase in the futures' price and a positive "roll-yield". Even if the spot price starts declining, an investor can still profit from a so-called "roll-yield". As the futures' contact maturity approaches, an investor needs to roll his/her near-term expiring futures' contracts into contracts with expiration dates further in the future to keep his/her positions open. In backwardation, the "roll-yield" (i.e., a price difference between the nearby contract that is closed and a more distant contract that is rolled into) is expected to be positive. However, if the market is in contango, rolling the long positions can negatively affect "roll-yields" and have a very damaging effect on total returns.

Portfolio rebalancing is the third structural source of return (Till 2016; Bakshi et al. 2019). The studies show meaningful returns from rebalancing portfolios of low-correlated, mean-reverting, high volatility investments, such as futures contracts. A rebalancing return can be accrued from periodically resetting the portfolio to its initial (often, equal) weights that cause an investor to frequently sell assets that have gone up and sell assets that have declined in value. Erb and Harvey (2006) and Sanders and Irwin (2012) have empirically confirmed that portfolio rebalancing represents a robust source of returns from owning and rolling a portfolio of futures.

In this study, we test the performance of the managed futures strategy that is based on momentum effects across various (i.e., equity index, FX, bonds, and commodity) futures markets. We construct a long/short futures portfolio based on the momentum factor. The momentum returns are estimated with the Elaut and Erdős (2019) asset-based momentum factor that aggregates time-series momentum signals over different time horizons. The strategy is called "adaptive time-series momentum" (*ATSMOM*), in which the momentum signal for any given security in the portfolio is averaged over several lookback horizons:

$$r_{T+1}^{ATSMOM} = \frac{1}{L}\sum_{I=1}^{L} sgn\left[\frac{\sum_{t=10}^{260} sgn\left(r_{T-t,T-1}^{I}\right)}{251}\right][\frac{\frac{0.4}{\sqrt{261}}}{\sigma_{T-60,T-1}^{I}}]r_{T+1}^{I} \tag{1}$$

where *sgn* is the sign of the two-day lagged return, L is the number of assets in the strategy, and σ is the two-day lagged, exponentially weighted moving average (EWMA) estimator of volatility with a 60-day rolling window that can be estimated as follows:

$$\sigma_{T-60,T-1}^{2} = (1-\lambda)\sum_{t=o}^{59}\lambda^{t}(r_{T-t-1}-\bar{r})^{2} \tag{2}$$

with λ as a decay factor. Similarly to Elaut and Erdős (2019), we use a decay factor of 0.4 as a way to achieve an ex ante volatility of 40% per security, which can be expected to result risk factors with an ex post volatility of approximately 12% per year (which represents a typical CTA target volatility of around 12%).

This model is based on the earlier works of Moskowitz et al. (2012) and Baltas and Kosowski (2012). The term "time-series momentum" was first introduced by Moskowitz et al. (2012) who documented a presence of persistent "trend" factors across a broad range of futures markets. Baltas and Kosowski (2012) later proposed improved volatility and momentum estimates for this model. In the Moskowitz et al. (2012) paper, the momentum strategy is called the "time-series momentum" (TSMOM), where the return of the momentum futures portfolio is calculated as follows:

$$r_{T+1}^{TSMOM} = \frac{1}{L}\sum_{I=1}^{L} sgn\left[r_{T-261,T-1}^{I}\right][\frac{\frac{0.4}{\sqrt{261}}}{\sigma_{T-60,T-1}^{I}}]r_{T+1}^{I} \tag{3}$$

If we compare the models, Moskowitz et al. (2012) estimate the momentum only as a binary signal that can be equal to only 1 ("up") or –1 ("down"). Considering that Elaut and Erdős (2019) aggregate the time-series momentum signals over several lookback periods, the momentum can result in any value within the range [−1,1], also referred to as the strength of this signal. In practice, if the TSMOM is only a sign or direction of a 251-day trend, the ATSMOM averages a range of TSMOM signals looking backward from 10 to 251 trading days. This new development introduces an opportunity to use Elaut and Erdős's (2019) model for quickly estimating and comparing momentum signals based on different lookback periods.

This study takes a closer look at a time-series strategy's performance based on two key separate long- and short- momentum signals. Due to the flexibility of the Elaut and Erdős (2019) model, it is possible to construct a momentum portfolio strategy with a selected lookback period length. For this purpose, we define a 1–3 month lookback period as a short-term momentum and a 9–12 month period as a long-term momentum. Thus, we contribute to "time-series momentum" research by estimating momentum signals separately for long and short horizons and further documenting that both signals respond differently to market conditions changes.

Indeed, each structural source of return's performance largely depends on a general situation in the market (Routledge et al. 2000; Koijen et al. 2018; Bakshi et al. 2019). This paper examines the relationship between a selected managed futures strategy's performance and the general economic conditions across time and markets. Given the current, rapidly changing market conditions, the market timing is an essential component of each successful managed futures' strategy. Hong and Yogo (2012) suggest that managed futures' returns vary with time and are predictable from macroeconomic and other specific variables. In particular, Sakkas and Tessaromatis (2020) relate that market volatility is a key factor for predicting returns in managed futures portfolios.

We use the Markov regime-switching model based on the S&P 500 time series for the sample period to distinguish between different economic states. Its performance is closely related to the general economic conditions. To allow for asymmetric exposure, we test for the existence of one, two, and three different states. Since the objective is to get an economic interpretation for managed futures' strategies, we start testing a three-state system. The test data is arranged so that state 1 represents an "up" state, state 2 a "down" state, and state 3 is an "intermediate" state in the Markov regime-switching model. To estimate the Markov regime-switching, we use the MATLAB package provided by Perlin (2015). In addition, we include an economic sentiment indicator (ESI) series available from Eurostat to confirm periods of economic recession. We also add the VIX index series as a proxy for future market uncertainty and conditions (low during expansions and high during recessions). Of particular interest is the period of the COVID-19 crisis. Contrary to traditional investments, the managed futures strategies are expected to perform exceptionally well during this clearly defined period of financial distress.

This paper also analyzes the benefits of adding a managed futures' exposure to institutional investors' portfolios. Considering that a long-term recorded correlation between futures' returns and a traditional (i.e., equity and bond) investment portfolio returns are surprisingly low or even negative, the institutional investors can potentially benefit from increased risk-adjusted returns and better portfolio resilience by including managed futures to their portfolio (Lintner 1996). We use our estimated portfolio (based on two short-term and long-term momentum factors) to represent managed futures investments. A "traditional" institutional portfolio is approximated by a 60% long position in the S&P 500 Index and a 40% long position Bloomberg Barclays US Aggregate Bond Index. We construct several portfolios with different (increasing) allocations to a managed futures' exposure for this analysis. Considering the pure 60:40 equity/bond portfolio as a benchmark, we will estimate how an increasing managed futures' position affects the overall portfolio's performance. Given the modern portfolio theory, a managed futures exposure should contribute to an absolute return and add valuable diversification to a "traditional portfolio" of stocks and bonds.

The daily data across futures markets is available from Tick Data LLC (www.tickdata.com, accessed as of 3 December 2020) that offers historical tick-by-tick prices on the futures and index markets. Our dataset consists of futures prices for 54 futures contracts in four asset classes (25 commodities, 9 equity index, 10 foreign exchange, 10 bond futures). We report the list of futures contracts in Table A1 (Appendix A). Both the daily S&P 500 and Bloomberg Barclays US Aggregate Bond indices' levels are available from Bloomberg. The sample period ranges from January 2010 to December 2020. The futures investment will be represented by a long/short position in front-month futures fully collateralized by holding a corresponding value of the contract in US government bills or a bank deposit paying EURIBOR interest rates. At the end of the day, all positions are rebalanced by marking them to market and adjusting the collateral position to reflect the corresponding cash inflow or outflow. The futures' positions are rolled into the next month's contract at the close on the day before expiration. Following Moskowitz et al. (2012), the most liquid contracts in each market will be considered.

4. Results and Discussion

In this section, we test and compare the performance of the managed futures' portfolios constructed based on two "short-term" and "long-term" momentum factors with the data set ranging from January 2010 to December 2020 and check whether the results are robust within a more extended period. In addition, we analyze the benefits of adding managed futures' exposure to the "traditional" equity/bond portfolio and confirm the substantial advantages over the sample period.

4.1. Momentum Factors

To evaluate the managed futures strategy that is based on momentum effect, we construct the time series that is based on the ATSMOM ("adaptive time-series momentum") factor as described in Elaut and Erdős's (2019) paper. To get an intial sense of the series performance, we plot it against the benchmark SG Trend Index. The SG Trend Sub-Index is a subset of the SG CTA Index designed to track the 10 largest (by AUM) trend-following CTAs and represent the momentum followers' performance in the managed futures market.

Figure 1 shows the ATSMOM factor's time-series compared to the SG Trend Index, based on daily returns data ranging from January 2010 to December 2020. For comparison purposes, an initial level for each series is set at one (as, for example, we invested USD 1 at the beginning of the period) and then adjusted based on their corresponding returns. We found a substantial correlation of 0.7397 between two series for the sample period that confirms, in essence, that the ATSMOM factor performs as it was expected to, i.e., it follows a general, average momentum strategy in the market. The performance of the ATSMOM factor is slightly worse than the benchmark index. However, this is mostly due to the transaction costs, as we added the average transaction costs per trade in our analysis to account for practical implementation issues of the ATSMOM strategy.

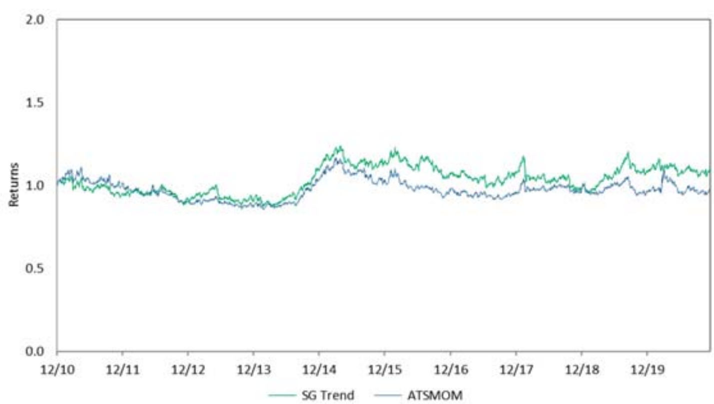

Figure 1. The performance of SG Trend Index and ATSMOM factor daily time-series.

Due to the flexibility of the Elaut and Erdős (2019) model, estimating and comparing momentum factors is possible based on different lookback periods. To take a closer look at the momentum factor performance, we estimate an ATSMOM series with four distinct lookback periods: 1–3 months, 3–6 months, 6–9 months, and 9–12 months (see Figure 2). The results indicate that "short-term" (e.g., 1–3 months) and "long-term" (e.g., 9–12 moth) series are often minor or even negatively correlated. For example, we found a negative correlation of −0.414 between the "short-term" and the "long-term" momentum series during the sample period from January 2010 to December 2020. The economic reasoning for this might be that the "long-term" series is more sensitive to the overall market's general trend. In contrast, the "short-term" series represents a correcting reversal to the mean effect. This phenomenon is already documented in other financial markets. For example, Zaremba et al. (2019) confirm that, contrary to the general trend, the stocks with a high (low) return in the previous month underperform (overperform) in the following month. It is a short-term reversal effect due to investors' overreaction, liquidity issues, institutional behavior, trading frictions, and/or transaction costs. We found this effect present in the futures market, too; contrary to a long-term momentum, short-term momentum is negatively correlated with the overall market trend.

Figure 2. The performance of ATSMOM factor with 1–3 month, 3–6 month, 6–9 month, 9–12 month lookback periods.

To evaluate the significance this effect has on the momentum strategy's performance, we construct an alternative portfolio where the positions with "long-term" momentum are bought (long position), and the ones with "short-term" momentum are sold (short position). Elaut and Erdős (2019) refer to this position as the "speed" factor. As illustrated in Figure 3, the momentum portfolio with the "speed" factor presents a better investment opportunity as it outperforms the ATSMOM portfolio during the sample period.

Figure 3. The performance of portfolios with ATSMOM and "speed" factors.

To compare performances of the portfolios, the main characteristics are presented in Table 1. Although the volatilities of both portfolios for the sample period are relatively similar (10.3% p.a. for the ATSMOM portfolio, 11.7% for the portfolio with the "speed" factor), the returns are improved in the case of the portfolio with the "speed" factor (i.e., 4.3% p.a. as compared to a 0.3% p.a. return of ATSMOM portfolio). This significantly increases the Sharpe ratio from 0.027 for the ATSMOM portfolio to 0.363 for the portfolio with the "speed" factor. The results also indicate that both portfolios' returns are negatively skewed (−0.432 for the ATSMOM portfolio, −0.285 for the portfolio with the "speed" factor), however, including the "speed" factor positively affects the portfolio skewness.

However, it also increased the portfolio kurtosis, which refers to a higher probability of obtaining extreme return values in the future.

Table 1. Summary statistics for portfolios with momentum factors.

Ratio	SG Trend Index	ATSMOM	"Speed" Factor
Annualized Return	1.4%	0.3%	4.3%
Annualized Std Deviation	10.5%	10.3%	11.7%
Sharpe Ratio	0.129	0.027	0.363
Skewness	−0.674	−0.432	−0.285
Kurtosis	3.130	3.661	4.783
Maximum Drawdown	−23.0%	−22.9%	−25.4%

Our main results favor the portfolio with the "speed" factor, as it is expected to increase the expected returns on a risk-adjusted basis. However, it should be noted that it also outperforms SG Trend Index (a benchmark for the industry) by offering increased returns and the reduced standard deviation of returns.

