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Bivariate Hedging Between Crypto-Currency And Traditional Assets

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Abstract

Crypto-currency is distinct featured digital asset designed to work as decentralized asset, yet it has raised many questions and doubts about its definition and regulations. Keeping in view the increasing interest of masses in crypto-currencies the research is extended to examine the role of crypto-currency in diversification of investment. Bivariate analysis of crypto-currency market and other asset classes like gold, exchange rate, stock returns and government bonds has been observed among countries where crypto-currencies are being traded most frequently over 2013 to 2020. Theoretically the study intends to provide substantial support for risk management by using estimates like hedge ratio, VECM and BEKK GARCH. Practically the study aims to provide empirical justifications for investors, managers and policy makers to figure out exactly where crypto-currencies stand along with other asset classes, and what actually it brings to the financial system. It concludes that there is long term causal relationship running from traditional assets to crypto-currency market, co-movements are observed. The change in crypto-currency returns may not affect returns of traditional assets yet as any change in traditional assets may possibly upsurge towards change in crypto-currency market in the long term which indicates opportunities for crypto-currencies to hedge.

Keywords: Crypto-currency, Hedge Ratio, Cointegration, VECM, BEKK GARCH

Introduction

The concept of competition among currency markets is not merely a competition among countries but competition within countries alike, (Hayek 1976). It encourages people to be allowed to pick currency whichever they want to use. The Austrian School of economics finds crypto-currency a stimulating currency, since it holds the probability of upsetting fiat currencies as it may possibly deteriorate the powers of financial authorities for instance central banks. It is believed that if the crypto-currency continues at about the same pace to attract interest of masses and becomes widely used by them, it may possibly become alternate option practically, and they would start switching to it to uphold against increasing inflation in domestic currencies.

However, the economists from Austrian school of economics Korda (2013) and Graf (2013) criticize that it violates the Mises's regression theorem of money, (Mises: 1912, Mises and Greaves: 1949), since crypto-currency does not back any tangible commodity. Though other economists, including Konrad and Graf (2013)

and Surda (2014) from the same school of thought are specialized in Bitcoin and interpret the regression theorem differently. They argue that although Bitcoin does not back any tangible security, yet it is uniquely framed scarce intangible asset that fulfills the requisites to be taken as a unique asset.

There is a controversial argument among financial experts and economists that crypto-currency could actually outclass existing fiat currency and traditional commodities yet this would entail a complete overhaul of the economic system. Though its practice as a sole system of making investment is not likely to be appearing in the very near future but crypto-currency remains a fascinating notion for imminent investigation. In the contemporary age of information, people like the idea of holding such as asset that is decentralized (e.g., like gold) and can be stored digitally, but not physically, besides proficient to be sent round the world within no seconds. This, in essence stands the value proposition for the emerging crypto-currencies which may be called tele-portable gold. Since crypto-currencies empower direct transmission of economic value completely over the internet, in the absence of any trusted intermediary. Thus this can be an exceptionally valuable thing.

The underpinned study is carried to investigate the crypto-currency market and a comparison between crypto-currency and other assets as a unique choice of investment. It aims to examine the role of crypto-currency (highly volatile asset) in hedging of risk along with other asset classes like traditional gold, currency exchange rate, stock returns and government bonds of ten countries where crypto-currencies are being traded frequently. The theory of portfolio provides framework for construction of a portfolio to maximize returns at certain level of risk with diversification in investment or hedging in a portfolio. It states that investment is the weighted average of estimated returns and how each security in a portfolio move together, rather individual estimated returns of any investment. Markowitz (1954) introduces the notion of covariance in order to quantify movement of securities along each other. He proposes investors to measure variances in returns as well as expected returns and rate first the combination that offers greater expected returns at certain level of risk, such portfolios are deemed to be efficient.

The study is designed on five chapters, first chapter opens with introduction, second chapter discusses about literature review, third chapter focuses on data and methodology, fourth chapter covers findings and the last chapter concludes the study.

Literature Review

Gronwald (2014) applies GARCH model and concludes that price of Bitcoin is strongly described by extreme shifts, which indicates it as an undeveloped immature market. However, Glaser et. al (2014) explains that Bitcoin is used as a speculative asset, rather than medium of payment. Baek and Elbeck (2015) report robust proof that volatility of Bitcoin is driven internally though buying and selling forces, lead to the inference that presently its market is greatly speculative. Moreover the interest rates are historically low, which indicates investments are risky yet have potentially high returns; so it is assumed if interest rates are lower, Bitcoin would become ultimate choice of risk-tolerant investors. Dyhrberg (2016) explores bitcoin's capabilities as a financial asset using GARCH models. With the help of asymmetric GARCH model, the author finds that bitcoin could possibly be beneficial in the risk management strategies, thus perfect opportunity for investors with risk aversed approach in expectation of negative extreme shifts in the market. In addition to this Bouoiyour and Selmi (2016) employ daily prices of Bitcoin to apply optimal GARCH model. They express that volatility of Bitcoin illustrates

declining trend in comparison of pre and post 2015 data. They report asymmetries in Bitcoin market as prices are prone towards negative rather positive shifts. Bouri et al, (2017) states Bitcoin may turn out as an effective diversifying alternative yet it may possibly not be an effective hedging instrument. Whereas volatility and forecasting ability of Bitcoin by applying GARCH model is also examined (Urquhart, 2017). They find realized volatility in the price is comparatively high in the sample, however declined afterwards and no evidence to support leverage effect is reported. Moreover, Latif et al. (2017) test crypto-currency market in respect of efficient market efficiency by applying time series data of Bitcoin and Litecoin. They conclude that these crypto-currencies reacts instantly to any new information, which is consistent with Efficient Market Hypothesis. Thus weak form of efficiency is reported as crypto-currencies depict greater predictability than stock market due to such sensitivity to information. Baur and Dimpfl (2018) state distinctive asymmetry relative to equity markets where positive movements result rise in the volatility more as compared to negative movements. The conclusions are consistent with FOMO (fear of missing out) of unsophisticated investors and the presence of pump and dump patterns in the prices of crypto-currencies. The distinctive illustration of stylized facts about the variance measures of crypto-currencies are employed by using log of daily returns, thus these results are then related to their corresponding cryptographic schemes for instance intended transaction speed Phillip, et al (2018). The overarching inference of these results is the volatility of the given crypto-currencies that can be better assumed and measured by means of functions of fast moving autocorrelation. However, Corbet, et al (2018) offers a systematic analysis of the literature of empirical studies that comprises the main areas about the market of crypto-currencies since its inception as a financial digital asset in 2009. Even though surprising increase in price in most recent years, crypto-currencies are subjected to allegations of financial pricing bubbles, its potential for illegitimate practice because of its anonymity, and infrastructural ruptures from conventional means of financial dealings that influences by means of growing cyber criminality.

On the other hand, Corbet, Lucey and Yarovaya (2018) also focus on the presence and periods of financial pricing bubbles in the prices of Bitcoin as well as Ethereum by employing the methodological approach initially proposed by Phillips et al., (2011) in order to inspect the key fundamental indicators of the bubbles in the prices. The study concludes presence of clear behavior of bubbles in Bitcoin prices, which is now; certainly exist in a bubble phase.

By applying the GARCH-MIDAS model Conrad, Custovic and Ghysels (2018) extract the short-term as well as long-term volatility elements of crypto-currencies. To potentially strong drivers that exist in Bitcoin volatility, they ponder approaches of risk and volatility of the US stock market along with the approach to global economic activity. Lastly, they conclude with the strongly positive relationship between the long-term Bitcoin volatility and Baltic dry index and states that global economic activity influences Bitcoin volatility thoroughly. However, Tu, DOdorico and Suweis (2018) study crypto-currencies (a progressive digital assets encoded to exercise as a medium of exchange), which is “protected” by design by means of block-chains and function of cryptography). The year 2017 observes escalation and reduction of crypto-currency market, tracked by high volatility in price of each crypto-currency. The semi-parametric method along with the Cornish-Fisher extension that estimates quantile by using high moments in the distribution which is provided to assess hedging proportions with CoVaR Chai and Zhou (2018). They also compare the

conventional Minimum-Variance model and the Minimum CoVaR model, where later outperforms in-sample criteria but is not consistent with out-sample. The CoVaR approach captures the structures of high moments along with high kurtosis and the heavy and fat tailed distribution. Whereas Shintate and Pichl (2019) provide the framework of random sampling measure (RSM) to predict trend based on deep learning (DL), to compare the performance of the two traditional baseline approaches for non-stationary time series data of crypto-currencies. The turnover rates on the basis of RSM beat the methods based on long short-term memory (LSTM), though the estimation does not exceed the buy and hold plan during the period, thus does not offer a base for algorithmic exchange.

