COINTEGRATION ANALYSIS OF THE WORLD'S SUGAR MARKET: THE EXISTENCE OF THE LONG-TERM EQUILIBRIUM

Elena Kuzmenko[1], Luboš Smutka[2], Wadim Strielkowski[3], Justas Štreimikis[4], Dalia Štreimikienė[5]

[1] *Czech University of Life Sciences, Faculty of Economics and Management, Department of Economics, Czech Republic, ORCID: 0000-0002-2091-4630, kuzmenko@pef.czu.cz;*

[2] *Czech University of Life Sciences, Faculty of Economics and Management, Department of Economics, Czech Republic, ORCID: 0000-0001-5385-1333, smutka@pef.czu.cz;*

[3] *Czech University of Life Sciences, Faculty of Economics and Management, Department of Economics, Czech Republic, ORCID: 0000-0001-6113-3841, strielkowski@pef.czu.cz;*

[4] *University of Economics and Human Science in Warsaw, Faculty of Management and Finances, Finance and Accounting Department, Poland, ORCID: 0000-0003-2619-3229, justas.streimikis@gmail.com;*

[5] *Vilnius University, Kaunas Faculty, Institute of Social Sciences and Applied Informatics, Lithuania, ORCID: 0000-0002-3247-9912, dalia.streimikiene@knf.vu.lt (corresponding author).*

Abstract: *This paper addresses the issue of interconnection among major sugar markets and commodity/exchange stocks in different parts of the world using the Johansen cointegration approach and vector error correction model. Due to a high degree of sugar market fragmentation and corresponding diversity in price levels and its volatility in different regions, the results of our analysis sheds some light on the very fact of a 'single' global sugar market existence and can be important not just with regard to producers and buyers of sugar but for the international investors as well, both in the light of risk governance and maximizing profitability. Using the evaluation of the extent of connection among regional sugar markets, one can assess potential benefits available to investors through international diversification between the analyzed markets. Our analysis has revealed the presence of mutual interaction among the selected sugar markets/commodity stock exchanges in individual regions and confirmed the long-term equilibrium among them. Therefore, despite an obvious diversity in price level and their fluctuations in different world regions, the selected for the analysis regional sugar markets are acting together as a single organism. The determining of the extent to which the analyzed sugar markets are interconnected have significantly strengthen the understanding of the latest sugar price developmental trends. In addition, the results of this study opened space and mapped out clear objectives and measurable targets for potential research – to reveal what markets can be referred to as leading ones in a sense that namely they primarily serve as a source of price turbulence. In summary, our results revealed and confirmed the long-term equilibrium among them and the outcomes of this study opened the new research realms and identified the clear and measurable targets for the future empirical research in this field.*

Keywords: *Sugar, exchange/commodity stocks, cointegration, VECM, equilibrium.*

JEL Classification: *O13, Q13, Q18.*

Introduction

In general, sugar markets are among the fastest developing markets in the world (Huang & Xiong, 2020). The significant global market liberalization resulted in the fast growth of supply and stocks (Zuckerindustrie, 2018). At the same time, continuous changes in consumption patterns are affecting the global demand for sugar and sugar products (Muhammad et al., 2019). On the other hand, global sugar market is still influenced by the existing protectionists measures (see Solomon, 2014). It is of note that protectionist policies are applied in sugar markets by both developed and developing countries (Haley, 2016). Eventually, global sugar market appears to be suffering because of high-applied tariffs, limited tariff quotas and production subsidies (da Costa et al., 2015). As a result, this is reflected in price transmission and significant sugar price differences existing among individual regions in the world. Another specific feature of global sugar market is its notable price fluctuation which is a result of speculative trade activities. This obviously happens since financial instruments proliferated and became in turn objects of speculation (Svatoš et al., 2013). Especially within the last decade the global sugar market attracted short-term-oriented investors. Those are interested in dynamic and rapid changes in price development as their activities are both price reduction and price growth oriented (Smrčka et al., 2012). This eventually results in a particular fragmentation in development of global sugar market which bears corresponding problems reflected in mutual price determination and its adequate transmission. With this regard, it becomes hard to talk about the existence of such a single global market of sugar. It is, in fact, represented by several regional markets that are more or less interconnected (Licht, 2008). Nevertheless, the very degree of interconnections among these regional markets that may exist through particular bilateral or multilateral agreements (Reinbergr, 2018), is not evident and, thus, is worth to be studied.

At the same time the sugar price is also a specific category, since its value is a result of mutually determined supply and demand interactions related only to a marginal portion of real production. It is estimated that approximately only forty percent of global sugar production is realized through free market (Reinbergr, 2018). The majority of global sugar production is realized and sold being based on mutual contracts between sugar producers and foodstuff producers (Reinbergr, 2018). As it was specified the global sugar price formation and mutual price interaction at the level of world market is extremely difficult process and there are numerous factors and various stakeholders that may and do influence this process (Zuckerindustrie, 2017). In order to understand the process of sugar price formation at least at the level of sugar production, which is directly contracted, it is necessary, first, to understand the relations existing among individual markets all around the world.