4.2. Market Regimes

We extend the analysis by comparing the performance of both "short-term" and "long-term" momentum series across economic regimes. Several studies (Routledge et al. 2000; Hong and Yogo 2012; Bakshi et al. 2019) indicate that the performance of the momentum factor series largely depends on the general economic conditions. Therefore, market timing is an essential component of each systematic momentum strategy.

We found that the correlation between the "short-term" and "long-term" momentum series increases during periods of financial distress, as "short-term" momentum also starts capturing a robust and prominent trend in the market. During the COVID-19 crisis, both series exhibit a coordinated upward movement (see Figure 4). The COVID-19 pandemic had a powerful impact on financial markets, but looking back, we can observe that the negative effect was concise. It gives valuable insight into momentum strategies' performance during such critical moments of market distress. Our estimated correlation between the "short-term" and "long-term" momentum series increased up to 0.9811 during the COVID-19 crisis compared to a negative correlation of −0.414 between the two series during the sample period of January 2010 to December 2020.

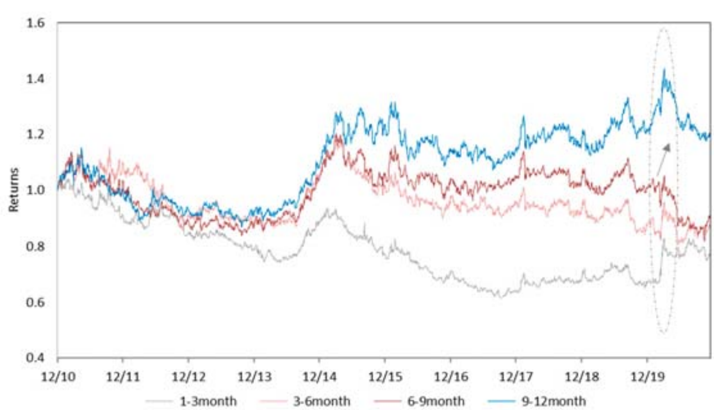

Figure 4. The performance of ATSMOM factor with 1–3 month, 3–6 month, 6–9 month, 9–12 month lookback periods during the COVID-19 crisis.

We used a Markov regime-switching model to distinguish between the periods of high and low volatility in the equity market (Perlin 2015). Using daily S&P 500 Index data, we define the periods of the "up", "intermediate", and "down" states of economic regimes. The evolving probability of the "down" economic state is presented in Figure 5. In addition, we use the economic sentiment indicator (ESI) series available from Eurostat as a control variable to confirm periods of economic recession. Considering that volatility is singled out as one of the most critical factors in the market (Sakkas and Tessaromatis 2020), we also consider the VIX Index as a proxy for the market's uncertainty. By definition, the VIX index measures an expected stock market volatility over the next 30 days as implied by the S&P 500 index options. Therefore, it must be strongly correlated with market sentiment and its current economic state. In general, VIX values greater than 30 are already linked to increased uncertainty and risk; therefore, we set a critical value of 30 to define the periods of significant financial distress. It seems that all indicators jointly capture critical moments in financial markets that occurred during the sample period from January 2010 to December 2020: the Black Monday in 2011 (when US sovereign debt was downgraded for the first time), the 2015 Chinese stock market turbulence, and the recent COVID-19 financial crisis.

Figure 5. Time evolution of market regime indicators and recession periods.

To incorporate the economic regime's effects into our momentum strategy, we use our portfolio with the "speed" factor, as constructed in the previous section. However, we allow for the long position in both "long-term" and "short-term" momentum factors during "down" state economic regimes. As illustrated in Figure 6, the resulting time series refers that the momentum portfolio, adjusted for the economic regimes, outperforms an initial "speed" factor portfolio. Both portfolios perform relatively similarly during periods of low volatility, and the volatility-adjusted momentum portfolio always outperforms the "speed-factor" portfolio during high volatility periods.

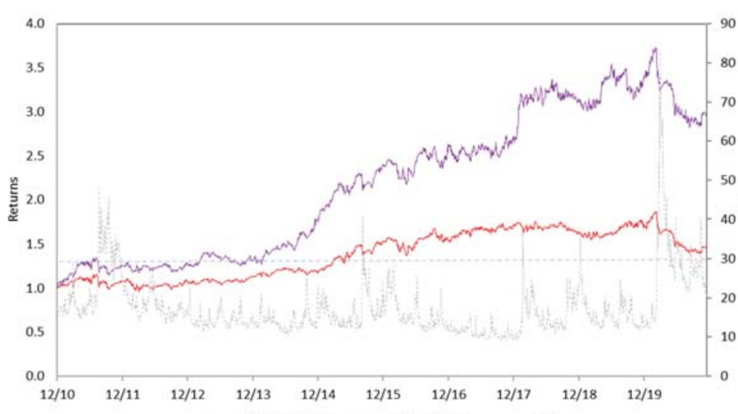

Figure 6. The performance of the portfolio with "speed" factor adjusted for economic regimes.

A more detailed analysis of the results is presented in Table 2. The results are clearly in favor of the momentum portfolio, adjusted for corresponding market regimes. Adjusting the portfolio exposure to incorporate a broader set of economic factors positively affects both risk and return of the portfolio, resulting in a significant increase in its Sharpe ratio (0.805 compared to 0.363 of the portfolio with the "speed" factor and 0.129 of the SG Trend Index). For example, the portfolio with the "speed" factor earns a 4.3% p.a. return with an 11.7% p.a. volatility for the sample period, and the portfolio adjusted for the market regimes has a somewhat similar 13.8% p.a. volatility but results in an impressive 11.1% p.a. return over the same period. Interestingly, both the portfolio skewness and kurtosis are also improved in the momentum portfolio adjusted for market regimes.

Table 2. Summary statistics for momentum factor portfolios adjusted for economic regimes.

Ratio	SG Trend Index	"Speed" Factor	Market Regime
Annualized Return	1.4%	4.3%	11.1%
Annualized Std Deviation	10.5%	11.7%	13.8%
Sharpe Ratio	0.129	0.363	0.805
Skewness	−0.674	−0.285	−0.072
Kurtosis	3.130	4.783	2.807
Maximum Drawdown	−23.0%	−25.4%	−24.4%

Overall, the results provide strong evidence of the benefits of adding the market outlook and its volatility to the portfolio construction. Furthermore, it indicates that adjusting the momentum portfolio exposure based on economic regimes increases its return performance and improves its key risk characteristics (e.g., standard deviation, skewness, kurtosis).

Unfortunately, the current sample period (from January 2010 to December 2020) is relatively short. Performing an out-of-sample test would be difficult as part of the data would still have to be withheld for validation purposes. Instead, in order to check if the momentum portfolio performance is robust over time, we constructed a smaller futures portfolio including only 28 futures contracts for which a complete data period is available for a more extended sample period ranging from July 2003 to December 2020. The results are presented in Table A2 (Appendix B) and confirm that the performances of all estimated portfolios' are consistent over this greater extended period and its corresponding market conditions.

We conclude that managed futures strategy's (based on two momentum signals) performance is highly correlated with the economy's state. Therefore, adjusting the strategy based on economic factors and/or volatility can significantly improve managed futures' portfolio performance.

4.3. Portfolio Diversification

Finally, we analyze the benefits of adding a managed futures' exposure to institutional investors' portfolios. Several studies indicate that a long-term correlation between managed futures returns and traditional (i.e., equity and/or bond) investment portfolio returns is low or even negative. Therefore, institutional investors can potentially benefit from increased diversification benefits. This section wants to assess whether those benefits can be found by including our proposed managed futures momentum strategy in their portfolio. We use our estimated portfolio constructed on two "short-term" and "long-term" momentum factors (and adjusted for the economic regimes) as a proxy for an efficient momentum strategy. A "traditional" institutional portfolio is approximated by a 60% long position in the S&P 500 Index and a 40% short position in the Bloomberg Barclays US Aggregate Bond Index.

For the purpose of this analysis, we constructed some investment portfolios with 10% increasing allocations to a managed futures' momentum exposure estimated based on the sample period ranging from January 2010 to December 2020. The analysis starts with the "traditional" portfolio as a benchmark case and adds 10% increments and a long-managed futures' momentum exposure to the portfolio. The results for the constructed portfolios are presented in Figure 7 in an efficient frontier format. It shows that gradually increasing the allocations to momentum exposure has a positive effect on overall portfolio performance initially—it both increases total portfolio returns and decreases its standard deviations of returns.

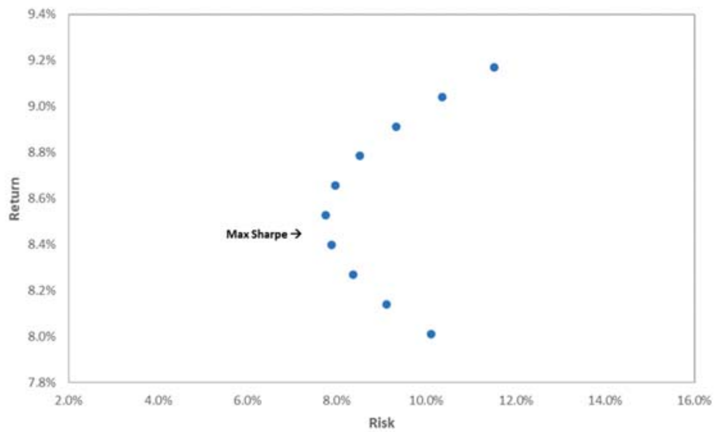

Figure 7. Impact of adding managed futures' momentum strategy exposure to an equity/bond portfolio in 10% increments.

In our sample, the maximum Sharpe ratio (1.101) is achieved for the portfolio with an approximately 40% allocation to the managed futures' momentum strategy and 60% allocation to the traditional equity/bond portfolio. Then, more allocation to managed futures' exposure starts increasing the overall portfolio volatility after this point. However, a pure "traditional" portfolio is still inferior to other investment opportunities, considering the existence of a diversified portfolio on the efficient frontier that has the same standard deviation as a "traditional" portfolio but offers significantly higher returns. The portfolios' summary statistics with different allocation levels to the managed futures' exposure are presented in Table A3 (Appendix C) for further comparison.

Overall, we found the results strongly favoring the diversified portfolio with a managed futures' exposure. We also confirm that managed futures may hedge for extreme events by improving overall portfolio performance during those difficult times.

5. Conclusions

In this paper, we analyze the performance of the managed futures strategy based on momentum signal across different economic regimes, with a particular focus on the COVID-19 pandemic period as a natural experiment of increased uncertainty in the market. We offer a new approach to the momentum strategies because we confirm that using the momentum signals based on different lookback periods can help manage portfolio returns. Moreover, the managed futures momentum strategy is highly dynamic and could be primarily improved if broader macroeconomic variables were added to the analysis. We think that macroeconomic indicators can improve the strategic decision-making process and achieve a higher level of diversification.

Firstly, we used the time-series based on the ATSMOM ("adaptive time-series momentum") factor for managed futures strategy with momentum effect. We compared the created strategy with the benchmark SG Trend Index and found a substantial correlation. Because of the transaction costs, the performance of the ATSMOM factor was slightly worse. Then, we tried to identify different lookback periods: 1–3 months, 3–6 months, 6–9 months, and 9–12 months. The results indicated that the 1–3 month and 9–12 month series were often little or even negatively correlated. Ther economic reasoning for this might be that the "long-term" series is more sensitive to the overall market's general trend.

In contrast, the "short-term" series represented a correcting reversal to mean effect. In scientific literature, it is described as a short-term reversal effect due to investors' overreaction, liquidity issues, institutional behavior, trading frictions, and/or transaction costs. We found this effect present in the futures market was contrary to a long-term momentum; a short-term momentum was negatively correlated with the overall market trend. To evaluate the significance this effect had on the momentum strategy's performance, we constructed an alternative portfolio where the positions with "long-term" momentum were bought (long position). The ones with "short-term" momentum were sold (short position). We revealed that the momentum portfolio with the "speed" factor presents a better investment opportunity as it outperforms the ATSMOM portfolio during the sample period. It should be noted that the "speed" factor also outperformed the SG Trend Index by offering increased returns and the reduced standard deviation of returns.

Secondly, we extended the analysis by comparing the performance of both the "short-term" and "long-term" momentum series across the economic regimes. We found that the correlation between "short-term" and "long term" momentum series increased during periods of financial distress, as "short-term" momentum also started capturing a robust and prominent trend in the market. Despite the fact that the COVID-19 pandemic had a strong impact on financial markets, looking back, we could point out that the negative effects were concise. It gave a valuable insight into momentum strategies' performance during such critical moments as the COVID-19 pandemic. We used a Markov regime-switching model to distinguish between the periods of high and low volatility in the equity market. We used our portfolio with the "speed" factor to incorporate the economic regime's effects into our momentum strategy. We revealed that the momentum portfolio, adjusted for the economic regimes, outperformed an initial "speed" factor portfolio. Both portfolios performed relatively similarly during periods of low volatility, and the "volume-adjusted" momentum portfolio always outperformed the "speed" factor portfolio during high volatility periods. The results provided strong evidence of the benefits of adding the market outlook and its volatility to the portfolio construction. It indicates that adjusting the momentum portfolio exposure based on economic regimes increased its return performance and improved its key risk characteristics. We conclude that managed futures strategy's performance is highly correlated with the economy's state. Therefore, adjusting the strategy based on economic factors and/or volatility can significantly improve managed futures' portfolio performance.