The three pair wise bivariate BEKK approaches in order to inspect the dynamics of conditional volatility with the interconnection and conditional correlations among the sets of crypto-currencies. The price volatility of crypto-currency is deemed to be reliant on the past and past volatility and shocks. Katsiampa, Corbet and Lucey (2019) classify bi-directional volatility effects of spillovers between the three sets of crypto-currencies and put forward the evidence regarding time dependent conditional correlations present that are generally positive. In addition to this, the hypothesis that hedging abilities and volatility spillovers abilities are present between Ethereum and Bitcoin by using multivariate BEKK-GARCH approach analysis for impulse response applied in value at risk estimates, (Beneki, et al, 2019). This study illustrates the unidirectional volatility transference from Ethereum to Bitcoin which suggests that cost-effective trading schemes may possibly be recognized for a recently established derivative market by the significances beside market efficiency. In the light of the literature crypto-currency has a dynamic role and can be an effective hedging instrument for a well-diversified portfolio. Fakhfekh et.al, (2021) studies dynamic and persistence in correlations among top five crypto-currencies with Gold, VIX, WTI, S & P 500, NIKKIE, FTSE and MSCIEM, for optimal hedging strategies by DCC, ADCC and GO GARCH models. They report Bitcoin along with gold display tremendous features for optimal hedging. Shalini (2022) examines the co-volatility of crypto-currencies along with traditional assets and analyzes time-varying correlation and covariance by using models of multi-factor volatility, and finds mixed results for various countries. Koutmos et.al, (2021) develops analytical model to find optimal weights for 11 crypto-currencies by using conditional correlation model and regression model to find connection between weights and economic uncertainty. The study finds better hedging under uncertain conditions. Murty et.al, (2022) states volatility dynamic connections between Bitcoin and other assets by EGARCH model. It observes DCC GARCH model check time dependent co-movements among the markets. Since positive movement between gold and Bitcoin show, that Bitcoin is safe option for investment.

Data and Methodology

The study is quantitative in nature and extracts secondary data for crypto-currency for the time period from 2013 to 2020. Crypto-currencies with market capitalization of USD 100,000 and above cover the sample of the study. There are about 498 crypto-currencies with market capitalization of USD 100,000 and above while collection of the data. The 10 countries with crypto-currency traders are selected for the analysis of the study. These countries include Brazil, Canada, Germany, Japan, South Korea, Russia, Turkey, United Kingdom, United States and Vietnam.

Description of Variables

Variables of interest are given in Table 1;

Table 1: Description of Variables

Variables/ Countries	**Crypto-currency Returns – CR**	Crypto-currency Index of 498 crypto-currencies on the basis of market capitalization of USD 100,000 and above.	
	Gold Rate – GR	Gold price per ounce.	
	Exchange Rate – ER	**Stock Returns – SR**	**10Y Government Bond Rate – GB**
BR	BRL	BOVESPA	BRGB10Y
CA	CND	TSX	CAGB10Y
GR	EURO	DAX	GRGB10Y
JP	JPY	Nikkei-225	JPGB10Y
KO	KOW	KOSI	KOGB10Y
RU	RUB	MCX	RUGB10Y
TR	TRY	BIST-100	TRGB10Y
UK	GBP	FTSE-100	UKGB10Y
US	USD	S&P-500	USGB10Y
VN	VND	HNX-30	VNGB10Y

All prices are taken in terms of USD.

Measures for Estimation

Hedge Ratio

In order to determine the relationship between crypto-currency and each of the assets in a portfolio hedge ratio will be utilized to achieve minimum portfolio risk. For static hedge ratio it utilizes VECM model and for time varying hedge ratio bivariate GARCH, (Ederington, 1979).

Static Hedge Ratio

Vector error correction model provides the dynamic estimation of correlation in returns and much insight about the lead lag relationship between two variables (Alexander, 2001). It structures the short run and long run variations from the equilibrium to be corrected. The model is given as below; where ΔC_t the change in crypto returns is, ΔK_t is the change in comparative asset returns.

$$\Delta C_t = \alpha_1 + \sum_{i=1}^{m_1} \beta_{1i}\Delta C_{t-1} + \sum_{i=1}^{m_2} \beta_{2i}\Delta K_{t-1} + \gamma_1 z_{t-1} + \varepsilon_{1t}$$

$$\Delta K_t = \alpha_2 + \sum_{i=1}^{m_3} \beta_{3i}\Delta K_{t-1} + \sum_{i=1}^{m_4} \beta_{4i}\Delta C_{t-1} + \gamma_2 z_{t-1} + \varepsilon_{2t}$$

Time Varying Hedge Ratio

The BEKK GARCH Engle and Kroner (1990) models the vigorous structure in defining correlations and covariance matrices between two variables. The general form of the model is given blow, where M_0 represents the lower triangular matrix, A_{ik} and B_{ik} represents T*T matrix.

$$H_t = M_0^T M_0 + \sum_{k=1}^{k} \sum_{i=1}^{q} A_{ik}\varepsilon_{t-i}\varepsilon_{t-1}A_{ik} + \sum_{k=1}^{k} \sum_{i=1}^{p} B_{ik}\sum_{t-1}B_{ik}$$

Whereas, hedge ratio is estimated as;

$$h_t = \frac{Cov(\Delta C_t \Delta K_t)}{Var(\Delta K_t)}$$

Findings and Interpretations

For analysis of the study daily data has been used total of 1564 observations. Firstly the returns of each series are defined as below, where i denote the variables; t represents present day price and t-1 price of the previous day for each series.

$$R_i = \log\left(\frac{R_t}{R_{t-1}}\right)$$

Descriptive Analysis

Table 2, captures the descriptive statistics. The returns of crypto-currency market show highest variability in mean 44.83%, maximum value 684.3026, minimum value -0.5818 and standard deviation as 17.3045%. Moreover skewness and kurtosis for all variables imply non-normal distribution. The mean series of each variable is used for further analysis of the study.

Table 2: Descriptive Statistics

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
RCM	0.4483	-0.0001	684.3026	-0.5818	17.3045	39.4995	1561.472
RGM	0.0001	-0.0001	0.1546	-0.1185	0.0168	0.6603	25.1899
REXBR	-0.0003	0	0.061	-0.0687	0.0102	-0.0134	6.157
RBBR	-0.0002	0	0.1707	-0.0508	0.0119	2.0174	31.2999
RSMBR	0.0006	0	0.066	-0.088	0.0141	-0.0089	4.8546
REXCA	-0.0001	-0.0003	0.0198	-0.019	0.0047	0.1225	4.0536
RBCA	0	0	0.1418	-0.0985	0.0239	0.395	5.0805
RSMCA	-0.0004	0.0004	0.0294	-1	0.0262	-35.7319	1365.805
REXGR	-0.0001	-0.0001	0.0307	-0.0238	0.0051	0.1454	5.6557
RBGR	-0.0119	-0.003	13	-32.6667	0.9995	-21.3178	754.7405
RSMGR	0.0003	0.0005	0.0497	-0.0682	0.0108	-0.2827	5.4154
REXJP	-0.0001	-0.0001	0.0303	-0.0806	0.0057	-1.7398	30.2198
RBJP	0.0145	0	30	-21	1.2582	6.755	356.6985
RSMJP	0.0004	0.0001	0.0771	-0.0792	0.0123	-0.1591	7.9915
REXKO	0	0	0.0333	-0.0326	0.0064	0.2144	5.4594
RBKO	-0.0004	0	0.0826	-0.0822	0.0132	0.0451	6.4823
RSMKO	0.0001	0	0.0353	-0.0444	0.0073	-0.4064	5.6813
REXRU	0.0044	-0.0017	9.1477	-0.0326	0.2314	39.4892	1560.931
RBRU	0.0001	0	0.2303	-0.1687	0.013	2.5475	86.7226