The problem of sugar price development at the level of selected commodity stock exchanges was addressed in the following several studies published in the past. Tahir et al. (2016) examined contemporaneous as well as causal relationship among trading volume, returns and sugar price volatility. Resende and Candido (2015) assessed the existing relationship among the sugarcane sector (represented by Ethanol and Sugar), Oil, BRL/USD Exchange Rate and Brazilian stock market (represented by the BOVESPA – Bolsa de Valores de São Paulo – Index). Lázaro (2013) analyzed a sugar price index of Havana Stock Exchange. Čermák (2009) analyzed the state of global sugar market in general and the role of NYSE (New York) and LIFFE (London). Tanner et al. (2018) analyzed sugar price development in the process of world economy financialization and influence of speculations. According to their findings considerable sugar price volatility to a large extent was due to operations in speculative funds (hedge funds). Gevorkyan (2018) studied short-term sensitivity among exchange market pressure and various domestic and external factors in primary commodity-exporting emerging markets. Agbenyegah (2014) analyzed sugar market specific and the role of commodity stock exchange operators at the level of Brazil, Thailand and China in relation to NYSE. Savant (2011) identified the basic fundamentals of the global sugar market. He analyzed sugar market specifics in relation to commodity market, sugar and sugar crops production, intercontinental exchange and world market.

In the light of the discussed above, the interconnection among major sugar markets in the world may have critical relevance not just to producers and buyers, but to international equity

investors both in the light of risk governance and maximizing profitability. By evaluating the extent of connection among sugar markets in different parts of the world, we can estimate the existence of potential gains for investors through international diversification between the examined markets (Giot, 2003). Because if the level of cointegration among them increases, the benefit of diversification falls (Narayan, 2005). Nevertheless, the very fact of the existence of such a long-term equilibrium (which can be referred to as a hypothesis of a 'single global sugar market') bears important implications as for potential investors, so as for sellers, suggesting that studying of cointegration would be valuable for all interested parties. Determining the extent to which the analyzed sugar markets are interconnected would significantly broaden the awareness of the latest sugar price development trends.

The main aim of this paper, thus, is to analyze the interconnection (if any) that exist among world major sugar markets. Specifically, to test for the presence and degree of the co-movement over the 5-year period from 2012 till 2017 we conduct a cointegration analysis regarding the following eight global sugar market players – sugar exchange stocks and International Sugar alliance:

1. NYSE/New York Stock: New York No. 11;
2. LSE/London Stock Exchange: London No. 5;
3. NCDEX/National Commodity and Derivatives Exchange – Kolhapur-M Grade (India);
4. ISA/International Sugar Agreement;
5. 3B/Brazil Bolsa Balcao/Brazil – São Paulo ESALQ;
6. BMV/Bolsa Mexicana de Valores/Mexico;
7. Zhengzhou Commodity Exchange/ZCE China;
8. MOEX/Moscow Exchange Russia.

The results of the analysis will help to gain insight into how cointegration among sugar markets contributes to development of sugar price in different parts of the world.

The rest of the study is organized as follows: section 2 describes data and methodology used in the research, section 3 provides a detailed procedure of application the presented above methods along with the achieved results and discusses them, section 4 takes stocks of relevant outcomes and summarizes the conclusions.

1. Methodology
1.1 Data Description

The raw data, consisted of daily closing prices at the selected stock exchanges, were retrieved from Licht-Interactive. The corresponding stock exchanges were selected according to a principle of representativeness. The three important representatives of American continent's sugar are Brazil, Mexico and USA. Brasil Bolsa Balcao is typical representative of Latino American sugar market, NYSE is representative of North American sugar market and Bolsa Mexicana de Valores can be referred to as a bridge between both previously mentioned markets. The most important sugar markets of India (National Commodity and Derivates Exchange) and China (Zhengzhou Commodity Exchange) were selected to be representatives of Asian sugar market. Both institutions have been operating under the specific national food market regulation and theirs sugar price development is quite specific one in comparison to other markets represented by e.g. NYSE or LIFFE. London Stock Exchange (being a typical representative of western European sugar market price formation) and Moscow Exchange (which operates under the significant national regulation) were chosen as representatives of European region.

For the purpose of having a sort of price development benchmark, one more representative of independent sugar price formation was chosen – ISA sugar prices. Being an International Agreement its objective is to secure expanded international collaboration related to world sugar issues, provide a forum for intergovernmental consultations on sugar so as to improve the world sugar economy, facilitate trade by collecting and providing information on the world sugar market and to encourage increased demand for sugar, particularly for non-traditional uses (EC, 2018). As a result, ISA price is based on sugar price records provided by individual ISA contractors: European Economic Community, Argentina, Australia, Austria, Barbados, Belarus, Belize, Brazil, Cameroon, Colombia, Costa Rica, Cuba, Côte d'Ivoire, the Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Fiji, Finland, Guatemala, Guyana, Honduras, Hungary, India, Iran, Jamaica, Japan, Kenya, Latvia, Malawi, Mauritius, Mexico, Moldova, Mozambique, Nigeria, Pakistan, Panama, Paraguay, the Philippines, Russia, Serbia and

Montenegro, South Africa, Sudan, Swaziland, Switzerland, Tanzania, Thailand, Trinidad and Tobago, Turkey, Vietnam, Zambia, Zimbabwe. Thus, these countries-contractors established the similarly named alliance ISA.

Some differences in measurement units were adjusted, for example, lb. was recalculated to tons, US cents – to US dollars. But at the same time local currency units remained unchanged in harmony with Alexander (2001), who strongly recommends performing cointegration analysis among markets using prices expressed in local currencies for better reflection the co-movements in different countries. Such a non-converting to a common currency ensures eliminating any potential exchange rate volatility. Since the analyzed countries have different non-trading days, we thoroughly examined the whole dataset to ensure consistent data representing main eight sugar markets players. Since, in addition, there was found a number of missing observations, it was decided to transform the initial daily-based data into a weekly-based data set using a geometric mean. As a result, we used weekly closing prices of sugar in their natural logarithm traded on the eight main sugar markets since 23. 08. 2012 until 16. 05. 2017. As a result, our dataset covers 5-year weekly timeframe that comprises 247 observations.