Finally, we analyzed the benefits of adding a managed futures' exposure to institutional investors' portfolios. We used our estimated portfolios constructed on two "short-term" and "long-term" momentum factors and adjusted for the economic regimes to proxy for an efficient momentum strategy. The results showed that gradually increasing the allocations to momentum exposure had a positive effect on overall portfolio performance initially—it both increases total portfolio returns and decreases its standard deviations of returns. Overall, we found the results strongly favored the diversified portfolio with a managed futures' exposure. We also confirm that managed futures may hedge for extreme events by improving overall portfolio performance during those difficult times.

In summary, we confirm that the construction of a portfolio based on academically/economically sound momentum signals and its allocation timing based on broader economic factors and market volatility can significantly improve managed futures strategies and add significant diversification benefits to the investors' portfolios. Some suggested avenues for future research might include using alternative momentum estimates, portfolio construction methods, economic regime factors, or using a more extended sample period to see if this model can still be further developed.

Author Contributions: Conceptualization, R.G. and D.T.; methodology, R.G.; software, R.G.; validation, R.G. and D.T.; formal analysis, R.G. and D.T.; investigation, R.G. and D.T.; resources, R.G. and D.T.; data curation, R.G.; writing—original draft preparation, R.G. and D.T.; writing—review and editing, R.G. and D.T.; visualization, R.G. and D.T.; supervision, D.T. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data across futures markets is available from Tick Data LLC (www.tickdata.com, accessed date: 3 December 2020).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Futures contracts.

Foreign Exchange	Equities	Fixed Income	Commodities
USD/AUD	E-mini Russell 2000	BOBL	Soybean oil
USD/GBP	E-mini S&P 500	BUND	Cocoa
USD/CAD	FTSE 100	BUXL	Crude Oil WTI
Dollar Index	E-mini MidCap 400	SCHATZ	Corn
EUR/USD	Nikkei 225	DAX	Cotton
USD/JPY	E-mini NASDAQ 100	Eurodollar	Feeder cattle
USD/MXN	Swiss Market	US 5-year	Gold
USD/NZD	DJ Euro Stoxx	US 2-year	Copper
EUR/CHF	E-mini Dow	US 10-year	Heating oil
E-mini EUR/USD		US Bond	Frozen orange juice
			Coffee
			Lumber
			Live cattle
			Lean hogs
			Natural gas
			Oat
			Palladium
			Platinum
			E-mini Crude oil
			Sugar
			Soybean meal
			Silver
			Soybeans
			Wheat
			RBOB

Appendix B

Table A2. Summary statistics for portfolios with momentum factors.

Ratio	SG Trend Index	ATSMOM	Market Regime
Annualized Return	3.2%	3.8%	5.6%
Annualized Std Deviation	10.9%	12.3%	14.7%
Sharpe Ratio	0.293	0.312	0.378
Skewness	−0.603	−0.199	0.040
Kurtosis	3.377	3.495	8369
Maximum Drawdown	−22.9%	−25.7%	−40.5%

28 futures contracts: USD/AUD, USD/GBP, USD/CAD, E-mini EUR/USD, USD/JPY, USD/MXN, EUR/CHF, E-mini S&P 500, E-mini NASDAQ 100, E-mini Dow, Euro-dollar, US 2-year, US 5-year, US 10-year, US Bond, Soybean oil, Crude Oil WTI, Corn, Gold, Copper, Heating oil, Natural gas, Palladium, E-mini Crude oil, Soybean meal, Silver, Soybeans, Wheat.

Sample period: from July 2003 to December 2020.

Appendix C

Table A3. Summary statistics for portfolios with 10% increasing allocation to managed futures momentum strategy.

Ratio	100% Bond/Equity	90% Bond/Equity + 10% Managed Futures	80% Bond/Equity + 20% Managed Futures	70% Bond/Equity + 30% Managed Futures	60% Bond/Equity + 40% Managed Futures
Annualized Return	8.0%	8.1%	8.3%	8.4%	8.5%
Annualized Std Deviation	10.1%	9.1%	8.4%	7.9%	7.7%
Sharpe Ratio	0.793	0.892	0.989	1.065	1.101
Skewness	−0.743	−0.628	−0.531	−0.476	−0.453
Kurtosis	19.461	14.572	10.139	7.474	6.801
Maximum Drawdown	−22.3%	−18.5%	−14.6%	−10.6%	−9.7%
Annualized Return	8.7%	8.8%	8.9%	9.0%	9.2%
Annualized Std Deviation	8.0%	8.5%	9.3%	10.4%	11.5%
Sharpe Ratio	1.087	1.032	0.956	0.874	0.796
Skewness	−0.411	−0.308	−0.151	0.026	0.196
Kurtosis	6.801	6.487	6.131	6.266	6.996
Maximum Drawdown	−9.4%	−10.4%	−15.5%	−20.6%	−25.4%

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Do Jumps Matter in Both Equity Market Returns and Integrated Volatility: A Comparison of Asian Developed and Emerging Markets

Hassan Zada [1], Arshad Hassan [1] and Wing-Keung Wong [2,3,4,*]

[1] Department of Management Sciences, Capital University of Science and Technology (CUST), Islamabad 44000, Pakistan; hassanzaada@gmail.com (H.Z.); aarshad.hasan@gmail.com (A.H.)
[2] Department of Finance, Fintech Center, and Big Data Research Center, Asia University, Taichung City 41354, Taiwan
[3] Department of Medical Research, China Medical University, Taichung City 40402, Taiwan
[4] Department of Economics and Finance, The Hang Seng University of Hong Kong, Hong Kong 999077, China
* Correspondence: wong@asia.edu.tw

Abstract: In this paper, we examine whether jumps matter in both equity market returns and integrated volatility. For this purpose, we use the swap variance (SwV) approach to identify monthly jumps and estimated realized volatility in prices for both developed and emerging markets from February 2001 to February 2020. We find that jumps arise in all equity markets; however, emerging markets have more jumps relative to developed markets, and positive jumps are more frequent than negative jumps. In emerging markets, the markets with average volatility earn higher returns during jump periods; however, highly volatile markets earn higher returns during jump periods in developed markets. Furthermore, markets with low continuous returns and high volatility are more adversely affected during periods of negative jumps. The average ratio of jump variations to total variation shows considerable variations due to jumps. Integrated volatility is high during periods of negative jumps, and this pattern is consistent in both developed and emerging markets. Moreover, the peak volatility of stock markets is observed during periods of crises. The implication of this study is useful in the asset pricing model, risk management, and for individual investors and portfolio managers for both developed and emerging markets.

Keywords: jumps identification; swap variance; integrated volatility; realized volatility

JEL Classification: C58; G12; G15; D53; C58

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1. Introduction

Over the past decade, integrated volatility and jumps in asset pricing have attracted particular attention in the literature of finance, and their importance is prominent (Brownlees et al. 2020; Buncic and Gisler 2017). As per the efficient market hypothesis (EMH), the stock market responds to the arrival of new information, leading to changes in returns and volatility of the stock market prices (Duangin et al. 2018). However, sometimes there are abnormal movements or large discontinuous changes in stock prices, which are infrequent but large; these extreme movements are known as jumps, associated with the arrival of unexpected new information (Ferriani and Zoi 2020; Jiang and Zhu 2017; Sun and Gao 2020). Accordingly to Bajgrowicz et al. (2016), jumps are related to macroeconomic news, prescheduled company-specific announcements, and news reports that included a variety of unscheduled and uncategorized events. The vast majority of news does not cause price jumps, but it may give rise to a market reaction in the form of bursts of volatility. Merton (1976) first introduced price jumps in his seminal paper, starting an extensive strand of literature in asset pricing and financial econometrics. Jumps identification has profound implications in risk management, asset pricing, valuation of derivatives, and portfolio allocation (Aït-Sahalia 2004; Bajgrowicz et al. 2016; Brownlees et al. 2020; Odusami 2021; Zhang et al. 2020).

Odusami (2021) stated that it is essential to include jumps in financial models for managing the risk in the portfolio because jumps bring movements in asset prices; therefore, risk premia should be accounting for jumps along with continuous sample path variance. This study has observed asymmetry in the distribution of jumps, with a higher magnitude of negative jumps than positive jumps. The implication of their study is that jump risk is non-diversifiable. Therefore, when pricing assets, investors should account for risk premia, and when selecting policy weights in their portfolios, they should consider the determinants of jump risks. Zhang et al. (2020) documented that in China, most of the listed companies are owned by the state and a limited portion of shares are available for trading in the stock market. Therefore, the Chinese stock market is highly susceptible to speculation. Furthermore, due to the increasing role of domestic and foreign institutions, stock market movements are still primarily driven by noise traders; that is, retail investors. Therefore, more jumps could be expected in emerging markets such as the Chinese stock market than in the developed stock markets.

The importance of jumps is illustrated in some early studies, including by Aït-Sahalia (2004), Aït-Sahalia and Hurd (2015), Amaya and Vasquez (2011), Nguyen and Prokopczuk (2019), Buncic and Gisler (2017), Carr and Wu (2003), Duangin et al. (2018), Dutta et al. (2020), Eraker et al. (2003), Ferriani and Zoi (2020), Jiang and Oomen (2008), Jiang and Yao (2013), Jiang and Zhu (2017), Pan (2002), and Wright and Zhou (2009).

Pan (2002) shows evidence that investors demand a higher risk premium for taking the risk associated with price jumps. Eraker et al. (2003) found strong evidence for jumps in returns and jumps in volatility. Jumps in the volatility model significantly increase implied volatility in the money and out of the money options than models having only jumps in returns. Carr and Wu (2003) state that to understand asset price behavior, it is necessary to determine whether the best model is based on a purely continuous process, a pure jump process, or a combination of both of these two processes. Aït-Sahalia (2004) comments that jumps play an important role in asset returns, diminishing marginal returns, currencies, and interest rates. Moreover, the decomposition of total risk into Brownian and jump components is very useful for portfolio allocation and risk management.

Jiang and Oomen (2008) document that jumps are an essential component of financial asset price dynamics. The arrival of unanticipated news or liquidity shocks often results in substantial and instantaneous revisions in the valuation of financial securities. Wright and Zhou (2009) explained that there is significant evidence of predictability in excess returns on various assets, and some of the predictability may be attributed to time-variation in the distribution of jump risk. They observed that jump risk measures could accurately predict future excess returns of the bond. Furthermore, the coefficient on the jump means it is statistically significant, implying that including jumps can increase the predictability of bond risk premia. The analysis has shown that root mean square prediction error can be reduced to 40% by including the jump mean in the model. Amaya and Vasquez (2011) suggest that positive jumps have a different effect on the future price of stocks than negative jumps. Positive jumps increase the prices of securities, and thus, a risk-averse investor prefers a positive over a negative jump. Therefore, stocks with negative jumps should earn a premium compared to stocks with positive jumps. Jiang and Yao (2013) stated that small and illiquid stocks have higher jump returns and the value premium is accounted for by the jumps. Jiang and Zhu (2017) using jumps as a proxy of informational shocks relaxed the requirements of planned event dates; therefore, they are not strictly related to events that are announced publicly. Jumps carry information that is beyond specific planned corporate events and bring large discontinued changes in the prices. Corradi et al. (2018) argued that considering the jump behavior improves the conditional variance forecasts of returns. Ferriani and Zoi (2020) noted that during phlegmatic market conditions, the relative contribution of jumps to total price variance is higher than during times of stress. Dutta et al. (2020) tested the presence of jumps in

OVX and explored their role to predict crude oil price volatility. According to the findings, OVX has a jump behavior that varies over time. They warrant investors, policymakers, and academics accounting for the presence of jumps to develop more accurate asset pricing models and volatility prediction methods.

Baker et al. (2020) explored the possible explanations for the stock market's unusual reaction to the COVID-19 pandemic. Previous pandemics had a very mild impact on the US stock market, whereas the COVID-19 pandemic has had a much more substantial impact on the stock market than previous pandemics such as the Spanish flu. The evidence suggests that government restrictions on commercial activity and voluntary social distancing, operating with powerful effects in a service-oriented economy, are the primary reasons that the US stock market reacted so strongly to COVID-19 than to the previous pandemic. Sharif et al. (2020) examined the relationship between COVID-19, oil price volatility shock, the stock market, geopolitical risk, and economic policy uncertainty using the coherence wavelet method and wavelet-based Granger causality tests. It is found from the analysis that COVID-19 and oil price shocks have an impact on geopolitical risk levels, economic policy uncertainty, and stock market volatility over low-frequency bands.

Apergis and Apergis (2020) analyzed the impact of the COVID-19 pandemic on the returns and volatility of the Chinese stock market. For COVID-19, they used two proxies: the total confirmed cases and the total daily deaths. The analysis shows that COVID-19, as measured by two different proxies, has a significant negative impact on stock returns; however, when total deaths are used as a proxy, the negative impact on stock returns is more pronounced. COVID-19, on the other hand, has a positive and statistically significant effect on the volatility. The findings are important for understanding the stock market implications of the COVID-19 pandemic. Uddin et al. (2021) studied the impact of the COVID-19 pandemic on stock market volatility to see if economic strength could help mitigate the negative effects of the global pandemic. According to the findings, country-level economic characteristics and factors help to mitigate the volatility caused by the pandemic. Based on economic factors, policymakers may devise policies to combat stock market volatility and avoid financial crises in the future. Empirical results of Kostrzewski and Kostrzewska (2021) indicate that a model with a time-varying jump intensity and a jump prediction mechanism is useful in forecasting.

A comprehensive study is needed to cover the existing gap in the literature related to the jump studies. As stated by Kongsilp and Mateus (2017), most existing studies on jump behavior are based on the developed market, whereas Zhang et al. (2020) stated that there are very few studies on jump behavior in the emerging market. We have conducted this study to cover the gap; first, by identifying jumps in Asian developed and emerging markets and to compare both markets. Second, to study asymmetric behaviour of positive and negative jumps in returns of Asian developed and emerging markets and to compare both markets. Third, to study asymmetric behavior of positive and negative jumps in integrated volatility of Asian emerging and developed markets and to compare their results.