RSMRU	0.0005	0	0.0526	-0.1079	0.0108	-0.7325	12.574
REXTR	-0.0003	0	0.137	-0.1163	0.0123	0.2002	21.8553
RBTR	-0.0001	0	0.1031	-1	0.0297	-24.4186	826.4488
RSMTR	-0.0004	0	0.0644	-1	0.0286	-27.424	960.0243
REXUK	-0.0007	-0.0003	0.0826	-0.1375	0.01	-1.5432	31.5384
RBUK	-0.0002	-0.0007	0.1397	-0.2093	0.0311	-0.0689	7.0067
RSMUK	-0.0005	0.0002	0.0358	-1	0.0266	-33.9343	1275.236
RBUS	0	0	0.113	-0.1044	0.0192	0.2241	5.3253
RSMUS	0.0004	0.0003	0.0496	-0.041	0.008	-0.3908	6.9893
REXVN	-0.0001	0	0.0166	-0.0158	0.002	-0.2337	22.6908
RBVN	-0.0004	0	0.0727	-0.0586	0.0071	0.0359	27.3634
RSMVN	0.0004	0.0006	0.0423	-0.1041	0.0107	-1.0772	11.2752

Table 2, captures the descriptive statistics, mean returns, maximum value, minimum value, standard deviation, skewness and kurtosis for all variables.

Stationary Test

For analyzing time series data in financial studies, the research begins with the unit root test to check if data is stationary. The standard Augmented Dickey Fuller- ADF test is applied on all the return series to check null hypothesis of unit root against alternate hypothesis for stationarity of each series. Table 3 (a) presents the unit root tests where are all series are stationary at 1st difference and hence significant at 1%.

Table 3: Unit Root, Lag Selection and Cointegration

	(a)		**(b)**							
	Unit Root Test		**Lag Selection and Co-Integrating Relationship**							
	Level t-Stat/ Probs.	**1st Diff. t-Stat/ Probs.**	**Lag**		**Trace Stat**	**C.Value 0.05**	**Prob.**	**Max-Eig**	**C.Value 0.05**	**Prob.**
RCM	-6.87 0.0000	-26.14 0.0000	-		-	-	-	-	-	-
RGM	-2.63	-39.67	5	None *	55.208	15.495	0.0000	50.446	14.265	0.0000
	0.0878	0.0000		At most 1 *	4.762	3.841	0.0291	4.762	3.841	0.0291
REXBR	-1.49	-43.38	5	None *	46.371	15.495	0.0000	44.243	14.265	0.0000

	0.5396	0.0001		At most 1	2.127	3.841	0.1447	2.127	3.841	0.1447
RBBR	-0.66	-40.01	5	None *	45.877	15.495	0.0000	45.628	14.265	0.0000
	0.8542	0.0000		At most 1	0.249	3.841	0.6178	0.249	3.841	0.6178
RSMBR	-0.02	-40.66	5	None *	47.124	15.495	0.0000	47.122	14.265	0.0000
	0.9558	0.0000		At most 1	0.002	3.841	0.9591	0.002	3.841	0.9591
REXCA	-1.93	-39.95	5	None *	49.595	15.495	0.0000	46.118	14.265	0.0000
	0.3204	0.0000		At most 1	3.477	3.841	0.0622	3.477	3.841	0.0622
RBCA	-1.79	-40.36	5	None *	54.937	15.495	0.0000	51.757	14.265	0.0000
	0.3864	0.0000		At most 1	3.180	3.841	0.0746	3.180	3.841	0.0746
RSMCA	-2.36	-36.69	5	None *	50.562	15.495	0.0000	45.204	14.265	0.0000
	0.1545	0.0000		At most 1 *	5.358	3.841	0.0206	5.358	3.841	0.0206
REXGR	-1.47	-40.82	5	None *	50.873	15.495	0.0000	49.086	14.265	0.0000
	0.5503	0.0000		At most 1	1.787	3.841	0.1813	1.787	3.841	0.1813
RBGR	-1.47	-40.07	5	None *	48.813	15.495	0.0000	46.835	14.265	0.0000
	0.5484	0.0000		At most 1	1.978	3.841	0.1596	1.978	3.841	0.1596
RSMGR	-2.19	-40.13	5	None *	51.106	15.495	0.0000	46.381	14.265	0.0000
	0.2092	0.0000		At most 1 *	4.725	3.841	0.0297	4.725	3.841	0.0297
REXJP	-2.04	-45.99	5	None *	52.897	15.495	0.0000	48.899	14.265	0.0000
	0.2683	0.0001		At most 1 *	3.998	3.841	0.0456	3.998	3.841	0.0456
RBJP	-2.06	-34.26	5	None *	47.956	15.495	0.0000	43.690	14.265	0.0000
	0.2630	0.0000		At most 1 *	4.266	3.841	0.0389	4.266	3.841	0.0389
RSMJP	-1.90	-41.37	5	None *	52.027	15.495	0.0000	48.741	14.265	0.0000

	0.3328	0.0000		At most 1	3.286	3.841	0.0699	3.286	3.841	0.0699
REXKO	-1.60	-39.40	5	None *	51.563	15.495	0.0000	48.887	14.265	0.0000
	0.4843	0.0000		At most 1	2.676	3.841	0.1019	2.676	3.841	0.1019
RBKO	-1.26	-40.29	5	None *	49.305	15.495	0.0000	47.313	14.265	0.0000
	0.6486	0.0000		At most 1	1.992	3.841	0.1581	1.992	3.841	0.1581
RSMKO	-1.95	-39.84	5	None *	51.684	15.495	0.0000	47.463	14.265	0.0000
	0.3096	0.0000		At most 1 *	4.221	3.841	0.0399	4.221	3.841	0.0399
REXRU	-2.01	-40.37	5	None *	49.832	15.495	0.0000	45.788	14.265	0.0000
	0.2807	0.0000		At most 1 *	4.044	3.841	0.0443	4.044	3.841	0.0443
RBRU	-1.75	-44.33	5	None *	51.410	15.495	0.0000	48.996	14.265	0.0000
	0.4077	0.0001		At most 1	2.414	3.841	0.1202	2.414	3.841	0.1202
RSMRU	-0.28	-40.11	5	None *	45.333	15.495	0.0000	45.288	14.265	0.0000
	0.9250	0.0000		At most 1	0.045	3.841	0.8324	0.045	3.841	0.8324
REXTR	-0.99	-39.06	5	None *	45.675	15.495	0.0000	44.859	14.265	0.0000
	0.7575	0.0000		At most 1	0.816	3.841	0.3663	0.816	3.841	0.3663
RBTR	-1.08	-39.22	5	None *	47.826	15.495	0.0000	46.951	14.265	0.0000
	0.7252	0.0000		At most 1	0.875	3.841	0.3495	0.875	3.841	0.3495
RSMTR	-1.68	-39.59	5	None *	51.361	15.495	0.0000	48.086	14.265	0.0000
	0.4399	0.0000		At most 1	3.274	3.841	0.0704	3.274	3.841	0.0704
REXUK	-0.88	-39.67	5	None *	45.873	15.495	0.0000	45.309	14.265	0.0000
	0.7939	0.0000		At most 1	0.563	3.841	0.4529	0.563	3.841	0.4529
RBUK	-1.36	-41.83	5	None *	46.671	15.495	0.0000	44.992	14.265	0.0000

	0.6048	0.0000		At most 1	1.679	3.841	0.1950	1.679	3.841	0.1950
RSMUK	-2.36	-39.25	5	None *	53.101	15.495	0.0000	47.878	14.265	0.0000
	0.1548	0.0000		At most 1 *	5.223	3.841	0.0223	5.223	3.841	0.0223
RBUS	-2.02	-42.76	5	None *	55.232	15.495	0.0000	51.800	14.265	0.0000
	0.2783	0.0000		At most 1	3.433	3.841	0.0639	3.433	3.841	0.0639
RSMUS	-0.88	-39.03	5	None *	47.049	15.495	0.0000	46.456	14.265	0.0000
	0.7947	0.0000		At most 1	0.592	3.841	0.4415	0.592	3.841	0.4415
REXVN	-0.61	-30.47	5	None *	45.121	15.495	0.0000	44.686	14.265	0.0000
	0.8663	0.0000		At most 1	0.435	3.841	0.5094	0.435	3.841	0.5094
RBVN	-1.24	-13.66	5	None *	46.829	15.495	0.0000	44.986	14.265	0.0000
	0.6583	0.0000		At most 1	1.843	3.841	0.1745	1.843	3.841	0.1745
RSMVN	-1.21	-38.81	5	None *	53.796	15.495	0.0000	52.279	14.265	0.0000
	0.6711	0.0000		At most 1	1.516	3.841	0.2182	1.516	3.841	0.2182

Table 3 (a) presents the unit root tests where are all series are stationary at 1st difference and hence significant at 1%.