1.2 Testing for a Unit Root and Cointegration

Cointegration may be referred to as a statistical expression of equilibrium relationship among mutually connected variables sharing generic stochastic trends. After publishing by Engle and Granger (1987) their seminal paper, which was broaden in the following years, a cointegration analysis has become a robust technique for analyzing general tendencies in time series, ensuring a robust methodology for simulation both long-run and short-run trends in an analyzed phenomenon.

When the cointegration analysis revealed the existence of a cointegrating vector, we can draw a conclusion that the investigated time series will not diverge in the long-run, and will return to an equilibrium level following any short-run shift that may occur. The 5-year period ensures collecting necessary and sufficient information to study the potential presence of a long-term equilibrium among the selected sugar markets. To examine financial

time series with the use of cointegration technique, the time series in it levels have to be non-stationary and integrated of the same order (I(n)), meaning that these series become stationary after a n-differentiating procedure. Variables are considered to be cointegrated if they are integrated of the same order and have a stationary linear combination of all the variables included into the analysis.

At the present time two main approaches to investigate cointegration exist: Engle-Grangers two step estimation method (1987) and Johansen's maximum likelihood method (1997) based either on the trace statistic or the maximum eigenvalue statistic. The Engle-Grangers approach bears one very important shortcoming – despite the fact, that it is quite simple to conduct, it can only be performed on a maximum of two variables and requires much more observations to prevent potential estimation mistakes (Brooks, 2014). With regard to the above, since our goal is to examine eight exchange stocks, we will apply the Johansen's methodology (1997) enabling the analysis in a multivariate framework.

Prior to applying the latter we, first, test the series for optimal lag length (as for individual variables and so for an underlying VAR model) and, second, conduct two different but consistent with each other the Augmented Dickey-Fuller (ADF) and the Phillip-Perron (PP) unit root tests to ensure that the analyzed time series have the same order of integration. Since the ADF test loses its power for high number of lags (p) and PP test does not (Ghosh et al., 1999), we performed both of them, where it was needed, to verify and confirm the correctness of the result. The model (ADF) to check the presence of a unit root is:

$$
\Delta y_t = \lambda_0 + \lambda_1 y_{t-1} + \lambda_2 T + \\
+ \sum_{i=1}^{p} \psi_i \Delta y_{t-i} + \varepsilon_t,
\tag{1}
$$

where Δ is the difference operator;
y is the natural logarithm of the series;
T is a trend variable;
λ and ψ are parameters to be estimated and
ε is the error term.

The optimal lag length was found by selecting the model with the lowest Schwartz Bayesian Information Criterion (SBIC) and Akaike Information Criterion (AIC), which ensures the needed accuracy. As per literature

related to cointegration analysis, the SBIC is usually more consistent but inefficient, while AIC is not as consistent, but is usually more efficient (Brooks, 2014).

Having performed the unit root tests on the analyzed time series and confirmed all the time series are integrated of the same order, we conducted a multivariate Johansen test involving all 8 variables. This enables to investigate the presence of a long-term equilibrium (if any).

The Johansen approach implies a maximum likelihood method that identifies a number of cointegrating vectors in a non-stationary VAR (vector autoregression) with restrictions imposed, known as a VECM (vector error correction model). Johansen's estimation model can be written the following way:

$$\Delta X_t = \mu + \sum_{i=1}^{p} \Gamma_i \Delta X_{t-i} + \alpha \beta' X_{t-i} + \varepsilon_t, (2)$$

where $X_t = (X1t, X2t, …, Xnt)$ is a n*1 vector of the n-cointegrated variables, which are supposed to be integrated of order I(n); $\mu = (\mu1, \mu2, …, \mu n)$ is a n*1 vector of intercepts; $\beta' = (\beta(1), \beta(2), …, \beta(r))$ is the n*r cointegrating matrix consisting of the r-cointegrating vectors.

β' represents the long-run cointegrating relationship between the variables; α is a n*r matrix of the r-adjustment coefficients for each of the n variables, where r is the number of cointegrating relationships in the variables, so that 0 < r < n. α estimate the speed at which the variables adjust to their equilibrium; Γ_i are n*n matrixes of autoregressive coefficients; $(\sum_{i=1}^{p} \Gamma_i \Delta X_{t-i})$ is a VAR or short-run component; $\varepsilon_t = (\varepsilon1t, \varepsilon2t, ..., \varepsilon nt)$ is a n*1 vector of mutually uncorrelated white noise disturbances from $(0, \sum)$ (Kocenda & Cerny, 2007).

Johansen (1991) suggests two different test statistics for testing cointegration: the Trace test and the Maximum eigenvalue test. The latter is used less often compared to the trace statistic method because no solution to the multiple-testing problem has yet been found (StataCorp, 2013). The Trace test tests the null hypothesis that there are no more than r cointegrating relations. Restricting the number of cointegrating equations to be r or less implies that the remaining (K – r) eigenvalues are zero. Johansen (1995) derives the distribution of the trace statistic:

$$-T \sum_{i=r+1}^{K} \ln(1 - \hat{\lambda}_i), \quad (3)$$

where T is the number of observations and $\hat{\lambda}_i$ are the estimated eigenvalues.

For any given value of r, large values of the trace statistic are evidence against the null hypothesis that there is r or fewer cointegrating relations in the VECM.

Then we normalize the resulting cointegrating relationship on one of the variables so that the coefficient on this variable equal to one. We could select any other variable, but in harmony with Juselius (2006) the ratios among coefficients in cointegrating relationships are the same, irrespective of which variable is used to normalize the data.

