Co-Movement and Volatility Analysis of Sugar: Spot and Future

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***Abstract*— Co-movement and volatility analysis between variables are an important considerations in investment related decisions. The relationships of spot and two future priced sugar contracts are examined against the currency and main index of Brazil, China, Colombia, India, Indonesia, Mexico, Pakistan, Philippines and Thailand. Sugar which is produced in many countries around the world is the world's largest crop by production in metric tons. Co-movement and volatility analysis includes correlation, vector autoregression, Johansen cointegration test, impulse responses, pairwise Granger causality test and three GARCH models. The three GARCH models are the GARCH, GJR-GARCH and EGARCH models. A long run relationships exists between the three sugar variables, the three sugar variables and the Shanghai SE A Share Index; as well as between the tree sugar variables and the Thai Bhat. Co-movement results indicate that unidirectional and bidirectional relationships exist among the variables. A bi-directional relationship exists between sugar spot and CSCE sugar 11 future as well as between sugar spot and Liffe sugar future. Sugar spot and sugar future have a uni-directional relationship with the indices of Bangkok, Indonesia, Philippines, China, and India. Sugar spot and sugar futures Granger causes the currencies of Brazil, Colombia, Indonesia, Philippines, Thailand and India. The volatility analysis done shows that the AIC and SIC results of the GARCH models which indicates that the original GARCH model fits the data the best for sugar spot and the CSCE sugar 11 future. The EGARCH model fits the data the best for Liffe sugar future.**

***Index Terms*— Causality, Cointegration, co-movement, GARCH, Sugar, volatility.**

I. Introduction

The effect of commodity price movements on currencies and indices; and the related relationship between the commodity, currency and index differ for each commodity, currency and index. The relationships are important to understand as they could be used to better determine investment decisions and policy implications.

This paper explores the relationships between the spot and future international sugar price, as well as sugar against the currency (against the United States Dollar) and the main equity index for the top nine countries producing sugar.

Historical time-series price data of the Brazilian Real, Chinese Yuan, Colombian Peso, Indian Rupee, Indonesian Rupiah, Mexican Peso, Pakistan Rupee, Philippine Piso, Thai Baht, Brazil Bovespa Index, Colombian IGBC Index, Indian Nifty 500 Index, Indonesian IDX Composite Index, Mexico IPC (Bolsa) Index, Pakistan Karachi SE 100 Index, Philippine SE I Index, Shanghai SE A Share Index, Thailand Bangkok S.E.T Index as well as the sugar spot and two international sugar futures are included in this study. The sugar price will be examined against the index and the currency of the included sugar producers.

The objective of the study is to determine the following the significant relationships as well as combinations between them:

- Sugar against the included country indices
- Sugar against the included country currencies
- Sugar spot against sugar future

The empirical data analysis of the study will include correlation, vector autoregression, Johansen cointegration test, impulse responses, pairwise Granger causality test and three GARCH models.

The remainder of the paper is structured as follows; Section II provides a brief review of current literature. Sections III and IV discussed the methodology and explanation of the data. Section V illustrates the results and interprets the findings. The final part, part VI, discusses the conclusion and implication of the study.

II. Review of the Literature

Sugar, produced around the world is the world's largest crop by production in metric tons [1]. It is a commodity used by many around the world and is constantly in demand. Worldwide Sugar production reached a high point in 2012/2013 at 177 550 000 metric tons of production and has been decreasing yearly since then and the amount is for 2015/2016 forecasted at 173 405 000 metric tons. Worldwide sugar consumption has been increasing year or year with the 2010/2011 year at 155 403 000 metric tons and 2015/2016 forecast at 173 413 000 [2].

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Sugar price movement is important to understand as the investment and farming related decisions of sugarcane and beet are executed with an understanding of the commodity and its relationship with other factors. Factors of importance are the world sugar price expectations as well as the weather expectations for future crop yields.

Prior studies exploring the relationships of commodities are discussed as follows. Reference [3] investigated the price movements between monthly prices for crude oil futures and monthly futures prices for a selection of agricultural commodities, being cocoa, coffee, corn, soybeans, soybean oil, wheat, rice, sugar, and gold futures. The data period was from July 1989 until February 2010. The data was analysed over the full period as well as two sub periods, July 1989 to December 2001 and January 2002 to February 2010, using Johansen cointegration test, causality from VECM, and Threshold cointegration. Over the full sample period as well as the two sub periods, the cointegration results show that cocoa, wheat, and gold prices are cointegrated. In addition, in the first sub period, cocoa, soybeans, soybean oil, wheat, corn, and gold futures are cointegrated with crude oil futures prices. The second sub period only coffee, cocoa, wheat, and gold prices are cointegrated with crude oil futures prices. Overall, the commodity markets which are well established indicate co-movement with crude oil prices over the long run.