Table 3 (b) demonstrates co-integration relationship between crypto-currency market and each of the variables.

Vector Error Correction Model – VECM

Lag Selection Criteria

The selection of optimal lag length to proceed with cointegration test, the Akaike Information Criteria- AIC is used which suggested optimal lag length as 5 for all sets. It is also confirmed by trace statistics and maximum eigen statistics that at lag 5 atleast 1 cointegration equation is found in all sets, Table 3 (b).

Cointegration Test

Before going to VECM analysis it is important to find that whether variables are cointegrated or not. Table 3 (b) demonstrates cointegration relationship between crypto-currency market and each of the variables where trace statistics and maximum eigen statistics show atleast one cointegration equation between crypto-currency market and all other asset classes. Hence the null hypothesis of no cointegration is rejected under trace as well as maximum eigen statistics at 5% level of significance. These results indicate that exchange rates, stock returns, government bonds and gold establish long run relationship with

crypto-currencies in countries where it is being traded frequently.

The coefficient of the model which is known as error correction term is denoted as λ_1. This term denotes the speed of convergence of variables towards their equilibrium. The significantly negative error correction term confirms the presence of long term causality flowing from one variable to the target variable. The results given Table 4 (a) illustrates that there is long term causality coming from each of the traditional asset classes towards crypto-currency market. About 8% to 9% traditional assets are adjusted in previous year's deviations from the equilibrium. However there is no long term causality found coming from crypto-currency market to the traditional assets except crypto-currency towards gold, REXJP and RSMVN. These sets show positive coefficient with significance at 5% and RESMVN at 10% which means any change, disequilibrium may arise.

Table 4: Vector Error Correction Model- VECM

	(a)				**(b)**			
	Long Term Causality (λ_1)				**Short Term Casuality**			
	Coeff.	**Std. Err**	**t-Stat**	**Prob.**	**F-stat**	**Prob.**	**Chi-sq**	**Prob.**
RGM	-0.0897	0.0131	-6.8236	0.0000	0.0729	0.9962	0.3645	0.9963
	0.0122	0.0060	2.0316	0.0424	17.9043	0.0000	89.5216	0.0000
REXBR	-0.0856	0.0128	-6.6729	0.0000	0.9386	0.4548	4.6930	0.4545
	0.0000	0.0000	-0.2031	0.8391	0.6119	0.6908	3.0597	0.6908
RBBR	-0.0880	0.0130	-6.7773	0.0000	0.5126	0.7670	2.5628	0.7670
	0.0000	0.0000	-0.2363	0.8132	0.4081	0.8434	2.0403	0.8435
RSMBR	-0.0904	0.0131	-6.8899	0.0000	0.4184	0.8362	2.0920	0.8363
	-0.0419	0.2782	-0.1507	0.8802	0.1553	0.9785	0.7763	0.9785
REXCA	-0.0871	0.0128	-6.7812	0.0000	1.8428	0.1015	9.2142	0.1008
	0.0000	0.0000	-0.3368	0.7363	0.4608	0.8056	2.3039	0.8057
RBCA	-0.0979	0.0135	-7.2255	0.0000	2.4076	0.0347	12.0381	0.0343
	0.0000	0.0000	-0.1331	0.8942	0.2603	0.9347	1.3013	0.9348
RSMCA	-0.0877	0.0130	-6.7473	0.0000	0.5433	0.7435	2.7166	0.7436
	0.0024	0.0298	0.0802	0.9361	0.5577	0.7325	2.7885	0.7326
REXGR	-0.0923	0.0133	-6.9365	0.0000	0.3867	0.8582	1.9333	0.8583
	0.0000	0.0000	1.1511	0.2499	1.1999	0.3068	5.9996	0.3063
RBGR	-0.0893	0.0130	-6.8485	0.0000	0.8477	0.5159	4.2385	0.5156

	0.0000	0.0000	-0.5841	0.5592	0.3388	0.8896	1.6939	0.8897
RSMGR	-0.0874	0.0130	-6.7399	0.0000	0.3251	0.8981	1.6254	0.8982
	-0.0448	0.0357	-1.2545	0.2099	1.0103	0.4100	5.0514	0.4096
REXJP	-0.0882	0.0130	-6.7932	0.0000	1.7484	0.1205	8.7420	0.1198
	0.0000	0.0000	2.0459	0.0409	0.5588	0.7317	2.7939	0.7317
RBJP	-0.0736	0.0118	-6.2540	0.0000	60.1478	0.0000	300.7389	0.0000
	0.0000	0.0000	1.4797	0.1392	4.0458	0.0012	20.2291	0.0011
RSMJP	-0.0882	0.0130	-6.7835	0.0000	0.5988	0.7009	2.9941	0.7009
	-0.0977	0.0692	-1.4112	0.1584	2.0684	0.0667	10.3418	0.0661
REXKO	-0.0937	0.0134	-7.0152	0.0000	0.0208	0.9998	0.1041	0.9998
	0.0000	0.0000	0.2484	0.8039	0.0050	1.0000	0.0249	1.0000
RBKO	-0.0915	0.0133	-6.8977	0.0000	0.5864	0.7104	2.9322	0.7104
	0.0000	0.0000	0.1842	0.8539	0.5867	0.7102	2.9336	0.7102
RSMKO	-0.0904	0.0131	-6.8790	0.0000	0.3341	0.8925	1.6707	0.8926
	-0.0037	0.0049	-0.7588	0.4481	1.1429	0.3355	5.7143	0.3350
REXRU	-0.0872	0.0130	-6.7288	0.0000	0.4696	0.7991	2.3480	0.7992
	0.0000	0.0000	-0.8964	0.3702	0.1912	0.9660	0.9560	0.9660
RBRU	-0.0932	0.0133	-7.0085	0.0000	0.0441	0.9989	0.2204	0.9989
	0.0000	0.0000	0.4998	0.6173	0.0678	0.9968	0.3392	0.9968
RSMRU	-0.0872	0.0129	-6.7411	0.0000	0.0631	0.9973	0.3155	0.9973
	-0.0019	0.0061	-0.3079	0.7582	0.4656	0.8021	2.3280	0.8022
REXTR	-0.0865	0.0129	-6.7074	0.0000	0.7430	0.5913	3.7148	0.5912
	0.0000	0.0000	-0.4305	0.6669	0.4812	0.7905	2.4061	0.7906
RBTR	-0.0900	0.0132	-6.8441	0.0000	0.4971	0.7786	2.4853	0.7787
	0.0000	0.0001	0.7275	0.4670	0.3666	0.8717	1.8329	0.8717
RSMTR	-0.0875	0.0130	-6.7475	0.0000	1.0978	0.3596	5.4889	0.3592