We enumerate the individual steps of our methodology for the cointegration analysis below:
1. Unit Root Tests (ADF plus PP if needed);
2. Johansen's cointegration testing (Multivariate framework using all 5 specifications of the test);
3. Trace test;
4. Multivariate long-run/short-run analysis – VECM construction (normalization against lnBRA, since it is the biggest sugar market among others);
5. Post-estimation analysis.

All tests were carried out in Stata 13.01 statistical software.

2. Results and Discussion
This section provides the outcomes of all the tests that were carried out. The calculations were performed in Stata 13.01 using natural logarithms of all variables (prices). Graphs of all the analyzed time series are represented in Fig. 1.

2.1 Testing for a Unit Root
Prior to test for cointegration or fit the cointegrating VECM we verify statistical properties of the series: whether or not they are stationary. As it can be seen from the Fig. 1, all the series seem to be non-stationary processes that combine a random walk with a stochastic trend.

The graphs show that although the series appear to move similarly, the relationship among them is not clear.

Before applying the ADF and PP tests to our data, first we need to identify the optimal lag order for each of the studied series. The optimal number of lags was selected according to the results of the tests applied for all the

Fig. 1: Graphical representation of the analyzed time series
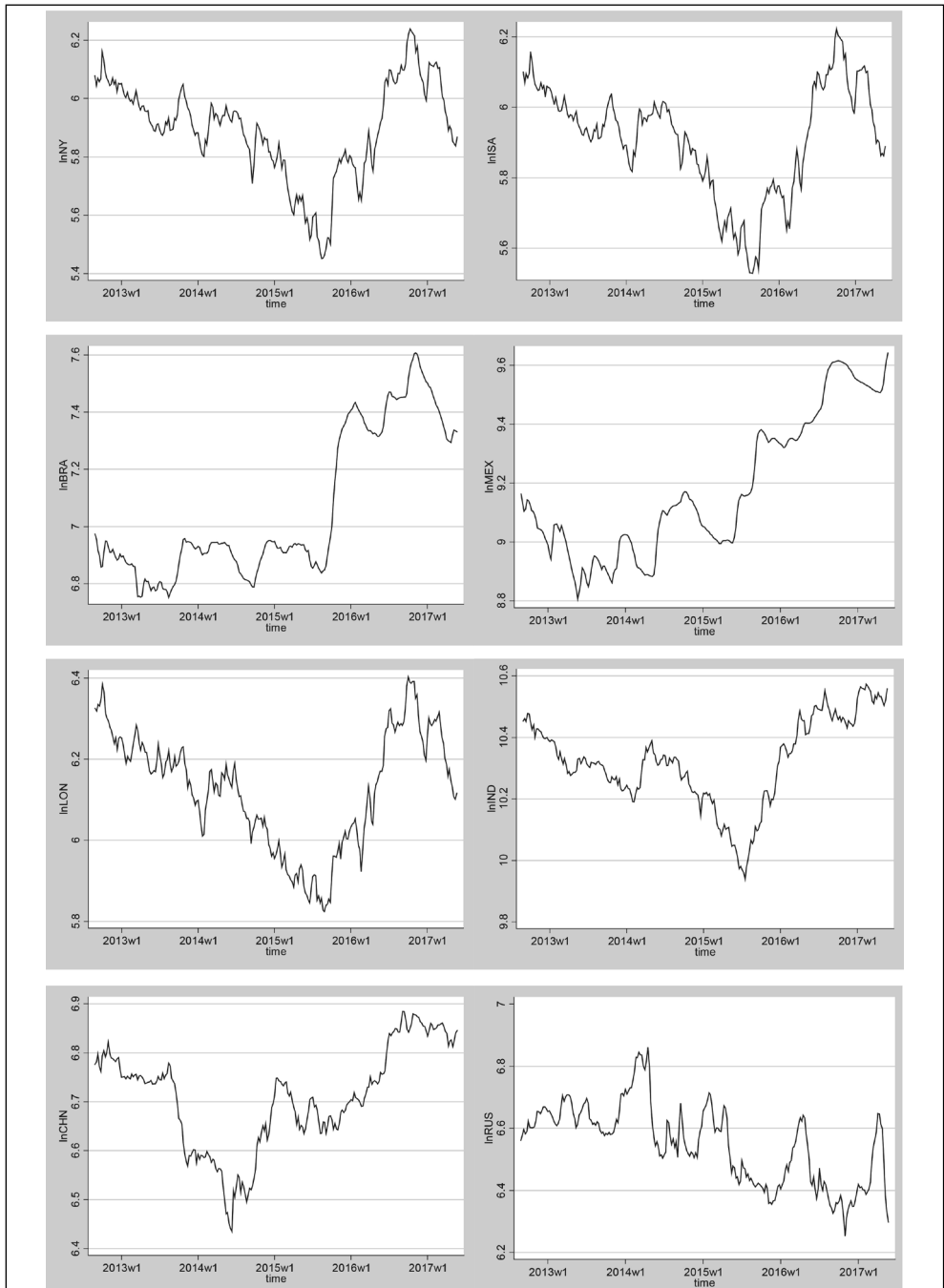
Tab. 1: Recommended lag orders for all the studied series

Series	Lag	Series	Lag
In level		In first differences	
lnNY	2	dlnNY	1
lnLON	2	dlnLON	1
lnIND	2	dlnIND	4
lnISA	2	dlnISA	1
lnBRA	4	dlnBRA	4
lnMEX	3	dlnMEX	2
lnCHN	2	dlnCHN	1
lnRUS	2	dlnRUS	1

Source: own

series both in levels and first differences, with the use of the following criteria, such as final prediction error (FPE), Akaike's information criterion (AIC), Hannan–Quinn information criterion (HQIC), Schwarz Bayesian information criterion (SBIC) and sequential likelihood-ratio (LR). The summary of the obtained results is given in Tab. 1.