The short and long run relationships between crude oil, natural gas and electricity prices in the United States and European commodity markets are investigated by [4]. Data from October 2001 to March 2009 was included in the study with the use of daily prices analysed using rolling correlation, cointegration, and Error Correction Model (ECM). In the short term, a volatile relationship is found, where as in the long run an equilibrium relationship is identified.

Prior studies evaluating the relationships of commodities, currencies and indices differ in the selection of the commodities, the currencies, indices, time period selected as well as models applied to evaluate the relationships. The relationships differ in each of them, but it is clear that commodities do show co-movement with currencies and indices depending on which variables are selected. The extent to which co-movement appears is also dependent on the variables. Commodities that are a vital contribution of the economy of the country show more co-movement. Understanding this relationship can is therefore critical and can be used for investment and policy decisions.

III. Methodology

The data methodology is based on secondary historical time-series price data analysis using econometric tests including correlation, vector autoregression, Johansen cointegration, impulse response, and Granger causality tests in order to determine co-movements between the time series.

The initial movements between the datasets will be examined by the means of visual inspection and correlation. After the initial movement are investigated, the vector autoregression model, Johansen cointegration, impulse response, and pairwise Granger causality tests will be run. Finally three GARCH models will be run on the commodities to model volatility.

These tests are utilised to identify if any long run and short run relationships are present [5]–[8].

The relationships to be investigated are:

- Movements in the sugar price against movements in the relevant country's currency and main equity index
- Movements between sugar spot and sugar future

The GARCH models that will be used are the generalised autoregressive conditional heteroscedastic (GARCH) model, Threshold GARCH (TGARCH) model also known as the Glosten-Jagannathan-Runkle generalised autoregressive conditional heteroscedastic (GJR-GARCH) model, and the exponential GARCH (EGARCH) model. The best fitting model will be determined by the Akaike information criterion (AIC) [9] and the Schwarz information criterion (SIC) [10].

The GARCH model as specified by [11] is:

$$\sigma^2 = \omega + \alpha\mu_{t-1}^2 + \beta\sigma_{t-1}^2$$

The GARCH model allows the conditional variance to be dependent on the included variables own lags. σ in the above equation represents the estimated conditional variance for one period ahead of the selected variable.

The GJR-GARCH model includes leverage effects and is specified by [11] as:

$$\sigma^2 = \omega + \alpha\mu_{t-1}^2 + \beta\sigma_{t-1}^2 + \gamma\mu_{t-1}^2 I_{t-1}$$

where

$$I_{t-1} = \begin{cases} 1 \; if \; \mu_{t-1} < 0 \\ Otherwise \end{cases}$$

where γ equals the asymmetry term representing the leverage effect. If the asymmetry term is positive and statistically significant, there is leverage present.

The EGARCH model also includes leverage effects and is specified by [11] as:

$$\ln(\sigma^2) = \omega + \beta\ln(\sigma_{t-1}^2) + \gamma\frac{\mu_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha\left[\frac{|\mu_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}}\right]$$

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where γ equals the asymmetry term representing the leverage effect. If the asymmetry term is negative and statistically significant, there is leverage present.

IV. Data

Historical time-series price data of the spot and future international sugar price, as well as currency (against the United States Dollar) and the main equity index for the top 3 emerging countries exporting sugar is included in this study. The currency and equity index variables are: Brazilian Real, Chinese Yuan, Colombian Peso, Indian Rupee, Indonesian Rupiah, Mexican Peso, Pakistan Rupee, Philippine Piso, Thai Baht, Brazil Bovespa Index, Colombian IGBC Index, Indian Nifty 500 Index, Indonesian IDX Composite Index, Mexico IPC (Bolsa) Index, Pakistan Karachi SE 100 Index, Philippine SE I Index, Shanghai SE A Share Index, Thailand Bangkok S.E.T Index.