	-0.2175	0.3518	-0.6182	0.5366	0.4367	0.8232	2.1833	0.8232
REXUK	-0.0857	0.0128	-6.6723	0.0000	0.4148	0.8387	2.0739	0.8388
	0.0000	0.0000	0.9010	0.3678	0.5309	0.7530	2.6545	0.7531
RBUK	-0.0867	0.0129	-6.7302	0.0000	1.2897	0.2656	6.4483	0.2650
	0.0000	0.0000	-0.0272	0.9783	0.4364	0.8234	2.1818	0.8235
RSMUK	-0.0911	0.0132	-6.8924	0.0000	0.3864	0.8584	1.9319	0.8585
	-0.0172	0.0173	-0.9928	0.3209	0.8849	0.4903	4.4245	0.4901
RBUS	-0.0987	0.0137	-7.2251	0.0000	1.8185	0.1061	9.0923	0.1054
	0.0000	0.0000	-0.0355	0.9717	0.4096	0.8424	2.0478	0.8425
RSMUS	-0.0891	0.0131	-6.8232	0.0000	0.3685	0.8704	1.8426	0.8705
	-0.0043	0.0058	-0.7503	0.4532	0.2742	0.9274	1.3710	0.9275
REXVN	-0.0859	0.0128	-6.6948	0.0000	0.1127	0.9896	0.5633	0.9896
	0.0000	0.0000	0.4127	0.6799	0.0852	0.9946	0.4258	0.9946
RBVN	-0.0863	0.0129	-6.7035	0.0000	0.0967	0.9927	0.4837	0.9927
	0.0000	0.0000	-0.4455	0.6560	0.2059	0.9601	1.0297	0.9601
RSMVN	-0.0961	0.0137	-7.0233	0.0000	0.1066	0.9908	0.5331	0.9909
	0.0049	0.0029	1.6725	0.0946	1.0693	0.3756	5.3463	0.3751

Table 4 (a) illustrates that there is long term causality coming from each of the traditional asset classes towards crypto-currency market. Table 4 (b) shows, Wald Test to find out the short term causality flowing between each of traditional assets and crypto-currency market.

Furthermore, Wald Test is used to find out the short term causality flowing between each of traditional assets and crypto-currency market. Table 4 (b), finds there is no short term causality flowing from any of the traditional assets to the crypto-currency market except short term causality running from crypto-currency market to gold, short term causality running from RBCA to crypto-currency market, short term causality running from RBJP to crypto-currency market and vice versa, short term causality running from crypto-currency market to RSMJP.

BEKK-GARCH

Table 5 exhibits the maximum likelihood estimation for the BEKK GARCH model. The model implies that the parameters of A (1,1) and A(2,2) turns out to be statistically significant for crypto-currency with all traditional assets except RCM-RBRU, A(1,1) insignificant in RCM-REXVN, RCM-RBVN. The positive and statistical significance of A (1,1) indicates short

term persistence in shocks on dynamic conditional correlations. However, positive value of A (1,1)+A(2,2) indicates presence of long term persistence of crypto-currency market with traditional assets.

Table 5: BEKK GARCH

RCM-REXBR					**RCM-REXCA**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00234	0.00024	9.73666	0.0000	Con. (RCM)	0.002582	0.000249	10.3675	0.0000
Con.(REXBR)	-9.90E-05	0.00019	-0.51061	0.6096	Con.(REXCA)	-0.00022	9.41E-05	-2.29645	0.0217
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	2.34E-07	5.84E-07	0.4001	0.6891	M(1,1)	-4.40E-08	4.61E-07	-0.09531	0.9241
M(1,2)	-1.31E-06	1.67E-06	-0.78336	0.4334	M(1,2)	-4.64E-08	3.53E-07	-0.13131	0.8955
M(2,2)	2.06E-05	1.14E-05	1.80356	0.0713	M(2,2)	1.20E-06	1.19E-06	1.002573	0.3161
A1(1,1)	-9.23E-06	2.62E-06	-3.52459	0.0004	A1(1,1)	-8.49E-06	2.46E-06	-3.4497	0.0006
A1(2,2)	0.84018	0.15868	5.29483	0.0000	A1(2,2)	0.601906	0.116726	5.156551	0.0000
B1(1,1)	1.00147	0.00012	8350.09	0.0000	B1(1,1)	1.001522	0.000123	8117.906	0.0000
B1(2,2)	0.96097	0.00964	99.7358	0.0000	B1(2,2)	0.978357	0.006352	154.027	0.0000
Log Likelihood		8592.11			Log Likelihood		9743.518		
RCM-RBBR					**RCM-RBCA**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.0023	0.00024	9.65655	0.0000	Con. (RCM)	0.002498	0.000242	10.3006	0.0000
Con. (RBBR)	-0.0006	0.00021	-2.85322	0.0043	Con. (RBCA)	-0.00086	0.000415	-2.06338	0.0391
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	Prob.
M(1,1)	3.06E-07	6.01E-07	0.50917	0.6106	M(1,1)	7.86E-08	5.38E-07	0.146158	0.8838
M(1,2)	-6.36E-07	4.73E-06	-0.13438	0.8931	M(1,2)	-3.43E-07	1.93E-06	-0.1772	0.8594
M(2,2)	0.00012	5.24E-05	2.3278	0.0199	M(2,2)	1.48E-05	1.74E-05	0.848618	0.3961
A1(1,1)	9.39E-06	2.59E-06	3.62132	0.0003	A1(1,1)	9.35E-06	2.48E-06	3.773721	0.0002
A1(2,2)	1.13999	0.21904	5.20439	0.0000	A1(2,2)	0.715282	0.133513	5.357378	0.0000
B1(1,1)	1.00145	0.00012	8620.99	0.0000	B1(1,1)	1.001492	0.000122	8237.472	0.0000
B1(2,2)	0.89771	0.02463	36.4436	0.0000	B1(2,2)	0.976312	0.005906	165.3167	0.0000
Log Likelihood		8443.18			Log Likelihood		7338.244		
RCM-RSMBR					**RCM-RSMCA**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00253	0.00024	10.4041	0.0000	Con. (RCM)	0.958938	4.546857	0.210901	0.8330
Con.(RSMBR)	0.00058	0.00028	2.04144	0.0412	Con.(RSMCA)	0.000136	0.001857	0.072978	0.9418
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	9.32E-08	5.03E-07	0.18522	0.8531	M(1,1)	25.71032	13.98571	1.838327	0.066
M(1,2)	-1.04E-06	2.51E-06	-0.41373	0.6791	M(1,2)	8.45E-05	0.026637	0.003173	0.9975