This study aims to examine whether jumps matter in equity market returns and integrated volatility in the context of Asian developed and emerging equity markets.

The contribution of this paper is as follows. First, we apply the swap variance (SwV) test developed by Jiang and Oomen (2008) to identify monthly jumps in Asian developed markets and Asian emerging markets. The SwV test is similar in purpose to the bi-power variation (BPV) test developed by Barndorff-Nielsen and Shephard (2006) but with different logic and properties. The BPV test identifies jumps by comparing RV to a jump robust variance measure. In contrast, the SwV test identifies jumps by comparing RV to a jump-sensitive variance measure involving higher-order moments of returns, making it more powerful in many circumstances. Moreover, the SwV jump test explicitly considers market microstructure noise and can be applied to daily data (Jiang and Oomen 2008; Jiang and Zhu 2017). Second, we examine the role of positive jumps and negative jumps in equity returns individually and collectively. Third, we identify the role of positive and negative jumps in integrated volatility separately and jointly. The study further provides insight into the varying dynamics of jumps in developed and emerging markets of Asia. The findings in our study provide insights to academics, practitioners, and policymakers on the asymmetric effect of jumps in equity market returns and integrated volatility in the context of developed and emerging markets.

The rest of the paper is organized as follows. Section 2 is a methodological review of the swap variance jump, Section 3 explains the theory, Section 4 describes the data and methodology, Section 5 provides empirical results and findings, Section 6 discusses the results with previous studies, whereas Section 7 concludes the study and provides future directions.

2. Methodological Review of Swap Variance Jump

Andersen et al. (2001, 2003b) proposed realized volatility (RV). RV is a model-free and error-free estimator of integrated volatility in the absence of noise and jumps. Barndorff-Nielsen and Shephard (2003) extended RV and introduced a generalized form of realized volatility known as realized power variation (RPV). Based on RPV, Barndorff-Nielsen and Shephard (2004) introduce realized bi-power variation (BPV), which is a partial generalization of quadratic variation. BPV has the same robustness property as RPV. However, BPV also estimates the integrated variance in stochastic volatility models. In this way, BPV provides a model-free and consistent alternative to realized variance. Barndorff-Nielsen and Shephard (2004) also introduced the generalized form of bi-power variation called tri-power variation (TPV). BPV was an unbiased estimator of integrated volatility in the presence of jumps, but it is subject to an upward bias in a finite sample. TPV is more efficient than BPV but also more vulnerable to market microstructure noise of high-frequency data.

Eraker et al. (2003) developed a likelihood-based estimation method and analyzed jumps in returns and jumps in volatility in the S&P 500 and Nasdaq 100 index. Empirics shows strong evidence for jumps in returns and jumps in volatility. Andersen et al. (2003a) developed a non-parametric technique to measure continuous sample path variation and discontinuous (the jump part) of a quadratic variation process separately. It was found that the jump component is less persistent than the continuous sample path. The coefficient of the jump component is highly significant in daily, weekly, and quarterly forecast horizons. This study shows that financial asset allocation, risk management, and derivatives pricing can be improved by separating the model for continuous and jump components.

Carr and Wu (2003) argued that it is essential to know whether it is the best model by using a purely continuous model, a pure jump process, or a combination of both of these two processes to understand asset prices' behavior. They developed a method to differentiate between these processes. They examined these processes using market prices of at-the-money (ATM) and out-of-the-money (OTM) options as the option maturity date approaches the valuation date. The speed of convergence varies across these possibilities when ATM and OTM options prices converge to zero as the maturity date approaches zero. They identified the type of asset price process by examining the convergence speed of the option prices. In a continuous process, there are low chances that the underlying asset prices will jump by a large amount over a short time interval. So there is a small possibility that the OTM option will move in the money. Whereas, in the jump process, there are high chances that the underlying asset prices can jump into the money in a short period. The behavior of these two types of processes is different for option prices in the short term because these two processes are difficult to distinguish from a discretely sampled path.

Johannes (2004) explores the statistical and economic role of jumps in continuous-time interest rate models. The results show that jumps are substantial both economically and statistically. Statistically, the presence of jumps means that models of diffusion are misspecified. Diffusion models ignore jumps and are incorrectly specified because the tail behavior of interest rate changes cannot be accurately captured. To quantify the statistical role of jumps in interest rates, he proposed and estimated a non-parametric jump-diffusion model.

Aït-Sahalia (2004) uses maximum likelihood statistical-based methods to disentangle volatility from jumps accurately. He decomposes total noise into a continuous Brownian part and a discontinuous jump part. The Levy process is the sum of three independent Levy processes, which are a continuous component (Brownian motion), a component of big jumps in the form of a compound Poisson process with jump size larger than one, and a component of small jumps in the form of a pure martingale jump with jump size smaller than one. In this paper, Aït-Sahalia separated the Brownian component from the big jumps component and disentangled the Brownian component from the small jumps components.

Barndorff-Nielsen and Shephard (2004) concluded that the probability limit of the bi-power estimator does not change by adding jumps to the SV model, meaning that realized variance can be combined with realized bi-power variation to estimate the quadratic variation of the jump component (the difference between realized variance and realized bi-power variation). This method separates quadratic variation into its continuous and jump components. Barndorff-Nielsen and Shephard (2006) propose two tests of jumps identification. One is the difference, and the second measure is the ratio of realized BPV and realized quadratic variation. They build the jump test on the idea of bi-power variation (BPV) provided by Barndorff-Nielsen and Shephard (2004) and Back (1991) that the sum of squared returns, a measure of variations in asset prices, is based on the quadratic variation process.

Lee and Mykland (2008) proposed a jump detection technique and conducted an empirical study on US equity markets. It found that more frequent jumps are observed in individual equity returns, and their size is larger than the index returns. In individual stocks, jumps are associated with company-specific news, i.e., scheduled earnings announcements and unscheduled news. Therefore, with earnings announcements, other firm-specific news is to be incorporated for option pricing. Whereas in the index, jumps occur because of general market news, i.e., Federal Open Market Committee (FOMC) meetings and macroeconomic reports. Therefore, general market news is to be incorporated for index options.

Jiang and Oomen (2008) established a non-parametric test to identify jumps in stock prices, known as the swap-variance (SwV) approach. They built their test from the concept of Neuberger's (1994) variance swap replication strategy—a short position in the log contract plus a continuously rebalanced long position in the swap contract. The profit/loss of such a replication strategy will accumulate to an amount proportional to the variance realized (RV) and, as such, allows the swap contract to be perfectly replicated. Such a strategy fails, though, with jumps, and the realized jumps fully determine the replication error. The accumulated difference between simple returns and log returns is calculated—a quantity called "swap variance"—and compared to RV.

The difference will be indistinguishable from zero when jumps are absent, but when jumps are present, it will reflect the variance swap replication error, which in turn, lends its power to detect jumps. This test is similar in purpose to Barndorff-Nielsen and Shephard's (2006) bi-power variation test, but with different underlying logic and properties. By contrasting RV to a jump robust variance measure, the BPV test identifies jumps. By comparing RV to a jump-sensitive variance measure involving higher-order moments of return, the SwV test identifies jumps, making it more powerful in many circumstances. They conducted extensive simulations to examine the performance of the SwV test and compared their results with the bi-power variation test. The results indicate that the SwV jump test performs well and is a useful addition to the bi-power variation test.

3. Theory

This study uses the theory of efficient capital market theory developed by Fama (1970) and others to explain three types of efficiency, namely, the weak form, the semi-strong form, and the strong form of efficiency known as the efficient market hypothesis (EMH). It states that security prices fully reflect all relevant information, eliminating arbitrage opportunities and bringing stock markets towards efficiency. The weak form of efficiency states that investors cannot earn an excess return based on past prices, returns, and trading volumes. In the semi-strong form of efficiency, the relevant information is publicly available information which states that investors cannot earn an excess return on information based on annual reports and news from media. In a strong form of efficiency, both past information and publicly available information are irrelevant for investors to earn excess returns.

There are, however, abnormal movements or large discontinuous changes in empirical stock analysis that are infrequent but large; these extreme movements are known as jumps and associated with the arrival of unexpected new information. (Ferriani and Zoi 2020; Jiang and Zhu 2017; Sun and Gao 2020). Jiang and Zhu (2017) define stock price jumps as a proxy of large information shocks, and large discontinued changes in stock prices called jumps or stock price jumps.

There are several advantages to using stock price jumps as a proxy for large information shocks; for example, studies on corporate events require event dates. The approach of using stock price jumps as a proxy for large information shocks, on the other hand, relaxes the requirements of event dates and is not limited to only publicly announced events. Private information, such as insider trading, can cause stock price changes. Jumps capture all types of information, whether it is public or private (Jiang and Oomen 2008; Jiang and Yao 2013; Jiang and Zhu 2017).

4. Data and Methodology

4.1. Data

We use the daily data of four developed and six emerging equity markets of Asia from February 2001 to February 2020. The Asian developed markets include Australia (S&P ASX), Hong Kong (Hang Seng index), Japan (Nikkei225 index), and New Zealand (NZX 50 index). Moreover, the emerging Asian equity markets include China (Shanghai Composite index), India (Nifty 50 index), Indonesia (JKSE index), Pakistan (KSE-100 index), Thailand (SET Index), and Sri Lanka (CSE All index). We use the Morgan Stanley Capital International (MSCI) classification to segregate the developed and emerging markets. The data of these equity indices are taken from the Thomson Reuters DataStream.

4.2. Methodology

There are various methods to identify statistically significant jumps. The methods can be grouped into five categories: first, jump tests based on bi-power variation include the tests developed by Andersen et al. (2007, 2012), Barndorff-Nielsen and Shephard (2004, 2006), Corsi et al. (2010), and Huang and Tauchen (2005); second, techniques based on higher-order variation include the techniques developed by Aït-Sahalia and Jacod (2009) and Podolskij and Ziggel (2010); third, jump tests based on returns include the tests developed by Lee and Hannig (2010) and Lee and Mykland (2008); fourth, tests based on swap variance include tests developed by Jiang and Oomen (2008); fifth, jump tests that mitigate the impact of microstructure noise include the tests developed by Aït-Sahalia and Jacod (2012) and Lee and Mykland (2012).

In this study, the jumps are estimated through the swap variance (SwV) jump identification method proposed by Jiang and Oomen (2008). The jump test statistic, J_t, at time t is given in the following equation under the null hypothesis of no jump:

$$J_t = \frac{BPV_t}{M^{-1}\sqrt{\hat{\Omega}_{SwV}}}\left(\frac{1 - RV_t}{SwV_t}\right), \tag{1}$$

where J_t is Jiang and Oomen (2008) swap variance jump test statistics and RV_t is the realized variance (Andersen et al. 2001), a measure of total volatility in asset prices calculated by summing daily squared returns filtered through an MA (1) process, that can be estimated by the following equation:

$$RV_t = \sum_{i=1}^{M-1} (r_i)^2, \tag{2}$$

where RV_t is monthly realized volatility and r_i is the daily logarithmic return, and BPV_t is the realized bi-power variation developed by Barndorff-Nielsen and Shephard (2004) to capture the continuous component of total variation, and is calculated as:

$$BPV_t = \frac{\pi}{2}\left(\frac{M}{M-1}\right)\sum_{i=2}^{M}|r_i|\,|r_{i-1}|, \quad (3)$$

where BPV_t is the monthly bi-power variation and SwV_t is swap variance and calculated as follows:

$$SwV_t = 2\sum_{i=1}^{M}(R_i - r_i), \quad (4)$$

where SwV_t is the monthly swap variance, R_i is simple return, and $\hat{\Omega}_{SwV}$ is estimated by the following equation:

$$\hat{\Omega}_{SwV} = \frac{\mu_6}{9}\,\mu_{6/4}{}^{-4}\frac{M^3}{M-3}\sum_{i=1}^{M}\prod_{k=0}^{3}|r_{i-k}|^{3/2}, \quad (5)$$

in which the value of $\frac{\mu_6}{9}\,\mu_{6/4}{}^{-4}$ = 3.05 (Maneesoonthorn et al. 2020), M is the number of equity market price observations per month with 22 observations per month, and r_i denotes the logarithmic returns of equity market prices.

In addition, the total numbers of months having total jumps, and positive and negative jumps are given as follow:

$$\text{Number of days having jumps} = \sum_{i=1}^{T}(|Jt| > c_\propto)\,, \quad (6)$$

$$\text{Number of positive jumps days} = \sum_{i=1}^{T}(\,Jt > c_\propto), \quad (7)$$

$$\text{Number of negative jumps days} = \sum_{i=1}^{T}(Jt < -c_\propto), \quad (8)$$

where $c_\propto$ is the critical value at the 5% significance level, which is 1.645 and the percentage of the month having jumps relative to the total number of the months is computed as under:

$$\text{Percentage of months having jumps} = \frac{\text{Number of jump days}}{\text{Total number of days}} * 100. \quad (9)$$

We note that the estimated value of J_t being greater than 1.645 indicates the presence of jumps at a significance level of 5%.

4.3. Integrated Volatility Due to Jump Component

Barndorff-Nielsen and Shephard (2004, 2006) developed robust jump estimators to capture only the continuous component of quadratic variation known as realized bi-power variation (BPV) and tri-power variation (TPV). BPV is an unbiased estimator of integrated volatility in the presence of jumps, but it is subject to an upward bias in a finite sample. Thereby, TPV is more efficient than BPV. Since RV estimates both continuous and discontinuous (jump) components of quadratic variation, while BPV and TPV capture only the continuous component, the jump component can be identified simply by the difference of RV and BPV (Barndorff-Nielsen and Shephard 2004, 2006), or RV and TPV (Andersen et al. 2007).