As it can be seen from the Tab. 1, relatively high number of lags was recommended for dlnIND, lnMEX series, as well as for lnBRA series both in levels and first differences. For that reason, when testing mentioned series for the presence of a unit root, both Augmented Dickey-Fuller and Phillips-Perron tests will be used as it was explained in the methodology.

Tab. 2: Testing for the presence of a unit root of all input data using ADF and PP tests – Part 1

Series	Data (lags)	Model modif.	Test statistic	Critical value (5%)	P-value	Reject H_0	Conclusion
lnNY	In levels (2)	N	−0.450 ADF	−1.950	x	No	I(1)
		C	−2.001 ADF	−2.880	0.2862 ADF	No	
		CT	−1.964 ADF	−3.431	0.6206 ADF	No	
	First differences (1)	N	−10.106 ADF	−1.950	x	Yes	
		C	−10.093 ADF	−2.880	0.0000 ADF	Yes	
		CT	−10.087 ADF	−3.431	0.0000 ADF	Yes	
lnLON	In levels (2)	N	−0.538 ADF	−1.950	x	No	I(1)
		C	−1.911 ADF	−2.880	0.3270 ADF	No	
		CT	−1.836 ADF	−3.431	0.6869 ADF	No	
	First differences (1)	N	−10.710 ADF	−1.950	x	Yes	
		C	−10.704 ADF	−2.880	0.0000 ADF	Yes	
		T	−10.728 ADF	−3.431	0.0000 ADF	Yes	
lnIND	In levels (2)	N	0.285 ADF	−1.950	x	No	I(1)
		C	−0.983 ADF	−2.880	0.7593 ADF	No	
		CT	−1.476 ADF	−3.431	0.8371 ADF	No	
	First differences (4)		−7.114 ADF		x		
		N	−7.106 ADF	−1.950	0.0000 ADF	Yes	
		C	−12.517 PP	−2.881	0.0000 PP	Yes	
		CT	−7.384 ADF	−3.431	0.0000 ADF	Yes	
			−12.660 PP		0.0000 PP		

Tab. 2:	Testing for the presence of a unit root of all input data using ADF and PP tests – Part 2

Series	Data (lags)	Model modif.	Test statistic	Critical value (5%)	P-value	Reject H_0	Conclusion
lnISA	In levels (2)	N	−0.498 ADF	−1.950	x	No	
		C	−1.955 ADF	−2.880	0.3067 ADF	No	
		T	−1.890 ADF	−3.431	0.6599 ADF	No	I(1)
	First differences (1)	N	−10.022 ADF	−1.950	x	Yes	
		C	−10.012 ADF	−2.880	0.0000 ADF	Yes	
		CT	−10.015 ADF	−3.431	0.0000 ADF	Yes	
lnBRA	In levels (4)	N	0.889 ADF 0.708 PP	−1.950	x 0.6915 ADF	No	
		C	−1.158 ADF −0.683 PP	−2.881	0.8511 PP 0.6039 ADF	No	
		CT	−1.995 ADF −2.164 PP	−3.431	0.5103 PP	No	I(1)
	First differences (4)	N	−4.562 ADF −6.486 PP	−1.950	x 0.0001 ADF	Yes	
		C	−4.600 ADF −6.503 PP	−2.881	0.0000 PP 0.0000 ADF	Yes	
		CT	−4.590 ADF −6.495 PP	−3.431	0.0000 PP	Yes	
lnMEX	In levels (3)	N	1.023 ADF 1.114 PP	−1.950	x 0.9499 ADF	No	
		C	−0.096 ADF 0.141 PP	−2.880	0.9687 PP 0.1575 ADF	No	
		CT	−2.915 ADF −2.751 PP	−3.431	0.2154 PP	No	I(1)
	First differences (2)	N	−6.813 ADF	−1.950	x	Yes	
		C	−6.888 ADF	−2.880	0.0000 ADF	Yes	
		CT	−7.069 ADF	−3.431	0.0000 ADF	Yes	
lnCHN	In levels (2)	N	0.148 ADF	−1.950	x	No	
		C	−1.138 ADF	−2.880	0.6996 ADF	No	
		CT	−1.799 ADF	−3.431	0.7051 ADF	No	I(1)
	First differences (1)	N	−9.908 ADF	−1.950	x	Yes	
		C	−9.889 ADF	−2.880	0.0000 ADF	Yes	
		CT	−10.016 ADF	−3.431	0.0000 ADF	Yes	
lnRUS	In levels (2)	N	−0.520 ADF	−1.950	x	No	
		C	−2.215 ADF	−2.880	0.2009 ADF	No	
		CT	−3.734 ADF	−3.431	0.0202 ADF	Yes	I(1)
	First differences (1)	N	−9.446 ADF	−1.950	x	Yes	
		C	−9.442 ADF	−2.880	0.0000 ADF	Yes	
		CT	−9.444 ADF	−3.431	0.0000 ADF	Yes	

Source: own

Note: N = model with no constant and no trend; C = model with a constant, CT = model with a constant and trend.
H_0: variable contains a unit root, H_1: variable was generated by a stationary process.

Then applying the recommended lag, we checked the presence of a unit root in each series both in levels and first differences.