M(2,2)	6.36E-05	3.34E-05	1.90004	0.0574	M(2,2)	6.92E-06	2.33E-06	2.974914	0.0029
A1(1,1)	-8.81E-06	2.45E-06	-3.58913	0.0003	A1(1,1)	-0.00016	3.72E-05	-4.21108	0.0000
A1(2,2)	0.78304	0.15352	5.10063	0.0000	A1(1,2)	0.008321	0.15514	0.053636	0.9572
B1(1,1)	1.00151	0.00012	8435.8	0.0000	A1(2,2)	-0.00033	4.30E-05	-7.63233	0.0000
B1(2,2)	0.95428	0.01326	71.9812	0.0000	B1(1,1)	0.865175	0.072301	11.96625	0.0000
Log Likelihood		8053.87			B1(1,2)	0.929519	3.596769	0.258432	0.7961
					B1(2,2)	0.979281	0.007093	138.0543	0.0000
					Log Likelihood		-142.779		
RCM-REXGR					**RCM-REXJP**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00237	0.00024	9.79848	0.0000	Con. (RCM)	0.001991	0.000211	9.433028	0.0000
Con.(REXGR)	-8.39E-05	9.18E-05	-0.91434	0.3605	Con. (REXJP)	-0.00012	0.000109	-1.08094	0.2797
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	-2.47E-08	5.12E-07	-0.04821	0.9615	M(1,1)	1.40E-06	1.35E-06	1.042285	0.2973
M(1,2)	-8.12E-08	3.70E-07	-0.21934	0.8264	M(1,2)	3.38E-06	6.20E-06	0.545568	0.5854
M(2,2)	8.65E-07	8.53E-07	1.01472	0.3102	M(2,2)	4.73E-05	2.22E-05	2.130252	0.0332
A1(1,1)	9.52E-06	2.48E-06	3.8294	0.0001	A1(1,1)	1.22E-05	3.20E-06	3.810627	0.0001
A1(2,2)	0.62687	0.12433	5.04188	0.0000	A1(2,2)	1.822232	0.389189	4.682131	0.0000
B1(1,1)	1.00151	0.00012	8235.91	0.0000	B1(1,1)	1.001404	0.00011	9137.014	0.0000
B1(2,2)	0.97981	0.00533	183.739	0.0000	B1(2,2)	0.866996	0.018779	46.16829	0.0000
Log Likelihood		9721.98			Log Likelihood		9458.905		
RCM-RBGR					**RCM-RBJP**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00215	0.00022	9.75534	0.0000	Con. (RCM)	0.002032	0.000218	9.338795	0.0000
Con. (RBGR)	-0.0031	0.00093	-3.35043	0.0008	Con. (RBJP)	-0.00275	0.000905	-3.04006	0.0024
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	5.41E-07	8.30E-07	0.65123	0.5149	M(1,1)	1.23E-06	1.08E-06	1.136424	0.2558
M(1,2)	-3.39E-05	2.59E-05	-1.30748	0.1910	M(1,2)	2.90E-05	5.14E-05	0.56501	0.5721
M(2,2)	0.00117	0.00046	2.52936	0.0114	M(2,2)	0.002672	0.000999	2.674734	0.0075
A1(1,1)	-1.14E-05	2.64E-06	-4.32105	0.0000	A1(1,1)	1.14E-05	3.08E-06	3.692452	0.0002
A1(2,2)	2.11678	0.37809	5.5986	0.0000	A1(2,2)	2.599417	0.476333	5.457141	0.0000
B1(1,1)	1.00142	0.00011	8905.81	0.0000	B1(1,1)	1.00127	0.000115	8698.99	0.0000
B1(2,2)	0.84282	0.01014	83.1203	0.0000	B1(2,2)	0.747105	0.012074	61.87755	0.0000
Log Likelihood		5139.31			Log Likelihood		4854.357		
RCM-RSMGR					**RCM-RSMJP**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.0024	0.00024	10.2262	0.0000	Con. (RCM)	0.00239	0.000232	10.30966	0.0000
Con. (RSMGR)	0.00077	0.00019	4.10017	0.0000	Con. (RSMJP)	0.000877	0.000201	4.368162	0.0000
Covariance Specifications					**Covariance Specifications**				

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	4.69E-07	6.21E-07	0.75491	0.4503
M(1,2)	-5.50E-07	1.10E-06	-0.50119	0.6162
M(2,2)	-3.77E-07	3.75E-06	-0.10043	0.9200
A1(1,1)	8.31E-06	2.81E-06	2.95623	0.0031
A1(2,2)	0.80635	0.14965	5.38818	0.0000
B1(1,1)	1.00144	0.00012	8439.18	0.0000
B1(2,2)	0.97179	0.00548	177.444	0.0000
Log Likelihood		8593.88		

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	8.41E-07	8.64E-07	0.973066	0.3305
M(1,2)	-1.51E-06	5.27E-06	-0.2873	0.7739
M(2,2)	6.03E-05	2.94E-05	2.051908	0.0402
A1(1,1)	9.85E-06	2.98E-06	3.29947	0.0010
A1(2,2)	1.380336	0.261645	5.275614	0.0000
B1(1,1)	1.001385	0.000115	8695.334	0.0000
B1(2,2)	0.911567	0.014088	64.70645	0.0000
Log Likelihood		8465.567		

RCM-REXKO

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	-0.0001	0.00024	-0.73518	0.4622
Con. (REXKO)	1.58E-0	1.28E-06	12.3096	0.0000

Covariance Specifications

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	0.10533	0.0587	1.79455	0.0727
M(1,2)	0.00186	0.00112	1.66262	0.0964
M(2,2)	-1.79E-05	8.08E-06	-2.21219	0.0270
A1(1,1)	0.02866	0.00812	3.53044	0.0004
A1(2,2)	-0.79788	0.23337	-3.41899	0.0006
B1(1,1)	1.00092	6.36E-05	15733	0.0000
B1(2,2)	1.00139	0.00013	8001.03	0.0000
Log Likelihood		13936.5		

RCM-REXRU

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	0.002644	0.000252	10.47861	0.0000
Con.(REXRU)	-0.00027	0.000167	-1.64096	0.1008

Covariance Specifications

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	-1.40E-07	4.04E-07	-0.34637	0.7291
M(1,2)	6.33E-07	8.27E-07	0.764711	0.4444
M(2,2)	7.00E-06	3.20E-06	2.187184	0.0287
A1(1,1)	8.12E-06	2.26E-06	3.589227	0.0003
A1(2,2)	0.700878	0.117123	5.984107	0.0000
B1(1,1)	1.001548	0.000126	7918.097	0.0000
B1(2,2)	0.965602	0.006748	143.0989	0.0000
Log Likelihood		8671.534		

RCM-RBKO

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	0.00239	0.00024	9.82275	0.0000
Con. (RBKO)	-0.0004	0.00024	-1.89006	0.0587

Covariance Specifications

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	1.79E-08	5.08E-07	0.03517	0.9719
M(1,2)	1.06E-06	1.19E-06	0.88881	0.3741
M(2,2)	8.43E-06	6.26E-06	1.34672	0.1781
A1(1,1)	-9.34E-06	2.47E-06	-3.77699	0.0002
A1(2,2)	0.65916	0.11583	5.69092	0.0000
B1(1,1)	1.00148	0.00012	8238.06	0.0000
B1(2,2)	0.97478	0.00598	163.058	0.0000
Log Likelihood		8249.52		

RCM-RBRU

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	0.001876	0.000174	10.78409	0.0000
Con. (RBRU)	-7.23E-05	0.000145	-0.50046	0.6168

Covariance Specifications

	Coeff.	Std. Err	Z-Stat	Prob.
M(1,1)	0.01867	3.079193	0.006063	0.9952
M(1,2)	-0.00819	1.351684	-0.00606	0.9952
M(2,2)	0.000505	0.083678	0.006033	0.9952
A1(1,1)	-0.00033	0.02735	-0.01216	0.9903
A1(2,2)	65.49637	5399.084	0.012131	0.9903
B1(1,1)	1.00109	8.80E-05	11381.99	0.0000
B1(2,2)	0.972904	0.003751	259.3832	0.0000
Log Likelihood		8789.363		

RCM-RSMKO

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	0.00255	0.00024	10.5988	0.0000
Con. (RSMKO)	0.00046	0.00014	3.28134	0.0010

RCM-RSMRU

Mean Equation

	Coeff.	Std. Err	Z-Stat	Prob.
Con. (RCM)	0.002525	0.000244	10.33298	0.0000
Con.(RSMRU)	0.000483	0.000198	2.440494	0.0147

Covariance Specifications				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	2.37E-07	5.44E-07	0.43653	0.6625
M(1,2)	-1.33E-06	1.53E-06	-0.8691	0.3848
M(2,2)	2.10E-05	1.18E-05	1.78811	0.0738
A1(1,1)	-8.97E-06	2.47E-06	-3.62857	0.0003
A1(2,2)	0.74224	0.14695	5.05086	0.0000
B1(1,1)	1.00144	0.00012	8375.27	0.0000
B1(2,2)	0.94751	0.01638	57.8436	0.0000
Log Likelihood		9155.33		

Covariance Specifications				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	6.98E-08	4.58E-07	0.152366	0.8789
M(1,2)	9.44E-07	2.53E-06	0.372876	0.7092
M(2,2)	5.07E-05	2.24E-05	2.266541	0.0234
A1(1,1)	-8.15E-06	2.43E-06	-3.36009	0.0008
A1(2,2)	0.852615	0.157886	5.400202	0.0000
B1(1,1)	1.001518	0.000121	8282.191	0.0000
B1(2,2)	0.932961	0.017739	52.59381	0.0000
Log Likelihood		8570.978		

RCM-REXTR

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00251	0.00024	10.4352	0.0000
Con. (REXTR)	-0.0003	0.00016	-2.13255	0.0330