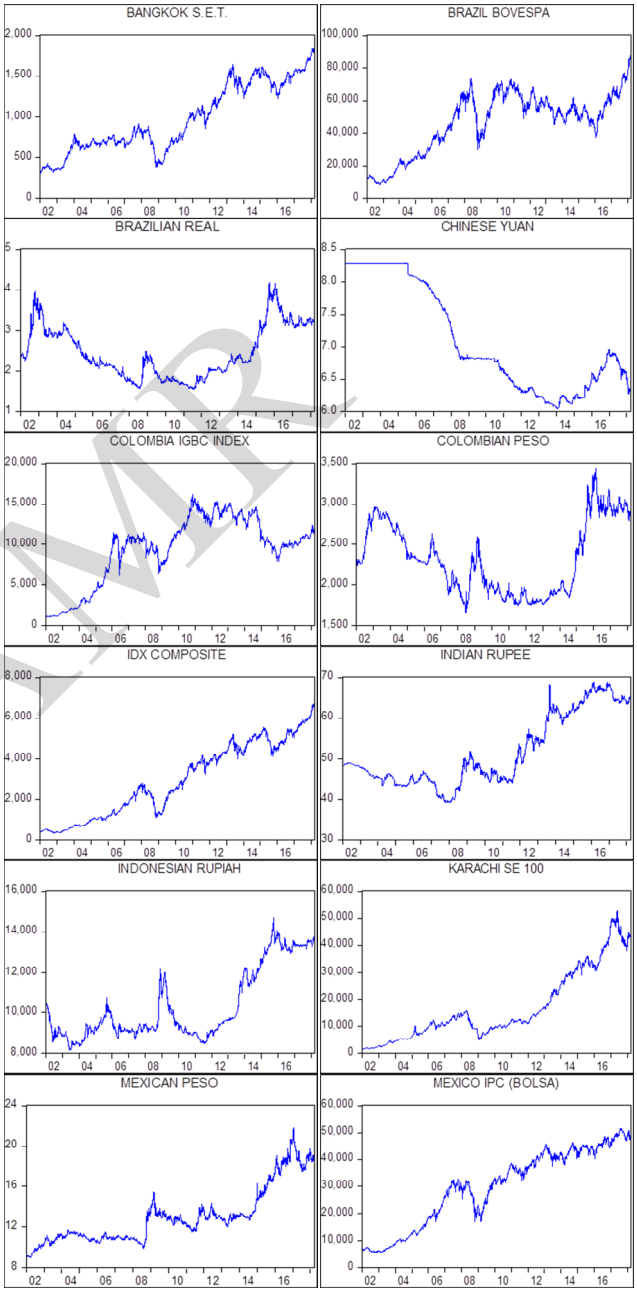
The spot and future sugar price will be examined against the main equity indices as well as the currencies. The datasets were obtained from the Thomson Reuters Datastream database. Daily spot prices from 1 January 2006 to 20 March 2018, which is 3187 datapoints is included in the study. The twenty one datasets included in the paper was analysed using EViews 9.5.

The empirical results are referenced as follows:

- Brazilian Real: BRAZILIAN_REAL
- Chinese Yuan: CHINESE_YUAN
- Colombian Peso: COLOMBIAN_PESO
- Indian Rupee: INDIAN_RUPEE
- Indonesian Rupiah: INDONESIAN_RUPIAH
- Mexican Peso: MEXICAN_PESO
- Pakistan Rupee: PAKISTAN_RUPEE
- Philippine Piso: PHILIPPINE_PISO
- Thai Baht: THAI_BAHT
- Brazil Bovespa Index: BRAZIL_BOVESPA
- Colombian IGBC Index: COLOMBIA_IGBC_INDEX
- Indian Nifty 500 Index: NIFTY_500
- Indonesian IDX Composite Index: IDX_COMPOSITE
- Mexico IPC (Bolsa) Index: MEXICO_IPC__BOLSA
- Pakistan Karachi SE 100 Index: KARACHI_SE_100
- Philippine SE I Index: PHILIPPINE_SE_I_PSEI
- Shanghai SE A Share Index: SHANGHAI_SE_A_SHARE
- Thailand Bangkok S.E.T Index: BANGKOK_S_E_T
- CSCE Sugar 11 future: CSCESUGARF11
- Liffe Sugar future: LIFFESUGARF
- Sugar spot: SUGARS

V. Empirical Results

The initial analysis of the data is in a graphical form shown in Figure 1. The daily price on the line graph of each variable is shown from 2002 to 2018.