This study uses the method developed by Andersen et al. (2007) to separate the variation due to the monthly jump component and the continuous components by using volatility measures RV and tri-power variation (TPV). Variations due to the jump component are estimated as follows:

$$JV_t = RV_t - TPV_t, \tag{10}$$

where tri-power variation (TPV) is given as follows:

$$TPV_t = \left(2^{\frac{1}{3}} \frac{\gamma\left(\frac{5}{6}\right)}{\gamma\left(\frac{1}{2}\right)}\right)^{-3} \sum_{i=3}^{M-1} |r_i|^{2/3} \, |r_{i-1}|^{2/3} |r_{i-2}|^{\frac{2}{3}}. \tag{11}$$

The ratio of jump variation to total variation is calculated as:

$$\text{The ratio of jump variation to total variations} = \frac{JV_t}{RV_t}. \tag{12}$$

4.4. Hypotheses

The hypotheses of this study are:

Hypothesis 1. *Jumps occur more frequently in emerging markets as compared to developed markets.*

Hypothesis 2. *Returns during positive jumps periods are larger than returns during non-jump periods and more pronounced in emerging markets as compared to developing markets.*

Hypothesis 3. *Integrated volatility during the negative jumps period is larger than integrated volatility during the positive jumps period and this pattern is more pronounced in emerging markets than developed markets.*

Hypothesis 4. *Total realized volatility consists of a significant portion of jump volatility.*

5. Empirical Analysis

Table 1 shows the number of months in which jumps have been identified. In the developed markets, it is observed that the Hang Seng index has the maximum number of jumps. The jumps have been identified in 71 months out of 229 months being studied, including 43 positive jumps and 28 negative jumps. Furthermore, the minimum number of jumps in the developed markets are identified in NZX50, which are in 56 months out of a total of 229 months. In these 56 months, 33 months have positive jumps, whereas 23 months have negative jumps.

In the emerging markets, the maximum number of jumps are identified in the CSE All index, which has jumps in 100 months with 63 positive jumps and 37 negative jumps. However, the minimum number of jumps is 63 for the Nifty50 index, including 40 positive jumps and 23 negative jumps.

It is concluded from Table 1 that, on average, the developed markets have fewer jumps as compared with the emerging markets. Similarly, positive and negative jumps also arise more frequently in the emerging markets in comparison with the developed markets. Furthermore, on average, the tendency of a larger number of positive jumps relative to negative jumps occurs in both developed and emerging markets.

The possible justifications of the occurrence of more jumps in the emerging markets relative to the developed markets could be the riskier and more volatile nature of the emerging markets due to political instability, poor corporate governance, thin structure of the markets, lack of liquidity, high inflation rate, deflation or currency devaluations, interest rate risk, and high cross-border cash flows. All these factors hurt the economy and make the stock markets highly volatile, which leads to an increase in the tendency of jumps.

Table 1. Number of monthly jumps (provides the percentage and the number of months having SwV jump at α = 0.05 significance level).

Markets	Overall Jumps		Positive Jumps		Negative Jumps	
	Number of Jumps	Percentage of Jumps	Number of Jumps	Percentage of Jumps	Number of Jumps	Percentage of Jumps
S&P ASX 200	62	27.0742%	33	14.4105%	29	12.6638%
Hang Seng	71	31.0044%	43	18.7773%	28	12.2271%
Nikkei225	56	24.4542%	33	14.4105%	23	10.0437%
NZX 50	58	25.3275%	32	13.9738%	26	11.3537%
Shanghai Compo	93	40.6114%	41	17.9039%	52	22.7074%
Nifty50	63	27.5109%	40	17.4673%	23	10.0437%
JKSE	67	29.2576%	41	17.9039%	26	11.3537%
KSE-100	73	31.8777%	56	24.4542%	17	7.4236%
SET Index	77	33.6245%	49	21.3974%	28	12.2271%
CSE All	100	43.6681%	63	27.5109%	37	16.1572%

The number of months with jumps, as identified in Table 1, is exhibited in the scatter plot (Figure 1), showing the total number of jumps, positive jumps, and negative jumps for all equity markets in the sample period from February 2001 to February 2020. It is reflected in Table 1 that the magnitude of some jumps is big whereas small for others. We set a cutoff point of +3 standard deviation and −3 standard deviation to distinguish small or average size jumps from big jumps. A jump with a magnitude greater than +3 standard deviation is considered a big positive jump. A jump with a magnitude between zero and +3 is considered a positive small or average size jump. Similarly, a jump with a magnitude less than −3 standard deviation is considered a big negative jump. A jump with a magnitude between zero and −3 is considered a negative average size or small jump.

It is observed from Figure 1 that in the context of developed markets, on average, the magnitude of big negative jumps is larger than the magnitude of big positive jumps. The same pattern is also observed for emerging markets as well. However, this pattern is much higher in emerging markets as compared with developed markets.

When considering small size jumps, we do not observe much of a difference in the magnitude of negative and positive jumps in the context of developed markets. However, on average, the magnitude of small negative jumps is slightly on the higher side of the small positive jumps in emerging markets.

This means that investors considered negative information more deeply than positive information. However, the depth of feeling is on the higher side in emerging markets. It may be due to the lack of confidence of investors in the information that may cause overreaction to negative information.

Table 2 presents descriptive statistics of continuous returns (r), returns during jump periods (Jr), returns during positive jump periods (Pjr), and returns during negative jump periods (Njr) for all of the equity markets.

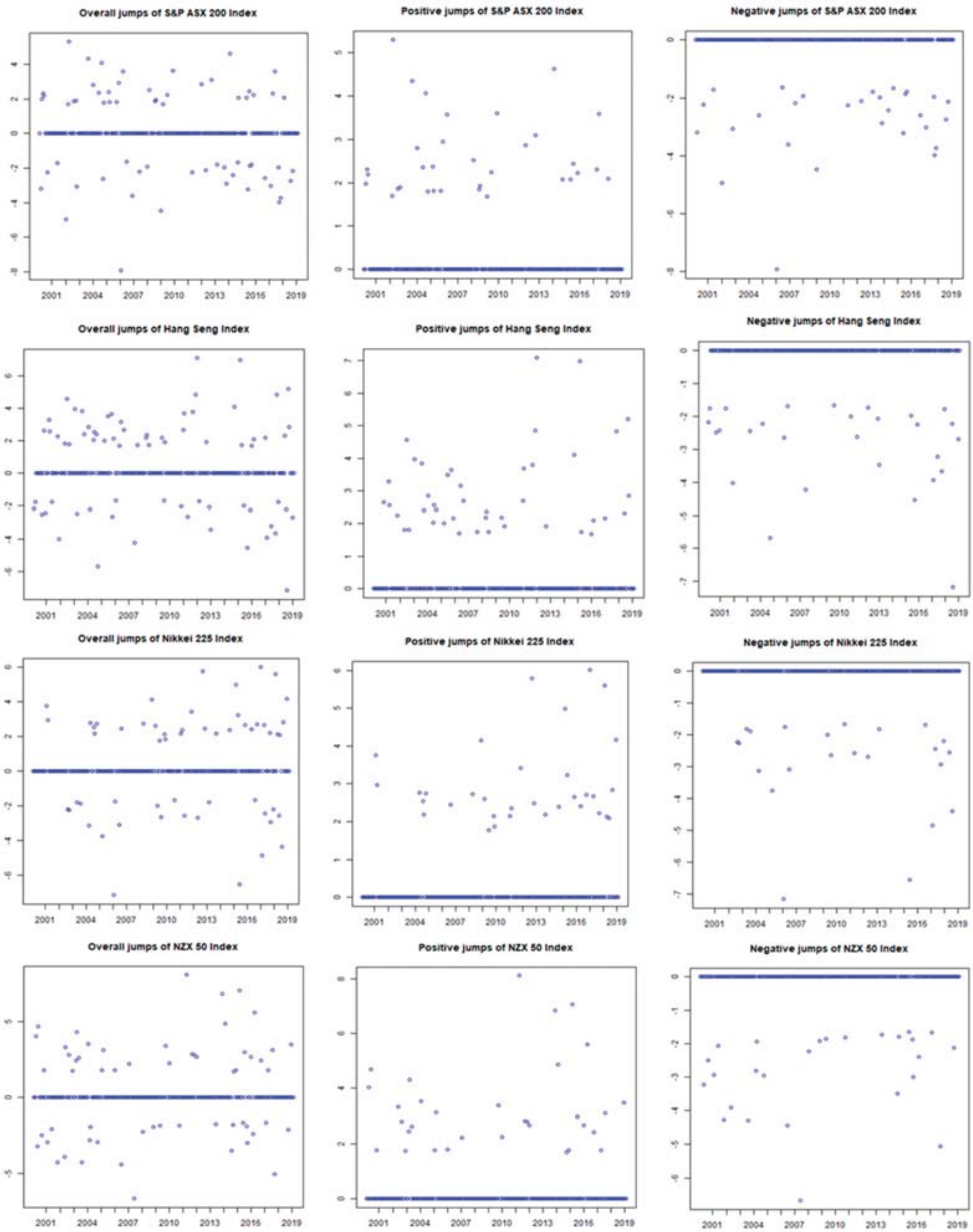

Figure 1. *Cont*.

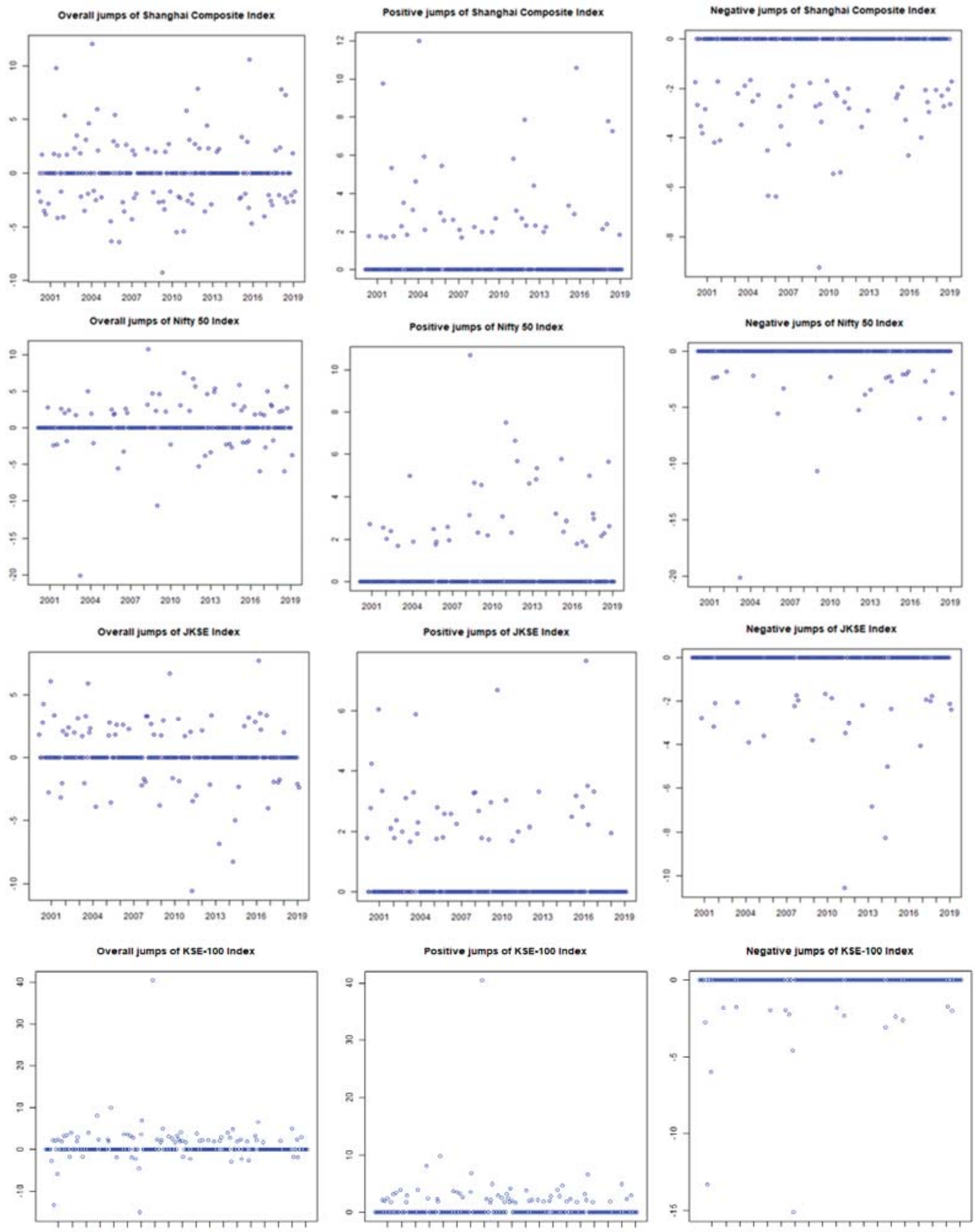

Figure 1. *Cont*.