Covariance Specifications

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	4.37E-07	6.18E-07	0.70744	0.4793
M(1,2)	6.89E-07	3.56E-06	0.19376	0.8464
M(2,2)	6.35E-05	2.68E-05	2.36636	0.0180
A1(1,1)	8.97E-06	2.69E-06	3.33608	0.0008
A1(2,2)	1.27173	0.23672	5.37241	0.0000
B1(1,1)	1.00139	0.00012	8486.89	0.0000
B1(2,2)	0.8832	0.02263	39.0206	0.0000
Log Likelihood		8883.4		

RCM-REXUK

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.002293	0.000238	9.647259	0.0000
Con. (REXUK)	-6.81E-05	9.79E-05	-0.69535	0.4868

Covariance Specifications

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	-9.89E-08	4.93E-07	-0.20073	0.8409
M(1,2)	-2.31E-07	3.77E-07	-0.61235	0.5403
M(2,2)	1.03E-06	9.10E-07	1.128683	0.2590
A1(1,1)	-9.64E-06	2.41E-06	-3.99706	0.0001
A1(2,2)	0.607778	0.117744	5.161837	0.0000
B1(1,1)	1.001537	0.000119	8416.266	0.0000
B1(2,2)	0.979585	0.004638	211.2218	0.0000
Log Likelihood		9630.458		

RCM-RBTR

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00282	0.00028	10.2147	0.0000
Con. (RBTR)	0.00011	0.00028	0.38637	0.6992

Covariance Specifications

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	-1.12E-08	2.73E-07	-0.04092	0.9674
M(1,2)	4.51E-07	3.24E-08	13.9345	0.0000
M(2,2)	-6.08E-06	1.04E-10	-58391	0.0000
A1(1,1)	-4.56E-06	2.13E-06	-2.1357	0.0327
A1(2,2)	-0.02216	0.00291	-7.6265	0.0000
B1(1,1)	1.00153	0.00013	7892.16	0.0000
B1(2,2)	1.00375	6.30E-05	15924.7	0.0000
Log Likelihood		8011.64		

RCM-RBUK

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.002484	0.00024	10.33466	0.0000
Con. (RBUK)	-0.00094	0.000515	-1.82601	0.0678

Covariance Specifications

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	3.40E-08	5.60E-07	0.060718	0.9516
M(1,2)	-5.12E-07	1.94E-06	-0.26421	0.7916
M(2,2)	3.41E-05	2.38E-05	1.434146	0.1515
A1(1,1)	-1.00E-05	2.49E-06	-4.02592	0.0001
A1(2,2)	0.654022	0.120639	5.42134	0.0000
B1(1,1)	1.00149	0.000119	8394.832	0.0000
B1(2,2)	0.97952	0.004629	211.5982	0.0000
Log Likelihood		6966.372		

RCM-RSMTR

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00223	0.00022	10.1489	0.0000

RCM-RSMUK

Mean Equation

	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.003066	0.000277	11.06248	0.0000

Con. (RSMTR)	0.00043	0.00027	1.5799	0.1141	Con.(RSMUK)	0.000159	0.000163	0.977869	0.3281
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	2.03E-06	1.59E-06	1.27475	0.2024	M(1,1)	-4.59E-07	2.59E-07	-1.77561	0.0758
M(1,2)	0.00019	0.00705	0.02708	0.9784	M(1,2)	-5.06E-08	2.26E-08	-2.23524	0.0254
M(2,2)	0.00364	0.05549	0.06566	0.9477	M(2,2)	-9.80E-07	6.37E-07	-1.53918	0.1238
A1(1,1)	-1.00E-05	3.54E-06	-2.83634	0.0046	A1(1,1)	-6.26E-06	1.53E-06	-4.09486	0.0000
A1(2,2)	-0.00017	7.89836	-2.15E-05	1.0000	A1(2,2)	0.012453	0.001372	9.074351	0.0000
B1(1,1)	1.00137	0.00011	9228.52	0.0000	B1(1,1)	1.001702	0.000146	6855.919	0.0000
B1(2,2)	-0.1719	43.2145	-0.00398	0.9968	B1(2,2)	1.001779	0.001203	832.5755	0.0000
Log Likelihood		8140.95			Log Likelihood		8930.516		
RCM-REXVN					**RCM-RBUS**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00669	0.00048	13.9462	0.0000	Con. (RCM)	0.00248	0.000246	10.10117	0.0000
Con.(REXVN)	2.17E-09	6.62E-06	0.00033	0.9997	Con. (RBUS)	-0.0002	0.000353	-0.57698	0.5640
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	0.00061	0.00106	0.57229	0.5671	M(1,1)	-5.81E-08	4.61E-07	-0.12592	0.8998
M(1,2)	-5.40E-10	2.42E-07	-0.00223	0.9982	M(1,2)	9.80E-07	1.23E-06	0.799592	0.4239
M(2,2)	1.19E-12	1.05E-12	1.12715	0.2597	M(2,2)	1.04E-05	1.05E-05	0.996768	0.3189
A1(1,1)	6.89E-07	5.86E-05	0.01177	0.9906	A1(1,1)	8.79E-06	2.37E-06	3.705828	0.0002
A1(2,2)	1.83187	0.22581	8.11249	0.0000	A1(2,2)	0.537285	0.10796	4.976726	0.0000
B1(1,1)	0.87642	0.22935	3.82136	0.0001	B1(1,1)	1.001523	0.000128	7841.964	0.0000
B1(2,2)	0.74371	0.00815	91.2102	0.0000	B1(2,2)	0.983511	0.00494	199.111	0.0000
Log Likelihood		11962.9			Log Likelihood		7635.333		
RCM-RBVN					**RCM-RSMUS**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
Con. (RCM)	0.00671	0.00047	14.1527	0.0000	Con. (RCM)	0.002412	0.000236	10.23933	0.0000
Con. (RBVN)	-2.28E-09	2.07E-05	-0.00011	0.9999	Con. (RSMUS)	0.00071	0.000125	5.684077	0.0000
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	0.00033	0.00035	0.94095	0.3467	M(1,1)	4.08E-07	6.53E-07	0.624194	0.5325
M(1,2)	1.47E-11	1.29E-06	1.14E-05	1.0000	M(1,2)	5.62E-07	2.40E-06	0.234101	0.8149
M(2,2)	2.17E-13	3.00E-13	0.7244	0.4688	M(2,2)	1.92E-05	8.41E-06	2.285062	0.0223
A1(1,1)	3.05E-06	9.06E-05	0.03362	0.9732	A1(1,1)	-9.54E-06	2.64E-06	-3.61176	0.0003
A1(2,2)	1.39974	0.20273	6.90445	0.0000	A1(2,2)	1.33286	0.228856	5.824018	0.0000
B1(1,1)	0.9469	0.05631	16.8146	0.0000	B1(1,1)	1.001456	0.000115	8693.384	0.0000
B1(2,2)	0.80995	0.0045	180.087	0.0000	B1(2,2)	0.91018	0.014264	63.80978	0.0000
Log Likelihood		9969.84			Log Likelihood		9171.604		
RCM-RSMVN					**RCM-RGM**				
Mean Equation					**Mean Equation**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**

Con. (RCM)	0.0027	0.00025	11.0196	0.0000	Con. (RCM)	0.002077	0.000218	9.516471	0.0000
Con.(RSMVN)	0.00083	0.00018	4.56098	0.0000	Con. (RGM)	-0.00011	0.00019	-0.56079	0.5749
Covariance Specifications					**Covariance Specifications**				
	Coeff.	**Std. Err**	**Z-Stat**	**Prob.**		**Coeff.**	**Std. Err**	**Z-Stat**	**Prob.**
M(1,1)	2.09E-07	4.88E-07	0.42766	0.6689	M(1,1)	1.24E-06	1.23E-06	1.001219	0.3167
M(1,2)	6.05E-07	2.81E-06	0.21536	0.8295	M(1,2)	-3.60E-06	5.62E-05	-0.06408	0.9489
M(2,2)	4.68E-05	1.89E-05	2.48074	0.0131	M(2,2)	0.001381	0.000513	2.690369	0.0071
A1(1,1)	-8.21E-06	2.56E-06	-3.20635	0.0013	A1(1,1)	-1.25E-05	3.06E-06	-4.07737	0.0000
A1(2,2)	1.06426	0.18483	5.75813	0.0000	A1(2,2)	2.159624	0.429764	5.025143	0.0000
B1(1,1)	1.00144	0.00012	8363.33	0.0000	B1(1,1)	1.001437	0.000107	9381.931	0.0000
B1(2,2)	0.90961	0.0174	52.2781	0.0000	B1(2,2)	0.127022	0.139253	0.912172	0.3617
Log Likelihood		8663.54			Log Likelihood		8535.88		

Table 5 exhibits the maximum likelihood estimation for the BEKK GARCH model.