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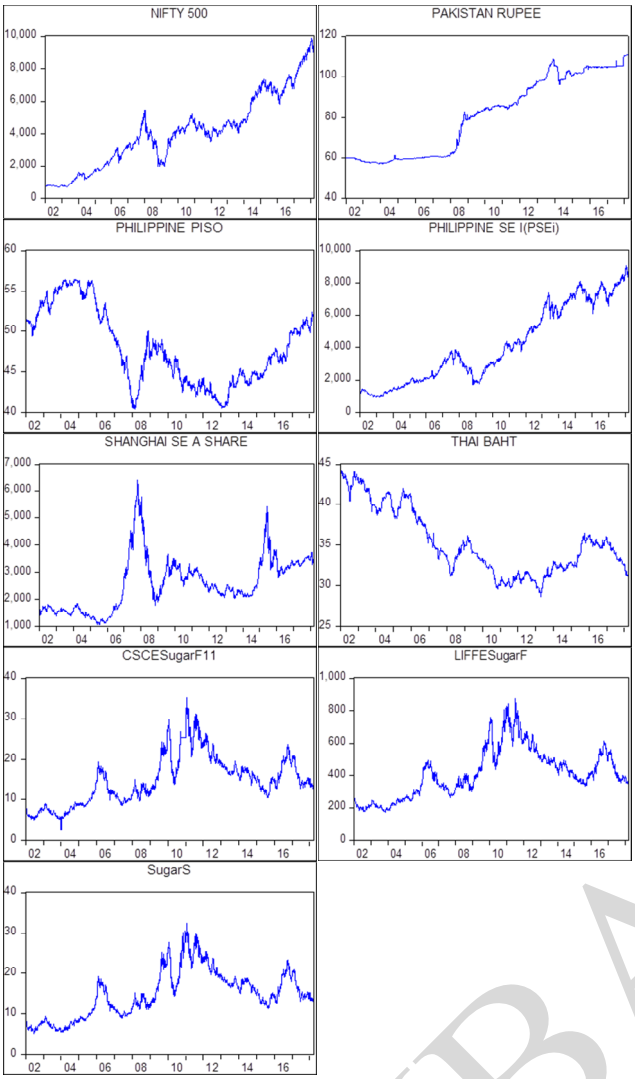


Figure 1: Graphical representation of movement in the twenty one datasets

Source: Researcher's analysis

The descriptive statistics of the twenty one datasets. The Jarque-Bera probability shows that the variables included are not normally distributed. In addition the Brazilian Real, Chinese Yuan, Indian Rupee, Indonesian Rupiah, Mexican Peso, Mexico IPC Index, Pakistan Rupee andCSCE Sugar 11 future are slightly positively skewed. All the other variables are slightly negatively skewed. The kurtosis in each case is greater than three which implies a leptokurtic distribution, meaning fatter tails are present. The Indonesian Rupiah, Pakistan Rupee and Thai Bhat have the highest kurtosis value.

Strong positive correlations based on logged return data (0.6 and above) are found between the following dataset combinations:

- Brazilian Bovespa Index and the Mexico IPC Index
- All three sugar data sets

Testing for unit roots are required in order to determine if the time series data is stationary or nonstationary. The data is tested using the Augmented Dickey-Fuller (ADF) [12] and Phillips-Perron (PP) [13]. The null hypotheses are:

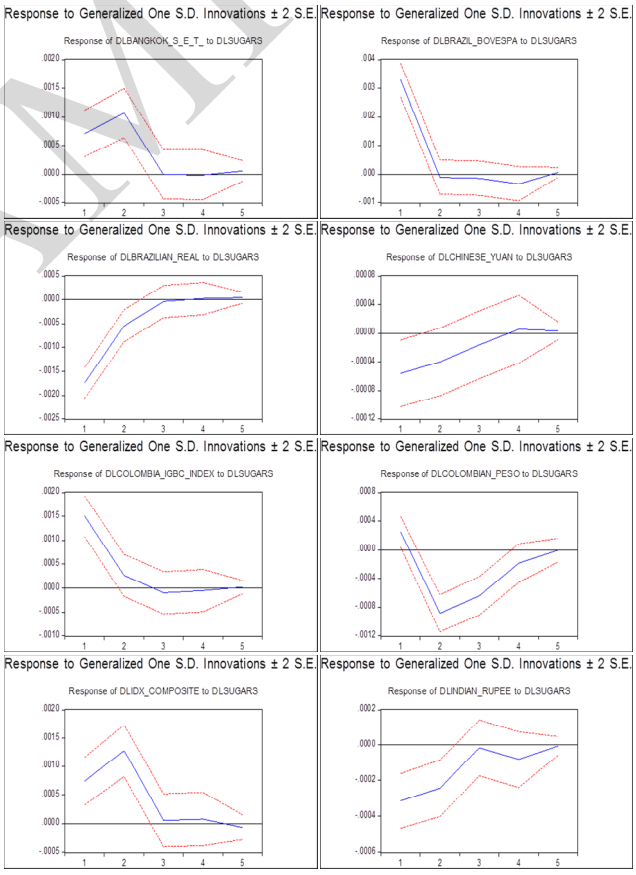
- ADF test: variable has a unit root
- PP test: variable has a unit root