If we cannot reject the null hypothesis that the analyzed series does have a unit root, then this series is considered to be a non-stationary process. Having tested all the series for the presence of a unit root with the use of both tests (when needed only, i.e. in case of high number of lags) in all modifications, it was confirmed

Tab. 3: **Multivariate Johansen's cointegration tests results**

Series tested	Test specification	Null hypothesis Trace test[1]
lnISA/lnNY/lnLON/lnBRA/ lnMEX/lnIND/lnCHN/lnRUS	Constant[2]	Rejected** (r = 1)
	Rconstant[3]	Fails to reject
	Trend[4]	Rejected** (r = 1)
	Rtrend[5]	Fails to reject
	None[6]	Fails to reject

Source: own

Note: [1]H_0: series are not cointegrated (r = 0); [2]Include an unrestricted constant in model; [3]Include a restricted constant in model; [4]Include a linear trend in the cointegrating equations and a quadratic trend in the undifferenced data; [5]Include a restricted trend in model; [6]Do not include a trend or a constant; **H_0 rejected at the 5% significance level.

that all the time series are integrated of the same order I(1). Phillips-Perron tests lead to similar conclusions. The summary of the results is given in Tab. 2.

Since all the analyzed series are I(1) processes it gives us all necessary preconditions to detect a cointegration among the analyzed markets. The results of the cointegration test will be used further for estimating VECMs.

2.2 Testing for Multivariate Cointegration

To check the presence or absence of a cointegration vector(s) we employed the Johansen maximum likelihood approach with different specifications of cointegrating relations (Johansen, 1995) as described previously in the methodology. We decided to focus on multivariate cointegration testing among all the analyzed series together with the use of Trace test. The results are displayed in Tab. 3.

According to the results displayed above we can conclude that the analyzed series do have one cointegrating vector. Since a cointegration among all the series exists, it makes sense to access long-run and short-run coefficients of the underlying model. We normalized the

Tab. 4: **Multivariate VECM summary outcome**

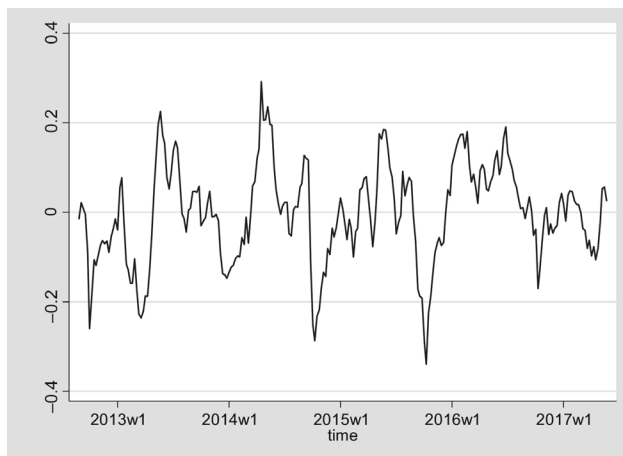| Series	Long-run relationship		Short-run relationship	
	Normalized cointegrating coefficients	P-value	Error correction term (speed of adjustment)	P-value
lnBRA	1.000	–	−0.020**	0.013
lnISA	4.412***	0.000	0.015	0.390
lnNY	−4.641***	0.000	0.016	0.415
lnIND	0.532**	0.046	0.011	0.390
lnLON	−0.125	0.800	0.018	0.250
lnMEX	−1.224***	0.000	0.043***	0.000
lnCHN	0.444*	0.064	−0.009	0.336
lnRUS	−0.432**	0.049	−0.011	0.560

Source: own

Note: *The coefficient is significant at the 10% significance level; **The coefficient is significant at the 5% significance level; ***The coefficient is significant at the 1% significance level.

resulting cointegrating relationship on lnBRA so that the coefficient on this variable equal to one. We could select any other variable, but according to Juselius (2006) the ratios among the coefficients in cointegrating relationships are the same, irrespective of which variable is used to normalize the data. So we chose BRA which is the largest sugar market among others and in the meantime – is one of the key players in the global sugar market. Tab. 4 provides summary information upon the outcome.

As a whole, the results indicate that the model fits well. The important outcome is that since the error correction term, or speed of adjustment to equilibrium, of lnBRA is negative in sign and statistically significant, it implies that the adjustment towards equilibrium does exist. The presence of such a long-run stable equilibrium was confirmed by the existence of one cointegrating equation among the analyzed time series.

The given above outcome demonstrates strong evidence for the following cointegrating

Source: own

equation: 1.0*lnBRA + 4.412*lnISA − 4.641*lnNY + 0.532*lnIND − 0.125*lnLON − 1.224*lnMEX + 0.444*lnCHN − 0.432*lnRUS is a stationary series (see Fig. 2).

In accordance with the methodology, the following information was obtained:

- $\widehat{\alpha}$ = (−0.020; 0.015; 0.016; 0.018; 0.043; 0.011; −0.009; −0.011);
- $\widehat{\beta}'$ = (1; 4.412; −4.641; 0.532; −0.125; −1.224; 0.444; −0.432).

Because of the normalization, the signs of the coefficients were reversed to enable us to interpret them properly. Thus, the obtained coefficients can be interpreted the following way:

- 1% increase in lnISA prices resulted in a 4.412% decrease in lnBRA prices in the long run, ceteris paribus (c.p.);

- 1% growth in lnNY prices lead to a 4.641% increase in lnBRA prices, c.p.;
- 1% increase in lnIND prices caused a 0.532% decline in lnBRA prices, c.p.;
- 1% increase in lnLON prices brought about a 0.125% increase in lnBRA prices, c.p.;
- 1% increase in lnMEX prices resulted in a 1.224% increase in lnBRA prices, c.p.;
- 1% increase in the lnCHN prices caused a 0.444% decrease in lnBRA prices, c.p.;
- 1% growth in lnRUS prices lead to a 0.432% increase in lnBRA prices, c.p.