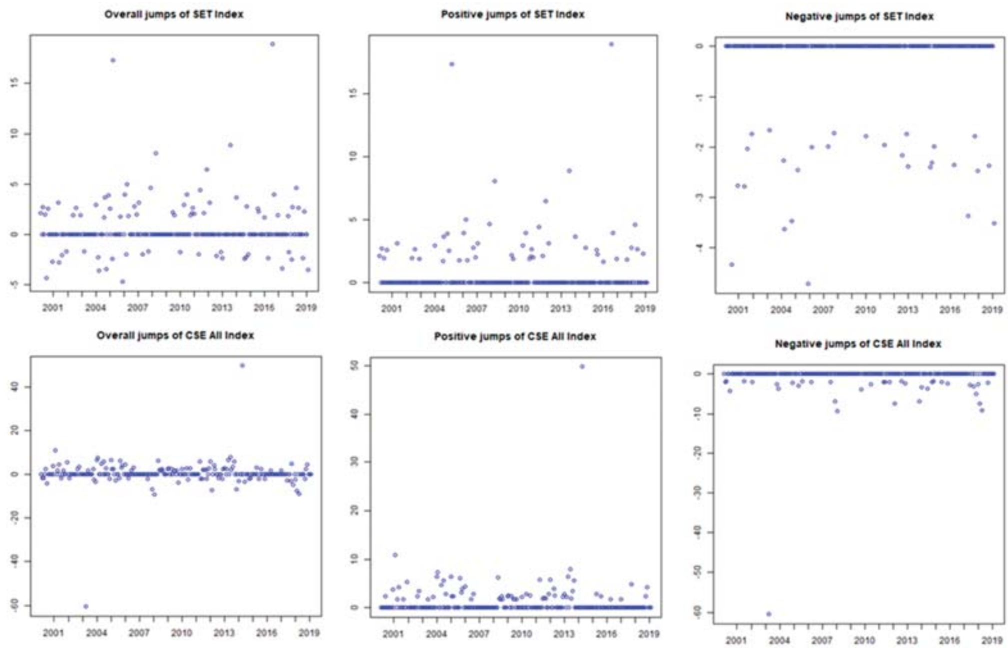

Figure 1. Number of months identified as having jumps.

Table 2 shows in developed markets, the NZX50 has earned higher continuous returns per month with minimum spread indicated by standard deviation, minimum, and maximum values followed by the S&P ASX 200, so these markets are the most attractive for risk-averse investors. In comparison, the Nikkei225 has the lowest monthly continuous returns, followed by the Hang Seng with maximum spread indicated by standard deviation, minimum, and maximum values. Therefore, these markets are more volatile. For average returns during jump periods and average returns during positive jump periods, the Hang Seng and the Nikkei225 have the highest average returns per month, with maximum spread shown by standard deviation, minimum, and maximum values. Therefore, these markets are the most attractive markets for risk-taking investors. Whereas the NZX50 and the S&P ASX 200 have the lowest returns during jump periods and lowest returns during positive jump periods with maximum spread indicated by standard deviation, minimum, and maximum values. It is observed from Table 2 that more volatile markets tend to earn larger jumps-based returns relative to less volatile markets. Furthermore, returns during positive jump periods are higher for a more volatile market than less volatile markets. Therefore, forecasting positive jumps plays an essential role for investors to earn larger returns. However, returns of more volatile markets like the Hang Seng and Nikkei225 are also more affected during negative jump periods relative to less volatile markets like the NZX50 and S&P ASX. It is worth noting that among volatile markets, a market having low returns is much more vulnerable to negative jumps.

In emerging markets, the KSE-100, Shanghai composite, and SET index are more volatile markets (as measured by the standard deviation of continuous returns) relative to others. The Shanghai Composite has the lowest continuous return, and the KSE-100 has the largest continuous return per month. In emerging markets, returns during jump periods behave differently as compared with developed markets. In the context of emerging markets, a market with average volatility and average continuous return earns the highest return during positive jump periods. Its returns are the least vulnerable during negative jump periods, i.e., the Nifty50 index. However, highly volatile markets tend to earn high returns during positive jump periods, i.e., the Shanghai Composite and KSE-100. However, highly volatile markets with high continuous returns are less vulnerable to negative jumps, i.e., the KSE-100. In contrast, highly volatile markets with the lowest continuous returns are highly vulnerable to negative jumps, i.e., the Shanghai composite.

The results of Table 2 provide important insights to the investors in developed and emerging markets to earn the highest returns during jump periods. Investors can earn the highest returns during jump periods by investing in more volatile markets in developed markets. Investors in emerging markets can earn the highest returns during jump periods by investing in averagely volatile markets.

Table 2. Descriptive statistics of the returns based on the SwV jump test for February 2001–February 2020.

Stock Markets	Jumps	Returns	Mean	Standard Deviation	Minimum	Maximum	Kurtosis	Skewness
S&P ASX 200	229	r	0.2519%	3.7637%	−18.0921%	9.7966%	2.2341	−0.9340
	62	Jr	0.5962%	4.2143%	−8.2234%	9.7263%	−0.7757	−0.3974
	33	Pjr	3.9866%	1.5751%	1.3901%	9.7263%	4.2457	1.4491
	25	Njr	−3.8613%	2.3048%	−8.2234%	−0.6418%	−1.0920	−0.3721
Hang Seng	229	r	0.1648%	5.8401%	−25.4455%	16.6256%	1.5706	−0.5375
	71	Jr	1.0020%	6.8924%	−14.8779%	15.7634%	−0.5823	−0.3384
	41	Pjr	5.9185%	3.2722%	1.5408%	15.7634%	1.2686	1.1281
	24	Njr	−6.7389%	3.0099%	−12.0998%	−2.2885%	−0.8648	−0.4476
Nikkei225	229	r	0.1477%	5.4474%	−28.1743%	13.2974%	2.4333	−0.8873
	56	Jr	0.8550%	6.0037%	−12.3916%	9.8655%	−0.6433	−0.5415
	32	Pjr	5.0995%	2.6530%	0.5388%	9.8655%	−0.8728	0.2364
	20	Njr	−5.7888%	3.7833%	−12.3916%	−0.1800%	−1.1042	−0.1636
NZX 50	229	r	0.6997%	3.3810%	−14.3129%	8.3074%	3.0201	−1.1127
	58	Jr	0.3917%	4.6059%	−12.6177%	8.3074%	0.4805	−0.7939
	31	Pjr	3.6863%	1.9506%	0.8938%	8.3074%	−0.2181	0.7173
	23	Njr	−4.0523%	3.5320%	−12.6177%	−0.1199%	0.6248	−1.1078
Shanghai Compos-ite	229	r	0.0815%	7.6954%	−28.2779%	24.1212%	1.8611	−0.5456
	93	Jr	−0.6212%	8.6095%	−25.6813%	24.1212%	1.2331	−0.2843
	38	Pjr	6.8995%	5.1041%	0.6321%	24.1212%	2.4278	1.4328
	47	Njr	−7.0862%	5.9507%	−25.6813%	−0.0324%	3.5054	−1.8611
Nifty 50	229	r	0.6610%	6.5050%	−31.4173%	24.7376%	3.2013	−0.6929
	63	Jr	2.7033%	7.1416%	−10.8108%	24.7376%	0.1439	0.1544
	39	Pjr	7.1890%	4.5174%	1.4348%	24.7376%	4.7044	1.5993
	21	Njr	−5.5176%	2.8865%	−10.8108%	−0.7725%	−0.2593	−0.2174
JKSE	229	r	0.9897%	5.8087%	−37.7197%	16.4299%	8.2715	−1.2736
	67	Jr	1.6460%	8.0112%	−37.7197%	16.4299%	7.5832	−1.7574
	39	Pjr	6.4671%	3.9302%	0.9253%	16.4299%	−0.5821	0.6120
	23	Njr	−6.2394%	7.6569%	−37.7197%	−0.2483%	13.7363	−3.3510
KSE−100	229	r	1.3069%	7.0634%	−44.8796%	26.8315%	8.3751	−1.1923
	73	Jr	3.9030%	7.0027%	−13.7559%	26.8315%	1.4439	0.1171
	54	Pjr	6.8973%	4.9518%	0.0459%	26.8315%	4.6486	1.8307
	15	Njr	−5.9510%	3.9652%	−13.7559%	−0.3821%	−0.5902	−0.5639
SET Index	229	r	0.4797%	5.9841%	−35.5678%	18.5915%	5.9222	−1.1025
	77	Jr	1.4052%	7.4367%	−35.5678%	18.5915%	7.0311	−1.5479
	47	Pjr	5.7665%	3.6945%	0.6036%	18.5915%	2.4544	1.5202
	26	Njr	−6.2224%	6.7966%	−35.5678%	−0.1218%	14.4451	−3.3977
CSE All	229	r	1.0549%	6.3166%	−16.6467%	22.6313%	1.4662	0.5101
	100	Jr	2.5260%	6.4478%	−16.6467%	20.6752%	0.5568	0.1856
	61	Pjr	6.3874%	4.6555%	0.3663%	20.6752%	0.8148	1.0713
	34	Njr	−4.1298%	3.3944%	−16.6467%	−0.5441%	4.6596	−1.9423

Notes: There were some months in which positive jumps occurred, but the average monthly returns were negative, and some months in which negative jumps occurred but the average monthly returns were positive. All those jumps are excluded in descriptive stats. The descriptive in Table 2 shows only positive returns due to the positive jump component and negative returns due to the negative jump component.

Table 3 summarizes integrated volatility, estimated using three volatility measures RV (measures total volatility), BPV (measures continuous component of quadratic variation), and TPV (also measures continuous component of quadratic variation). The mean, standard deviation, minimum and maximum values are all in terms of 10^{-3}. It is observed from Table 3 that in terms of total realized volatility, the Nikkei225 and Hang Seng are more volatile markets among the developed market. Whereas among emerging markets, the Shanghai Composite shows maximum price fluctuations because it shows the highest average values of total integrated volatility. The SET index is the least volatile as its mean value of total integrated volatility is the lowest among all emerging markets. On average, emerging markets show higher integrated volatility than developed markets.

TPV is a better estimation technique of continuous components of quadratic variation than BPV as it understates the average integrated volatility and has the minimum standard deviation. This pattern is consistent across all markets. So jump-based volatility can be better estimated by the difference between RV and TPV.

Table 3. Descriptive statistics of integrated volatility measures: sample period February 2001–February 2020 (gives the descriptive statistics of integrated volatility measures. Mean, standard deviation, min, and max values are all in terms of 10^{-3}).

Stock Markets	Volatility Measures	Mean	Standard Deviation	Minimum	Maximum	Kurtosis	Skewness
S&P ASX 200	RV	1.4529	1.0798	0.3504	5.8022	2.6574	1.6117
	BPV	1.3487	1.0277	0.2972	6.0158	3.8336	1.7818
	TPV	1.1553	0.8899	0.2314	5.3050	3.6988	1.7786
Hang Seng	RV	2.9317	2.1556	0.7857	11.0237	3.3522	1.8495
	BPV	2.5073	1.9507	0.5426	9.1724	2.1121	1.6347
	TPV	2.1091	1.6157	0.4468	8.1189	1.6944	1.5100
Nikkei225	RV	3.4247	2.2574	0.7966	11.9135	1.7765	1.3347
	BPV	2.9765	1.9456	0.6879	10.3380	1.2428	1.2221
	TPV	2.4844	1.6604	0.5497	7.7575	0.7183	1.1457
NZX 50	RV	0.7701	0.4649	0.2971	2.2417	1.3827	1.4432
	BPV	0.7297	0.4296	0.2327	2.1032	1.3560	1.3851
	TPV	0.6335	0.3801	0.1796	1.9327	2.3059	1.5606
Shanghai Composite	RV	3.9949	3.5074	0.7680	17.2122	3.3589	1.8907
	BPV	3.3525	3.1388	0.6017	14.9277	3.2916	1.9231
	TPV	2.8382	2.6639	0.5087	12.3048	2.7118	1.8095
Nifty50	RV	2.8283	2.3282	0.6211	13.4125	4.5987	2.0518
	BPV	2.5720	2.2265	0.5642	11.7466	3.7416	1.9675
	TPV	2.1730	1.9485	0.4271	10.0456	4.5098	2.0855
JKSE	RV	2.5999	1.9488	0.5215	9.0865	1.8538	1.5339
	BPV	2.3813	1.8998	0.4648	9.5842	2.7272	1.7110
	TPV	1.9888	1.5631	0.3861	7.9878	2.2781	1.5908
KSE-100	RV	2.5977	2.0689	0.4544	10.7500	3.3322	1.7166
	BPV	2.4521	2.2364	0.4140	12.3546	5.5840	2.2072
	TPV	2.0947	2.0537	0.3541	11.6393	6.9485	2.4353
SET Index	RV	2.3601	1.7509	0.4492	7.7646	0.9081	1.2198
	BPV	2.0880	1.6596	0.3018	8.2530	1.8726	1.4467
	TPV	1.7931	1.5607	0.2368	7.8282	2.6481	1.6559
CSE All	RV	1.4006	1.5549	0.1686	8.2032	5.8931	2.3293
	BPV	1.2959	1.4847	0.1510	8.1328	6.8381	2.3862
	TPV	1.0759	1.2836	0.1110	6.9735	6.9342	2.4332

To get a clearer idea of how volatility differs across the stock markets, we turn to Figures 2–11. They show the integrated volatility of the stock markets. It is noted that all individual stock markets have volatility during the financial crisis. Most of the stock markets also had their highest volatility in the 2008 crisis period. This is also in line with earlier discussion on jumps identification; in Figure 1, it can be observed that most of the jumps have occurred during crisis periods.