Secondly, to measure variances and covariances between crypto-currency market and traditional assets, positive coefficients of B(1,1) and B(2,2) indicate increase in variance in returns of crytocurrency market puts positive impact on the covariances between crypto-currency market and traditional assets in future period. Whereas positive value of B(1,1)+B(2,2) depicts increase in covariances flows increase in covariances in future period between crypto-currency and traditional assets. The results show statistically significance between crypto-currency market and traditional assets except RCM-RSMTR and RCM-RGM.

Hedge Ratio

The hedge ratio determines the volatility of crypto-currency relative to traditional assets. The optimal hedge ratio is 1. The ratio above 1 for a crypto-currency market shows rapid change in returns and inclines high risk yet typically high returns and less than 1 hedge ratio means slow change in returns, declining risk yet potentially low returns. In comparison of crytptocurrency marker and traditional assets the hedge ratio is calculated given in Table 6.

Table 6: Hedge Ratio

	VaR(ΔK_t)	**CoVaR($\Delta C_t \Delta K_t$)**	**Hedge Ratio**
RGM	0.00028	-0.00875	-30.9873
REXBR	0.00010	-0.01298	-124.7906
RBBR	0.00014	0.01759	124.0705
RSMBR	0.00020	0.00114	5.7292
REXCA	0.00002	-0.00001	-0.5837
RBCA	0.00057	-0.00476	-8.3430
RSMCA	0.00068	0.00439	6.4164

REXGR	0.00003	0.00106	41.1781
RBGR	0.99839	0.03633	0.0364
RSMGR	0.00012	0.00182	15.7275
REXJP	0.00004	-0.01303	-320.1866
RBJP	1.57090	-0.02726	-0.0174
RSMJP	0.00015	0.02054	134.7619
REXKO	0.05354	-0.01110	-0.2073
RBKO	0.00017	0.02234	127.9688
RSMKO	0.00005	-0.00690	-130.5068
REXRU	0.00015	-0.00151	-9.9725
RBRU	0.00017	0.00309	18.3281
RSMRU	0.00012	-0.00448	-38.1845
REXTR	0.00010	0.00421	41.8028
RBTR	0.00088	0.01303	14.8104
RSMTR	0.00082	-0.01062	-13.0185
REXUK	0.00003	0.00048	15.0310
RBUK	0.00096	0.02595	26.8933
RSMUK	0.00071	0.00466	6.5849
RBUS	0.00037	-0.01179	-31.9163
RSMUS	0.00006	0.01562	244.4527
REXVN	0.00000	0.00037	90.3260
RBVN	0.00005	-0.00394	-78.0156
RSMVN	0.00011	-0.00011	-0.9198

Table 6, determines hedge ratio to report volatility of crypto-currency relative to traditional assets.

The highest hedge ratio is stated between crypto-currency market and RSMUS as 244.4527 which indicates that crypto-currency returns are 144.4% times more volatile than stock returns in United States. Whereas the lowest hedge ratio is reported between crypto-currency market and REXJP as -320.1866 which indicate that crypto-currency returns are 220.2% times less volatile than currency exchange rate in Japan.

Conclusion

The paper attempts to investigate the role of crypto-currency market in comparison with other traditional assets like currency exchange rates, stock returns, government bonds and gold in ten countries where crypto-currency is being traded most frequently. The empirical results suggests that there is long term uni-directional causality running from each of the given asset towards crypto-currency market yet no causality is running from crypto-currency market to other assets. These results show long term relationship and any change in returns of the traditional assets cause change in returns of crytpcurrencies. However no short term causality is reported except uni-directional causality coming from crypto-currency to gold, RBCA and RSMJP and bi-directional causality between RBJP and crypto-currency.

Moreover, statistical significance of BEKK GARCH model proves short term and long term persistence in conditional correlations between crypto-currency market and traditional assets except RCM-RBRU, RCM-REXVN and RCM-RBVN. The results indicate that returns of crypto-currencies and traditional assets are correlated and conditional to any change. On the other hand change in variance in returns of cyptocurrencies (traditional assets) changes covariances between them. The positive increase in variances positively impacts the covariances between them in the future period for all combinations except RCM-RSMTR and RCM-RGM. These results show co-movements between crypto-currencies and traditional assets. Finally the hedge ratio reports the volatility in returns of crypto-currencies as compares to each of the traditional assets. The highest volatility is reported in crypto-currency returns against stock market of US whereas lowest is reported against currency exchange rate of Japan. The hedge ratio on crypto-currency market and other asset classes by applying bivariate BEKK GARCH model and vector error correction (VECM) model, find that hedging with crypto-currency provide risk reduction and increase returns.

The study finds the long term relationship between traditional assets and cryptocurreny market, yet no short term relationship is observed as a whole. It also finds the comovements in conditional correlations and covariances, where change in returns of one asset effects covariances between them. The study concludes that crypto-currency can be safe haven for investment in times of unfavorable macro-economic indicators, since crypto-currency is independent of such changes. The change in crypto-currency returns may not effect returns of traditional assets yet any change in traditional assets may possibly upsurge towards change in crypto-currency market in the long term. The volatility in returns of crypto-currencies show degree of variations over time, the more volatility means more sensitivity in change in prices which ultimately leads to more opportunities for masses interested to invest in crypto-currencies. Therefore it can be used as an investment alternative along with other asset classes in order to hedge the risk in times of unfavorable macroeconomic conditions. The findings of the study are consistent with Fakhfekh et.al, (2021), Shalini (2022), and Murty et.al, (2022).

The study can be tested with other parametric models of Value at risk. It has wide scope to be framed for other countries where attempts are being taken to regulate crypto-currencies. The results of the study are deemed useful for investors, managers and policy makers.

List of Abbreviations

Abbreviations	Title
RCM	Returns of Crypto-currency Market
RGM	Returns of Gold Market
REXBR	Returns of Exchange Rate of Brazil
RBBR	Returns of 10Y Government Bond of Brazil
RSMBR	Returns of Stock Market of Brazil
REXCA	Returns of Exchange Rate of Canada
RBCA	Returns of 10Y Government Bond of Canada
RSMCA	Returns of Stock Market of Canada
REXGR	Returns of Exchange Rate of Germany
RBGR	Returns of 10Y Government Bond of Germany
RSMGR	Returns of Stock Market of Germany
REXJP	Returns of Exchange Rate of Japan
RBJP	Returns of 10Y Government Bond of Japan
RSMJP	Returns of Stock Market of Japan
REXKO	Returns of Exchange Rate of South Korea
RBKO	Returns of 10Y Government Bond of South Korea
RSMKO	Returns of Stock Market of South Korea
REXRU	Returns of Exchange Rate of Russia
RBRU	Returns of 10Y Government Bond of Russia
RSMRU	Returns of Stock Market of Russia
REXTR	Returns of Exchange Rate of Turkey
RBTR	Returns of 10Y Government Bond of Turkey
RSMTR	Returns of Stock Market of Turkey
REXUK	Returns of Exchange Rate of United Kingdom
RBUK	Returns of 10Y Government Bond of United Kingdom
RSMUK	Returns of Stock Market of United Kingdom
REXUS	Returns of Exchange Rate of United States
RBUS	Returns of 10Y Government Bond of United States
RSMUS	Returns of Stock Market of United States
REXVN	Returns of Exchange Rate of Vietnam
RBVN	Returns of 10Y Government Bond of Vietnam
RSMVN	Returns of Stock Market of Vietnam

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