Thus, the strongest and nearly identical in strength long-term equilibrium relationships were detected between lnNY/lnBRA and lnISA/lnBRA. Three times weaker are links between lnMEX/lnBRA. Almost ten times weaker than above are connections between lnIND/lnBRA,

lnCHN/lnBRA and lnRUS/lnBRA. The weakest long-term linkage is found to be between lnLON and lnBRA, however this cointegrating coefficient is not statistically significant.

It is worth noting that the error correction terms (ECT) of all the variables are comparably the same in value (except for ECT of lnMEX, which is several times higher comparing to the rest), meaning identical speeds of adjustment to an equilibrium level of all the prices or almost equal response to their last period's equilibrium error. Nevertheless, just two of them have appeared to be statistically significant – ECT of MEX and BRA.

Taking into account these results we can assert, that there is little, if no, advantage of risk diversification or investment portfolio diversification in terms of choosing one sugar market over another both in the short and long-run. The matter is that the speeds of

prices adjustment towards equilibrium in all the analyzed markets are relatively even, being at the same time very small in value (only 0.9% to 4.3% of a disequilibrium is adjusted depending on a concrete market during the next period, i.e. one week). The values of long-term equilibrium coefficients are also relatively low (ranging between 0.4% and 4.6%) that points to the fact of a very close association among the analyzed markets.

2.3 Post-estimation Analysis

Validity of the model has to be proved by a number of tests applied on residuals. Thus, it is important to conduct a post-estimation analysis to be sure that all necessary assumptions (i.e. normality, no serial correlation, stability) are fulfilled. In order to test serial correlation in residuals' series we applied Lagrange multiplier test. The obtained results proved (see Tab. 5)

Tab. 5:   **Lagrange multiplier test for autocorrelation in the residuals of VECM**

Lag	Chi2	Df	Prob > chi2
1	68.7935	64	0.31841
2	82.9665	64	0.05566
3	54.2951	64	0.80114
4	80.4810	64	0.07994

Source: own

Note: H_0: no autocorrelation at lag order.

the fact of no serial correlation, since we failed to reject the null hypothesis asserting that there is no serial correlation at each lag order up to 4.

The normality of disturbances was checked with the use of the Jaque-Bera test. The output is provided in Tab. 6.

Judging by low p-values of the Jarque-Bera statistics we forced to reject H_0 of normality in corresponding equations except for some of them on conventional 0.05% or 0.01% significance levels.

Indeed, since the analyzed time series represent prices it implies that almost certainly these data come from a process with 'heavy tails' and therefore the residuals are not normal. It may occur due to rapid change in economic situation all over the world, meaning that we virtually unable to achieve normal distribution. At the same time, according to the theory, if

Jarkue-Bera test fails, it may be an indicator of insufficient number of lags chosen for the model which is not relevant for our model. In general, as regards the failed Jarque-Bera test and especially in case of close to small data samples, it should be noticed that this is a quite common phenomenon which will not crucially distort the results (Sukati, 2013). The non-normal distribution is problem if we want to apply t-tests, to calculate the confidence intervals or to make predictions. However, forecasting falls outside the scope of this paper.

If multivariate VECM was specified correctly and the number of cointegrating equations was correctly identified, it is expected that cointegrating equation is supposed to be stationary. The STATA command *vecstable* provides indicators of whether the number of cointegrating equations is misspecified or

Tab. 6: **Normality test for distribution of the error terms**

Jarque-Bera test			
Equation	**Chi2**	**Df**	**Prob > chi2**
D_lnBRA	53.416	2	0.00000
D_lnISA	3.237	2	0.19824
D_lnNY	769.764	2	0.00000
D_lnIND	7.034	2	0.02968
D_lnLON	16.096	2	0.00032
D_lnMEX	254.827	2	0.00000
D_lnCHN	98.959	2	0.00000
D_lnRus	51.518	2	0.00000
ALL	1,254.849	16	0.00000
Skewness test			
Equation	**Skewness**	**Chi2**	**Df**	**Prob > chi2**
D_lnBRA	−0.02429	0.024	1	0.87667
D_lnISA	0.26332	2.831	1	0.09244
D_lnNY	0.81759	27.295	1	0.00000
D_lnIND	0.39601	6.404	1	0.01139
D_lnLON	0.12945	0.684	1	0.40812
D_lnMEX	0.95588	37.309	1	0.00000
D_lnCHN	0.52744	11.359	1	0.00075
D_lnRus	−0.000088	0.000	1	0.99553
ALL		85.907	8	0.00000
Kurtosis test			
Equation	**Kurtosis**	**Chi2**	**Df**	**Prob > chi2**
D_lnBRA	5.287	53.391	1	0.00000
D_lnISA	3.1992	0.405	1	0.52439
D_lnNY	11.528	742.469	1	0.00000
D_lnIND	3.2486	0.631	1	0.42706
D_lnLON	4.2287	15.411	1	0.00009
D_lnMEX	7.616	217.517	1	0.00000
D_lnCHN	5.9294	87.599	1	0.00000
D_lnRus	5.2465	51.517	1	0.00000
ALL		1,168.942	8	0.00000

Source: own

Note: H_0: the disturbances in the VECM are normally distributed.

Tab. 7: Stability of multivariate VECM

Eigenvalue stability condition		Modulus
Eigenvalue		**Modulus**
1		1
1		1
1		1
1		1
1		1
1		1
1		1
0.7694022	+0.1466814i	0.783259
0.7694022	+0.1466814i	0.783259
0.660271		0.660271
0.3450779		0.345078
0.1664901	+0.2241246i	0.279197
0.1664901	−0.2241246i	0.279197
0.1544746	+0.03904945i	0.159334
0.1544746	−0.03904945i	0.159334
0.07236695		0.0723747

Source: own

Note: The VECM specification imposes 7 unit moduli.