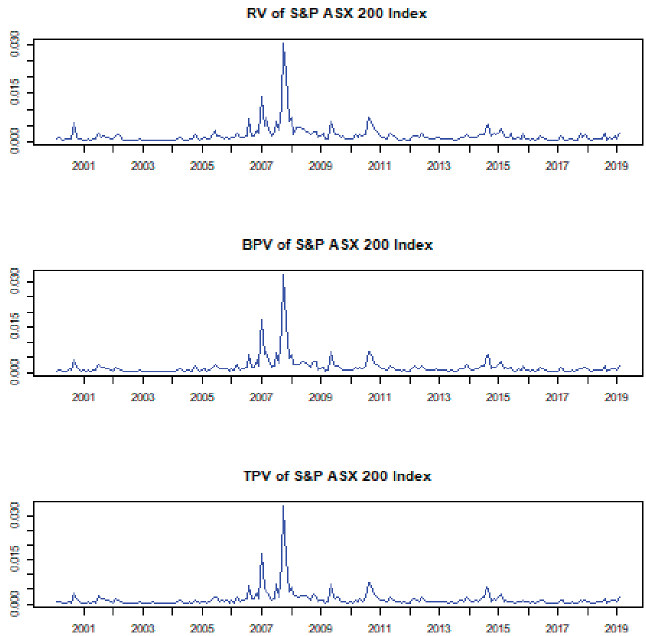

Figure 2. Integrated volatility measures—S&P ASX 200. Notes: Figure 2 displays volatility of the S&P ASX 200 across the sample period February 2001—February 2020 for realized volatility (RV), bi-power variation (BPV), and tri-power variation (TPV).

For the S&P ASX 200 (Figure 2), Hang Seng (Figure 3), Nikkei225 (Figure 4), NZX 50 (Figure 5), JKSE (Figure 8, and SET Index (Figure 10), there seems to be little difference in terms of estimated volatility across the different volatility measures. However, in the Shanghai Composite (Figure 6), the highest volatility was in the 2015 period, a crisis period in China; however, a similar pattern is also observed during 2008. For the Nifty50 index (Figure 7), the peak was during 2008, but few spikes were recorded in 2003. The KSE-100 (Figure 9) index is somewhat different from all others, which had major spikes in 2003, 2005, 2006, 2008, and at the beginning of 2009; all these periods were crisis periods in Pakistan. However, the CSE index (Figure 11) had major spikes during 2008 for all volatility measures.

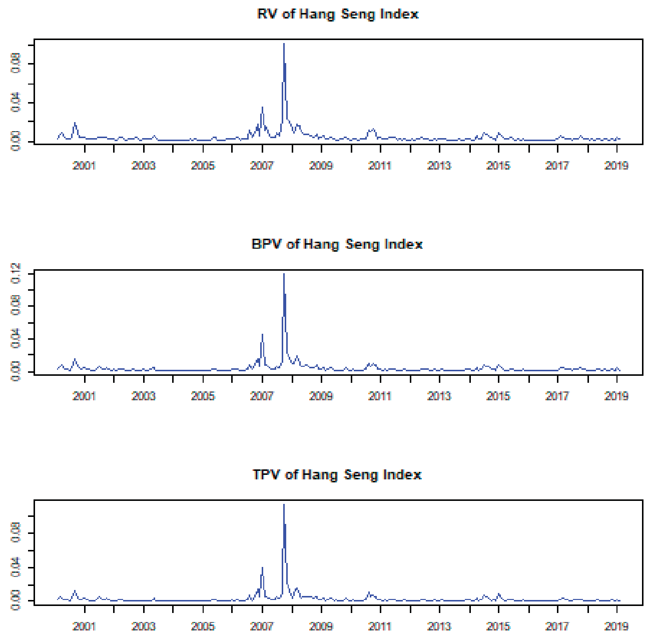

Figure 3. Integrated volatility measures—Hang Seng. Notes: Figure 3 displays the volatility movements of Hang Seng. See the notes in Figure 2.

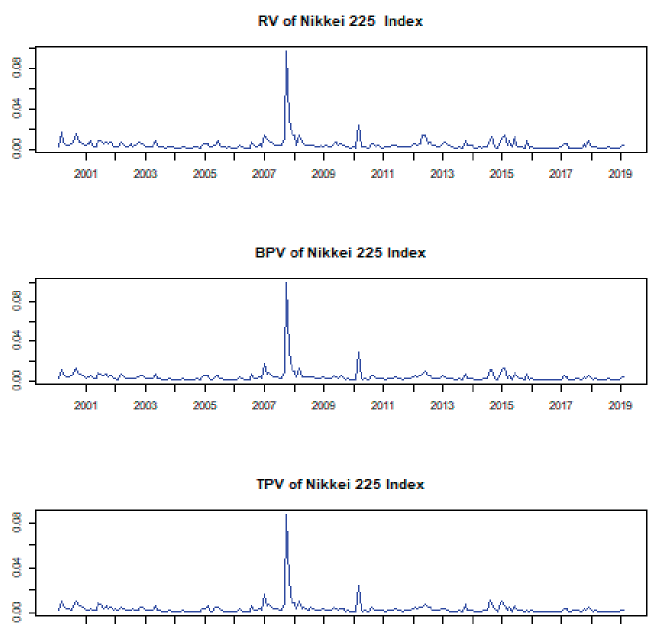

Figure 4. Integrated volatility measures—Nikkei225. Notes: Figure 4 displays the volatility movements of the Nikkei225. See the notes in Figure 2.

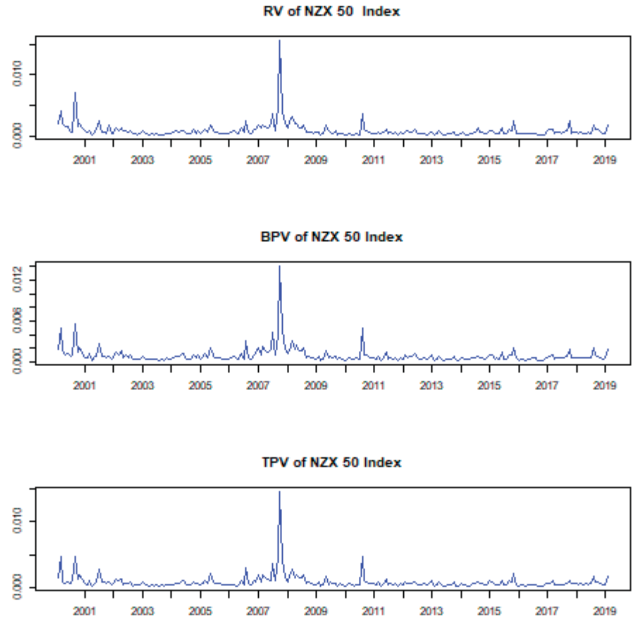

Figure 5. Integrated volatility measures—NZX 50. Notes: Figure 5 displays the volatility movements of the NZX 50. See the notes in Figure 2.

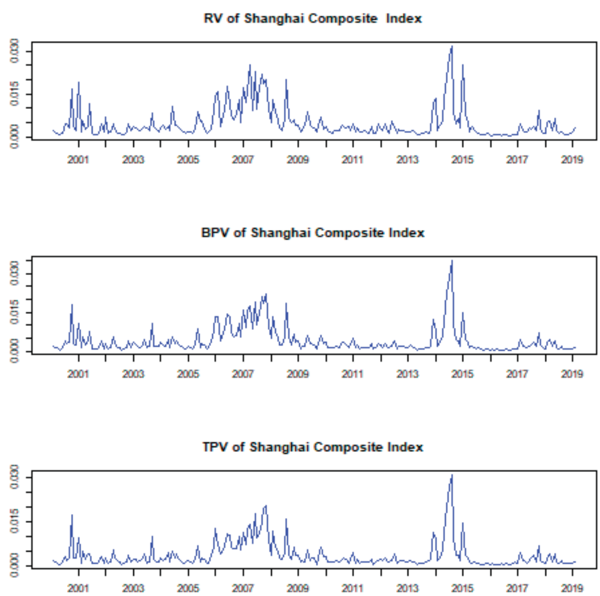

Figure 6. Integrated volatility measures—Shanghai Composite. Notes: Figure 6 displays the volatility movements of the Shanghai Composite. See the notes in Figure 2.

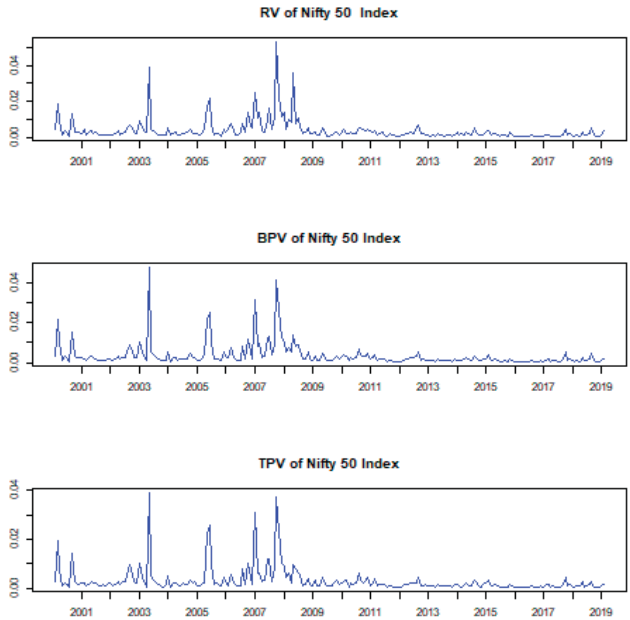

Figure 7. Integrated volatility measures—Nifty50. Notes: Figure 7 displays the volatility movements of the Nifty50. See the notes in Figure 2.

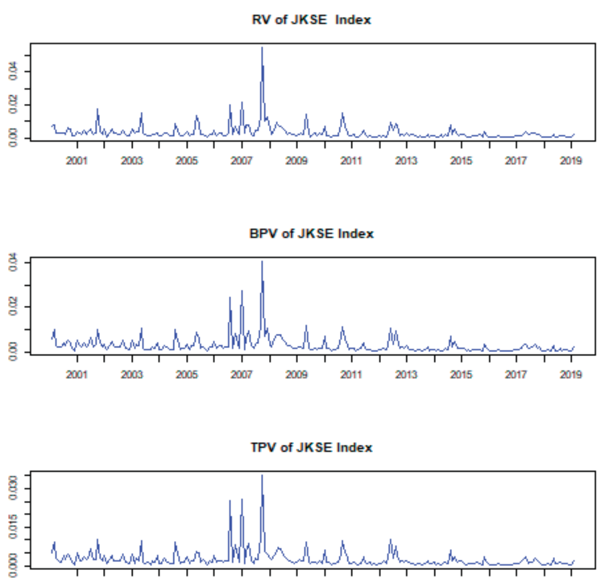

Figure 8. Integrated volatility measures—JKSE. Notes: Figure 8 displays the volatility movements of the JKSE. See the notes in Figure 2.

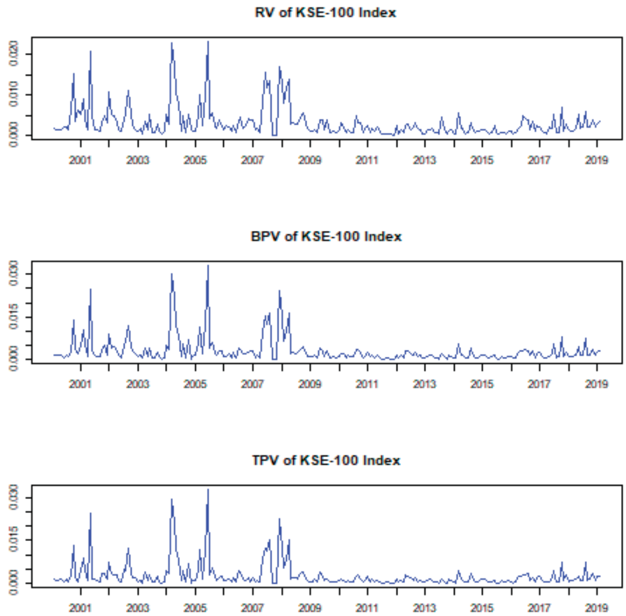

Figure 9. Integrated volatility measures—KSE-100. Notes: Figure 9 displays the volatility movements of the KSE-100. See the notes in Figure 2.

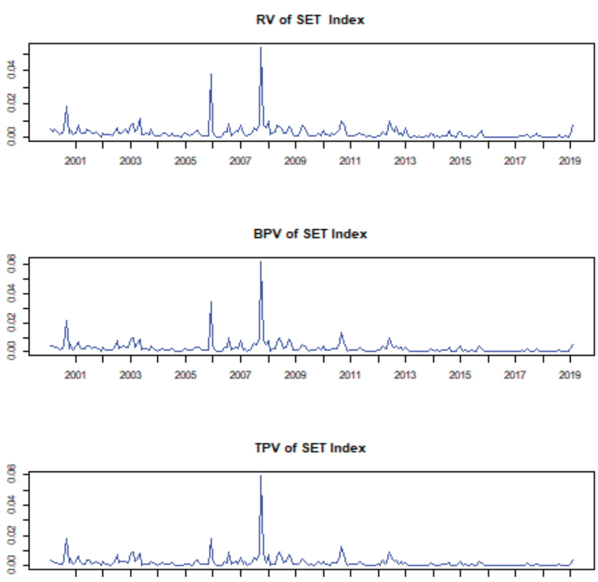

Figure 10. Integrated volatility measures—SET Index. Notes: Figure 10 displays the volatility movements of the SET Index. See the notes in Figure 2.