The unit root test results show that all the variables are stationary at first difference at a 1% significance level, hence we conclude that the variables are integrated of order one.

The Johansen cointegration test, led by the VAR analysis is run for a number of combinations. The results obtained from the Johansen cointegration test showed that long run relationships are present between the following relationships:

- Three sugar datasets
- Three sugar datasets and the Shanghai SE A Share Index
- Three sugar datasets and the Thai Bhat

Figure 2 displays the impulse responses of sugar spot obtained.



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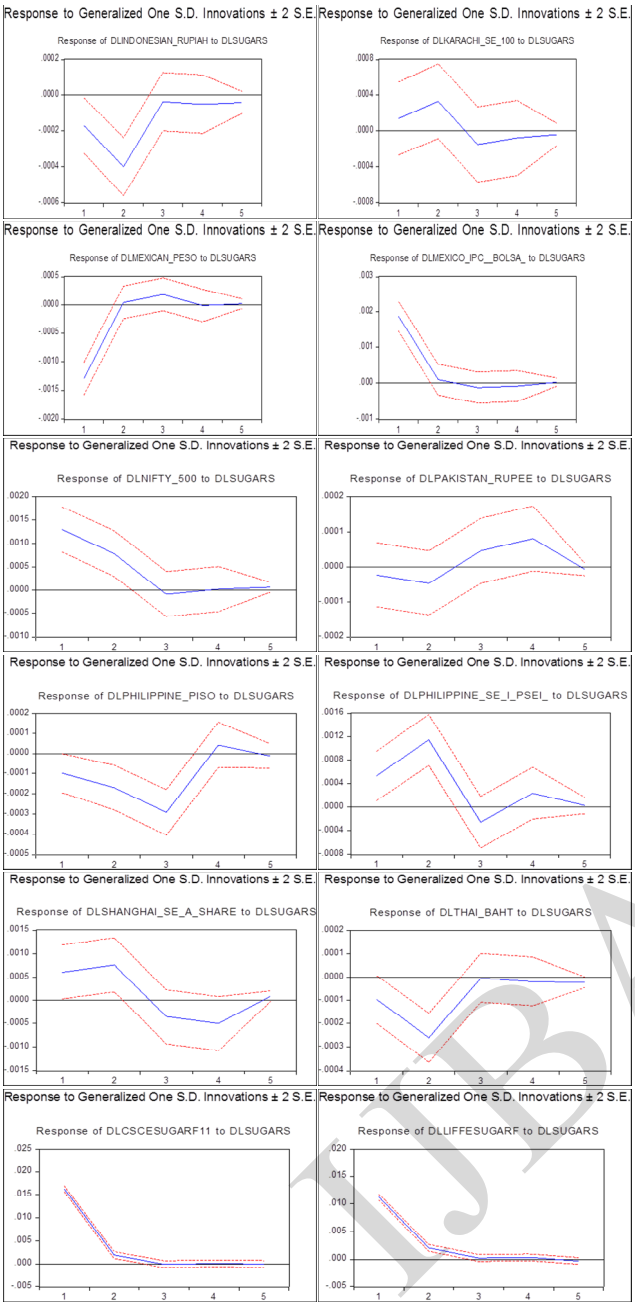


Figure 2: Impulse responses: Sugar spot

Source: Researcher's analysis

The pairwise Granger causality shows that bidirectional or feedback relationships exist between the following relevant datasets:

- Sugar spot and CSCE sugar 11 future
- Sugar spot and Liffe sugar future

The pairwise Granger causality shows that unidirectional relationships exist in the following relevant datasets:

- From CSCE sugar 11 future to Bangkok S.E.T Index
- From Liffe sugar future to Bangkok S.E.T Index
- From sugar spot to Bangkok S.E.T Index
- From Brazilian Bovespa Index to CSCE sugar 11 future
- From Brazilian Bovespa Index to sugar spot
- From sugar spot to Brazilian Real
- From CSCE sugar 11 future to Colombian Peso
- From Liffe sugar future to Colombian Peso
- From sugar spot to Colombian Peso
- From CSCE sugar 11 future to Indonesian IDX Composite Index
- From CSCE sugar 11 future to Indonesian Rupiah
- From Mexico IPC Index to CSCE sugar 11 future
- From CSCE sugar 11 future to Philippine Peso
- From CSCE sugar 11 future to Philippine SE Index
- From CSCE sugar 11 future to Shanghai SE A Share Index
- From CSCE sugar 11 future to Thai Bhat
- From Liffe sugar future to Indonesian IDX Composite Index
- From sugar spot to Indonesian IDX Composite Index
- From Liffe sugar future to Indian Rupee
- From sugar spot to Indian Rupee
- From Liffe sugar future to Indonesian Rupiah
- From sugar spot to Indonesian Rupiah
- From Mexico IPC Index to Liffe sugar future
- From Liffe sugar future to Philippine Peso
- From Liffe sugar future to Philippine SE Index
- From Liffe sugar future to Shanghai SE A Share Index
- From Liffe sugar future to Thai Bhat
- From Mexico IPC Index to sugar spot
- From sugar spot to Indian Nifty 500 Index
- From sugar spot to Philippine Piso
- From sugar spot to Philippine SE Index
- From sugar spot to Shanghai SE A Share Index
- From sugar spot to Thai Bhat
- From CSCE sugar 11 future to Liffe sugar future

The volatility modelling was done for sugar spot and sugar future. Table 1 displays the GARCH results for sugar spot and futures based on the GARCH, GJR-GARCH and EGARCH models. The GARCH model fits the data the best for sugar spot and CSCE sugar 11 future. The EGARCH model fits the data the best for Liffe sugar future. All three models indicate the shocks are persistent in the series. The gamma terms for Liffe Sugar future based on the EGARCH mils shows that leverage effects are present.

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TABLE 1: GARCH MODELS

Sugar spot	GARCH	GJR-GARCH	EGARCH
ω	0	0	-0.142
α	0.044	0.045	0.101
β	0.951	0.951	0.992
γ	-	-0.001	0.010
AIC	**-5.181**	-5.180	-5.180
SIC	**-5.173**	-5.171	-5.171
CSCE Sugar 11 future	**GARCH**	**GJR-GARCH**	**EGARCH**
ω	0	0	-0.911
α	0.012	0.013	0.114
β	0.986	0.986	0.893
γ	-	-0.003	0.034
AIC	**-4.934**	-4.933	-4.900
SIC	**-4.926**	-4.921	-4.891
Sugar spot	**GARCH**	**GJR-GARCH**	**EGARCH**
ω	0	0	-0.115
α	0.028	0.040	0.070
β	0.967	0.967	0.992
γ	-	-0.023	0.018
AIC	-5.367	-5.370	**-5.376**
SIC	-5.359	-5.360	**-5.366**

Source: Researcher's analysis

VI. CONCLUSIONS

The relationships of the spot and future international sugar price, as well as currency (against the United States Dollar) and the main equity index for nine countries producing sugar were investigated. The pairwise Granger causality tests identified a number of unidirectional relationships between the sugar variables and the currency and index of selected countries. Sugar spot and sugar future Granger causes the indices of Bangkok, Indonesia, Philippines, China, and India. Sugar spot and sugar futures also Granger causes the currencies of Brazil, Colombia, Indonesia, Philippines, Thailand and India. The AIC and SIC results of the GARCH models shows that the original GARCH model fits the data the best for sugar spot and the CSCE sugar 11 future. The EGARCH model fits the data the best for Liffe sugar future.

Further opportunities for study include further analyses of commodities as well as similar studies on other combinations of commodities, currencies, and indices. The results of the study are important to market participants as the movement in the commodity price does have an effect on the index and the currency which can influence the policy and business decisions in a country.

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