Fig. 3: Roots of the companion matrix

The VECM specification imposes 7 unit moduli
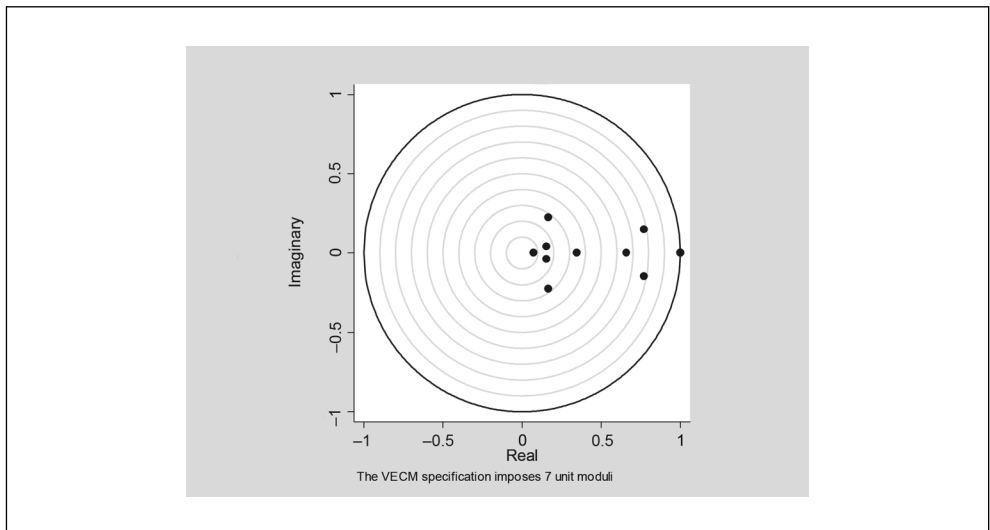
Source: own

whether the cointegrating equations, which are assumed to be stationary, are not stationary. It uses the estimates of coefficients from the previously fitted VECM to back out estimates of the coefficients of the corresponding VAR and then compute the eigenvalues of the companion matrix (StataCorp, 2013). In Tab. 7 and Fig. 3 stability of multivariate VECM and roots of the companion matrix are given.

The availability of the integrated variables (and unit moduli) in the VECM representation implies that shocks may be permanent as well as transitory. Tab. 7 and Fig. 3 (showing the eigenvalues of the companion matrix and their associated moduli) proofs that seven of the roots equal to 1, as it should be since 8 – 1 = 7. As it can be seen in the table footer – the specified VECM imposes exactly 7 unit modulus on the companion matrix. If any of the remaining moduli is too close to one it means that either the cointegrating equation is not stationary or there is another common trend and the rank that was specified in VECM is too high (StataCorp, 2013). In our case the remaining moduli are fairly far from one, implying correct VECM rank of the multivariate model along with overall stability of VECM estimates. Thereby, it may be inferred that the multivariate VECM is appropriate one to be used since it has high stability.

3. Conclusions

All in all, sugar markets, being one of the most rapidly developing markets are, without any doubt, worth to be studied because of several reasons. Among these reasons may be listed the following ones: significant price differences in individual world regions, notable price fluctuations, continuous changes in consumption patterns, fast growth of supply and stocks, which is a result of ever-increasing speculative trade activities, strong influence of protectionists measures etc. National and regional policies, applied in relation to food market, play one of the most important roles. Food market, including sugar market, can be characterized, as it was already mentioned, by significant price differences among individual countries (and even among markets within a single country) and by a various sets of protecting/supporting instruments that are applied in different countries uneven. The underlying reason of governments' interventions is ensuring of food security, food safety and stability of market. These interventions usually result in a limitation or distortion of price transmission among markets in contrast to a free market mechanisms. In other words, fragmentation in development of sugar markets bears corresponding problems connected with a distortion in price determination and its inadequate transmission. In this light the very possibility to talk about the existence of a 'single' global sugar market has become questionable, since it is, in fact, represented by several regional markets that are more or less interconnected through particular bilateral or multilateral agreements. Nevertheless, the very degree of such interconnections among regional markets is not evident and, thus, worth to be studied.

All these circumstances aroused our interest to investigate the extent of interconnection among sugar markets in various parts of the world (represented by eight major sugar price makers – sugar exchange stocks/markets and International Sugar alliance) and predetermined the goal of this paper – to analyze the presence of a long-term equilibrium among them (i.e. the hypothesis of a 'single global sugar market'). The very fact of the existence of such a long-term equilibrium bears important implications not just to producers and buyers of sugar, but to international investors as well both in the light of risk governance and maximizing profitability. The conducted analysis has revealed the presence of mutual interaction among the selected sugar markets/commodity stock exchanges in individual regions and did confirmed the long-term equilibrium among them. It means that despite an obvious diversity in price level and their fluctuations in different world regions, the very hypothesis of a 'single global sugar market' has been confirmed – the selected for the analysis regional sugar markets do act together as a single organism. Eventually, the determining of the extent to which the analyzed sugar markets are interconnected have significantly strengthen the understanding of the latest sugar price developmental trends. In addition, the results of this study opened space and mapped out clear objectives and measurable targets for potential research – to reveal what markets can be referred to as leading ones in a sense that namely they primarily serve as a source of price turbulence. In other words, the goal of the potential study could be to identify markets-

drivers of price changes, markets-transmitters and markets-recipients.

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