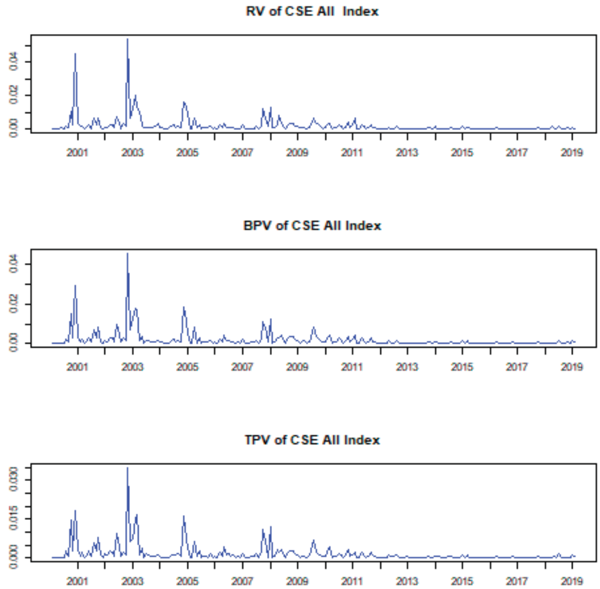

Figure 11. Integrated volatility measures—CSE All. Notes: Figure 11 displays the volatility movements of the CSE All. See the notes in Figure 2.

Table 4 shows the monthly volatility during jump periods for selected equity markets. First, volatility is estimated based on significant jumps. The volatility of positive and negative jumps is separated from total realized volatility.

In developed markets, the jump component shows a considerable amount of volatility in total realized volatility for all markets. However, volatility in negative jumps is higher than volatility in all jumps and volatility in positive jumps in developed markets except for with the Hang Seng, where volatility in positive jumps is higher than volatility in negative jumps. This pattern of high volatility for negative jumps is also consistent across emerging markets except the Nifty50 and CSE All index, where volatility in positive jumps is higher than in negative jumps. However, on average, total realized volatility and jumps-based volatility are larger for emerging markets than developed markets.

Table 4. Average variation due to jump component at a 5% significance level (gives the descriptive statistics of jump volatility. Mean, standard deviation, min, and max values are all in terms of 10^{-3}).

Stock Markets	Jumping Volatility	Jumps (n)	Mean	Standard Deviation	Minimum	Maximum	Kurtosis	Skewness
S&P ASX 200	JV	62	0.5221	0.5005	0.0032	2.1914	2.7766	1.7027
	PJV	32	0.3765	0.3574	0.0032	1.5698	3.0047	1.6782
	NJV	27	0.6947	0.5911	0.0311	2.1914	1.1230	1.3516
Hang Seng	JV	71	1.3341	1.8391	0.1259	11.9661	18.5439	4.0233
	PJV	43	1.3845	2.1349	0.1259	11.9661	16.1284	3.8601
	NJV	28	1.2566	1.2917	0.1286	6.9190	13.9425	3.3268
Nikkei225	JV	56	1.5360	1.8130	0.0012	8.3438	4.3579	2.1030
	PJV	33	1.3843	1.6807	0.1586	7.2191	4.1437	2.0988
	NJV	23	1.7537	2.0062	0.0012	8.3438	4.9369	2.1477
NZX 50	JV	58	0.3423	0.4204	0.0106	2.4044	9.8693	2.8173
	PJV	32	0.2248	0.2674	0.0106	1.2783	8.6934	2.8753
	NJV	26	0.4870	0.5244	0.0243	2.4044	6.4010	2.3138

Table 4. *Cont.*

Stock Markets	Jumping Volatility	Jumps (n)	Mean	Standard Deviation	Minimum	Maximum	Kurtosis	Skewness
Shanghai Composite	JV	93	1.9444	2.1683	0.1199	10.9971	6.2757	2.3618
	PJV	41	1.8759	2.1943	0.1199	10.9740	7.5715	2.5677
	NJV	52	1.9984	2.1676	0.1579	10.9971	6.0724	2.2749
Nifty50	JV	63	1.4304	3.3792	0.0511	25.9597	48.0811	6.6383
	PJV	38	1.5502	4.2256	0.0511	25.9597	32.1919	5.5233
	NJV	23	1.2325	1.0230	0.1213	4.0245	1.9210	1.5553
JKSE	JV	67	1.5593	2.8102	0.0761	19.5782	26.2145	4.6318
	PJV	41	1.0867	1.4862	0.0761	8.2438	13.2699	3.2588
	NJV	26	2.3046	4.0461	0.2385	19.5782	13.8387	3.5188
KSE-100	JV	73	0.9959	1.0711	0.0001	5.6903	5.2415	2.1014
	PJV	51	0.7395	0.7675	0.0001	3.3940	4.3766	2.0441
	NJV	17	1.7651	1.4578	0.2410	5.6903	1.9721	1.3910
SET Index	JV	77	1.0861	2.3810	0.0454	20.3652	59.0289	7.3028
	PJV	49	0.7889	0.7984	0.0579	4.1480	5.9939	2.1599
	NJV	27	1.6255	3.8352	0.0454	20.3652	24.2577	4.8260
CSE All	JV	100	0.8958	2.9551	−0.3937	27.0898	64.1616	7.5430
	PJV	59	1.0205	3.6129	0.0275	27.0898	48.8064	6.7857
	NJV	36	0.8407	1.6953	0.0160	9.6081	21.3262	4.3165

Table 5 shows the ratio of jump variations to total variations. The highest ratio is found in the Shanghai Composite Index. The minimum overall ratio is found for the S&P ASX 200 index. The ratio of positive jump variation to total variation is maximum for the Hang Seng index and minimum for the S&P ASX 200 index. The ratio of positive variation due to negative jump to total variation is maximum for the Nifty50 index and minimum for the NZX 50. When comparing developed and emerging markets, on average the ratio of jump variations to total variations is higher in emerging markets, Similarly, the ratio of variation during negative jump periods to total variation is also higher for emerging markets. It is concluded from the analysis that integrated volatility during a negative jump period is higher than integrated volatility during a positive jump period in both developed and emerging markets but this pattern is more pronounced in emerging markets.

Table 5. Average ratio of jump variation to total variations.

	The Average Ratio of Jumps Variations to Total Variations	The Average Ratio of Positive Jumps Variations to Total Variations	The Ratio of Negative Jumps Variations to Total Variations
S&P ASX 200	32.56%	33.17%	36.04%
Hang Seng	41.34%	44.12%	37.08%
Nikkei225	39.86%	42.47%	36.13%
NZX 50	33.94%	34.12%	33.72%
Shanghai Composite	41.82%	43.20%	40.73%
Nifty50	39.55%	38.23%	45.53%
JKSE	36.60%	33.85%	40.94%
KSE-100	37.03%	38.93%	44.11%
SET Index	39.34%	41.81%	36.71%
CSE All	38.99%	39.97%	44.11%

6. Discussion

Our results are in line with those of (Aït-Sahalia 2004; Amaya and Vasquez 2011; Apergis and Apergis 2020; Baker et al. 2020; Dutta et al. 2020; Eraker et al. 2003; Odusami 2021; Sharif et al. 2020; Zhang et al. 2020).

Zhang et al. (2020) conducted a study on the Chinese stock market, an emerging market, and emerging markets are mostly speculative due to the availability of a limited number of shares for trading in stock markets and the increasing role of institutional investors who act as noise traders. Therefore, they expected more jumps to occur in emerging markets. We found similar results of more jumps in emerging markets than developed markets.

Eraker et al. (2003) found evidence for jump returns and volatility. Similarly, Aït-Sahalia (2004) also documented that jumps play a vital role in asset returns. Amaya and Vasquez (2011) suggest that positive jumps raise the prices of securities; therefore a risk-averse investor prefers positive jumps over a negative jump. Dutta et al. (2020) suggested including jumps to developed a more reliable model for volatility and for asset pricing. We also found that jumps play a crucial role in asset returns. Our study provides a very important piece of information to investors in developed and emerging markets to earn maximum returns during jump periods. During jump periods, investors can earn the highest returns by investing in more volatile markets in developed markets. Whereas investors in emerging markets can earn the highest returns during jump periods by investing in averagely volatile markets.

Baker et al. (2020) investigated the potential causes of the unusual reaction of the US stock market to the COVID-19 pandemic. He found that the COVID-19 pandemic has had a much more significant impact on the US stock market than others. Sharif et al. (2020) investigated the relationship between COVID-19, the stock market, geopolitical risk, and economic policy uncertainty. Analysis has shown that COVID-19 and oil price shocks have been found to have an impact on geopolitical risk levels, economic policy uncertainty, and stock market volatility. Apergis and Apergis (2020) analyzed the impact of the COVID-19 pandemic on the returns and volatility of the Chinese stock market. The analysis shows that COVID-19 has had a significant negative impact on stock returns and a significant positive effect on volatility. Odusami (2021) observed asymmetry in the distribution of jumps, with a higher magnitude of negative jumps than positive jumps. We also found similar results in our analysis; we found that the magnitude of big negative jumps is larger than the magnitude of big positive jumps, and this pattern is consistent for both developed and emerging markets. However, the pattern is much higher in emerging markets as compared with developed markets. Moreover, emerging markets show higher integrated volatility than developed markets. We observed that integrated volatility during the negative jump period is higher than integrated volatility during the positive jump period in both developed and emerging markets. However, this pattern is more pronounced in emerging markets. We note that all stock markets have volatility during financial crises. Most of the stock markets had their highest volatility in the 2008 crisis period.

7. Concluding Remarks

The purpose of this study is to examine whether jumps matter in equity market returns and integrated volatility. To accomplish the goal, we first determined jumps in market returns for both developed and emerging equity markets in Asia, including the S&P ASX 200, Hang Seng, Nikkei225, NZX 50, Shanghai Composite, Nifty50, JKSE, KSE-100, SET Index, and CSE All and disentangled the identified jumps into positive and negative jumps. We then computed both monthly average return and integrated realized volatility and compared them with monthly average returns and integrated realized volatility during positive and negative jump periods.

This paper uses the concept in an efficient capital market theory (Fama 1970) that security prices fully reflect all relevant information and bring stock markets towards efficiency and leave no room for investors to earn excess returns. However, sometimes there exist abnormal movements or large discontinuous changes in stock prices that are infrequent but large. These extreme movements are known as jumps associated with the arrival of unexpected new information (Ferriani and Zoi 2020; Jiang and Zhu 2017; Sun and Gao 2020). Jumps capture all types of information, regardless of whether it is public or private information, including insider trading. Since risk-averse investors prefer positive jumps over negative jumps as positive jumps raise stock prices, stocks with more negative jumps should receive a higher premium than those with more positive jumps (Amaya and Vasquez 2011).

We then used the swap variance (SwV) approach developed by Jiang and Oomen (2008) to identify monthly jumps in the equity prices from both developed and emerging markets from February 2001 to February 2020. Further, the method developed by Andersen et al. (2007) was used to separate the volatility of the jump component from the total realized volatility.

Our analysis shows that jumps matter in both equity market returns and integrated volatility. We find that jumps arise in all equity markets; however, developed markets have fewer jumps relative to emerging markets. Furthermore, in all markets, positive jumps occur more frequently than negative jumps. Moreover, the magnitude of negative jumps is larger than that of positive jumps in both big and small jumps categories in emerging markets. However, the magnitude of negative jumps is larger than positive jumps only in the big jumps category for the developed market.

When average monthly continuous returns are compared with average monthly returns during jump periods, we observe that average monthly returns are higher than continuous returns during jump periods. In emerging markets, the market with average volatility earns higher returns during jump periods, whereas highly volatile markets earn higher returns during jump periods in developed markets. Moreover, markets having lower continuous returns with higher volatility are more adversely affected during negative jump periods.

Furthermore, this study reveals that realized volatility consists of a significant portion of jumps-based volatility. Integrated volatility is high during periods of negative jumps compared with periods during positive jumps. This pattern is consistent in both developed and emerging markets. The average ratio of jump variations to total variation also shows considerable variations due to jumps, indicating total realized variation consisting of substantial variations due to jumps.

Our findings infer that emerging markets are not as efficient as developed markets, and thus, jumps occur more frequently in emerging markets. Investors in all markets prefer to get positive jumps to negative jumps so that stocks with more negative jumps should have a jump risk premium. Our findings also infer that investors should avoid markets with lower continuous returns and higher volatility due to adverse effects during negative jump periods. Investors in emerging markets perceive more serious negative information than in developed markets because integrated volatility is high during negative jumps compared with periods during positive jumps, and this pattern is more pronounced in emerging markets.

The implication of this study is for all types of investors for both developed and emerging markets. The findings in our study suggest individual investors and portfolio managers of developed emerging markets avoid investment in assets and markets that are too volatile and have lower returns because these assets and markets are adversely affected by negative jumps. However, this study encourages investors and portfolio managers to invest in highly volatile assets with positive jumps because it will enable investors to earn higher returns. Furthermore, for investors in developing markets, investment in the averagely volatile assets and markets is the most efficient investment during the positive jumps period. The implication is also very important for asset pricing theory as investors prefer positive jumps to negative jumps. Therefore, stocks with negative jumps should earn a premium compared to stocks with positive jumps. This is also an important factor in the consideration of investment. This study provides insights to academics, practitioners, and policymakers on the asymmetric effect of jumps in equity market returns and integrated volatility in the context of developed and emerging markets.

One of the limitations of our study is that our data have not covered the COVID-19 period and our study is limited to Asian developed and emerging equity markets.

Thus, future researchers could extend our study to cover the COVID-19 period and by including other markets in their study. Moreover, future research could consider using other techniques to estimate jumps, for example, the jump identification methods developed by Aït-Sahalia and Jacod (2009), Barndorff-Nielsen and Shephard (2006), and Lee and Mykland (2008). Most importantly, future studies could also incorporate jumps as a factor in asset pricing models.

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