Impact of global ethanol market on EU: Testing for cointegration and causality among EU, USA and Brazil

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Tiivistelmä

Ethanol is a renewable biofuel produced from sugar crops such as sugar cane or sugar beet, or from cereals like wheat, barley and corn. Currently, the US and Brazil are the two dominant users and producers of ethanol. More than half of world production of ethanol came from them. The share of the European countries is rather small, only representing 15% of the total share. However, it has increased dramatically since 2004. The main driver might come from two biofuel directives by the European Commission. One is the Directive 2003/30/EC[1], and the other is the one on taxation of energy products[2] . The global price of ethanol is mainly determined by two countries, Brazil and USA. The expanding trade volumes have created incentives to establish new marketing boards and hedging tools for increasing transparency and managing risks in the bio-fuels market. An example of the new and emerging hedging tools is the new ethanol futures contract designed and quoted by the Chicago Board of Trade (CBOT) in USA. So far European marketing boards, such as the EURONEXT, have not launched new contracts for open trade and quotations for bio-fuels. Therefore, the bio-fuels market is not transparent from the Finnish traders' and ethanol processors' perspective. The reason is that the existing open quotations represent different market regimes and, in addition to the transportation costs, they are separated from the European market by different tariff regimes. Thus, it is not really known, what is the opportunity cost for the domestic, large scale ethanol production, and how competitive the domestic market is in the international context. The goal of this study is to investigate the market integration of world ethanol market with focus on three main markets: EU, USA and Brazil, using the methodology of Granger causality and vector auto regression (VAR). Evidence shows that there is a unidirectional Granger causation from both USA and Brazil to EU market. USA price of ethanol is the most influential among the three price series, and EU has very least on the contrary. Thus CBOT in USA may not perform as an efficient predictor of expected spot price for EU ethanol.

Asiasanat: ethanol, directives, CBOT, Granger causality, VAR .

[1] See Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003, on the promotion of the use of biofuels and other renewable fuels for transport
[2] See Directive 2003/96/EC of 27 Octobor 2003 (O.J.L283, 31/10/2003)

Johdanto

Using biofuels including bioethanol have potential advantages: less greenhouse gas emissions, increasing the sources of income employment in rural areas and most importantly diversifying fuel supply sources. Ethanol is a renewable biofuel produced from sugar crops such as sugar cane or sugar beet, or from cereals like wheat, barley and corn. Currently, the US and Brazil are the two dominant users and producers of ethanol. More than half of world production of ethanol came from them. The share of the European countries is rather small, only representing 15% of the total share. However, it has increased dramatically since 2004. The main driver might come from two biofuel directives by the European Commission. One is the Directive 2003/30/EC[3], and the other is the one on taxation of energy products[4] In the US, corn is the most popular raw material to produce ethanol, while Brazil uses sugar beet. EU bioethanol is generally produced using a combination of sugar beets and wheat.

The global price of ethanol is mainly determined by two countries, Brazil and USA. The expanding trade volumes have created incentives to establish new marketing boards and hedging tools for increasing transparency and managing risks in the bio-fuels market. An example of the new and emerging hedging tools is the new ethanol futures contract designed and quoted by the Chicago Board of Trade (CBOT). The trade for the new ethanol contract started in July 2005. Thereafter, the trading volumes have been increasing drastically and also the traditionally thought price parity between the fossil fuels and ethanol has broken down. The price of ethanol has continued to increase even if the price of fossil fuels has developed more steadily, though remaining at very high level in the historical perspective. So, far European marketing boards, such as the EURONEXT, have not launched new contracts for open trade and quotations for bio-fuels. Therefore, the bio-fuels market is not transparent from the Finnish traders' and ethanol processors' perspective. The reason is that the existing open quotations represent different market regimes and, in addition to the transportation costs, they are separated from the European market by different tariff regimes. Thus, it is not really known, what is the opportunity cost for the domestic, large scale ethanol production, and how competitive the domestic market is in the international context. Further, it is unclear how the bio-fuels markets are linked to the agricultural commodity markets and how the price movements in these markets reflect each others. The goal of this study is to investigate the market integration of world ethanol market with focus on three main markets: EU, USA and Brazil. To what extent price shocks are transmitted between three ethanol markets, which are EU, USA and Brazil is also analysed. The extent to which a price shock at one market affects a price at another point can broadly indicate whether efficient arbitrage exists in the space that includes the two markets. A full transmission of price shocks can indicate the presence of a frictionless and well functioning market, while a total absence of transmission may make the very existence of a market questionable. Therefore, the degree of price transmission can provide at least a broad assessment of the extent to which markets are functioning in a predictable way, and price signals are passing-through consistently between different markets. Should different markets of ethanol prices be conitegrated, their relationship can be represented by an Error Correction Model (ECM) on the basis of which movements in any one of them can be used to predict movements in the other. accordingly, the ECM associated with cointegrated ethanol price indexes provides traders and

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policy makers with valuable information regarding their investment decisions and for economic policy.

Aineisto ja menetelmät

Data

The data includes monthly ethanol prices in EU, USA and Brazil, provided by Agronet[5]. European price is collected average price in Rotterdam, while Brazilian spot prices are FOB price collected from Santos in Brazil. USA price is average price collected from different harbours in United States. The data spans from January of 1998 to January of 2007 (Figures 1). Both EU and USA price series include 109 observations, but price series of Brazil include only 101 data as the price of the first 8 month in 1998 was not available. We exchange the currency of USA and Brazilian price from the original US dollars to Euro accordingly.[6]

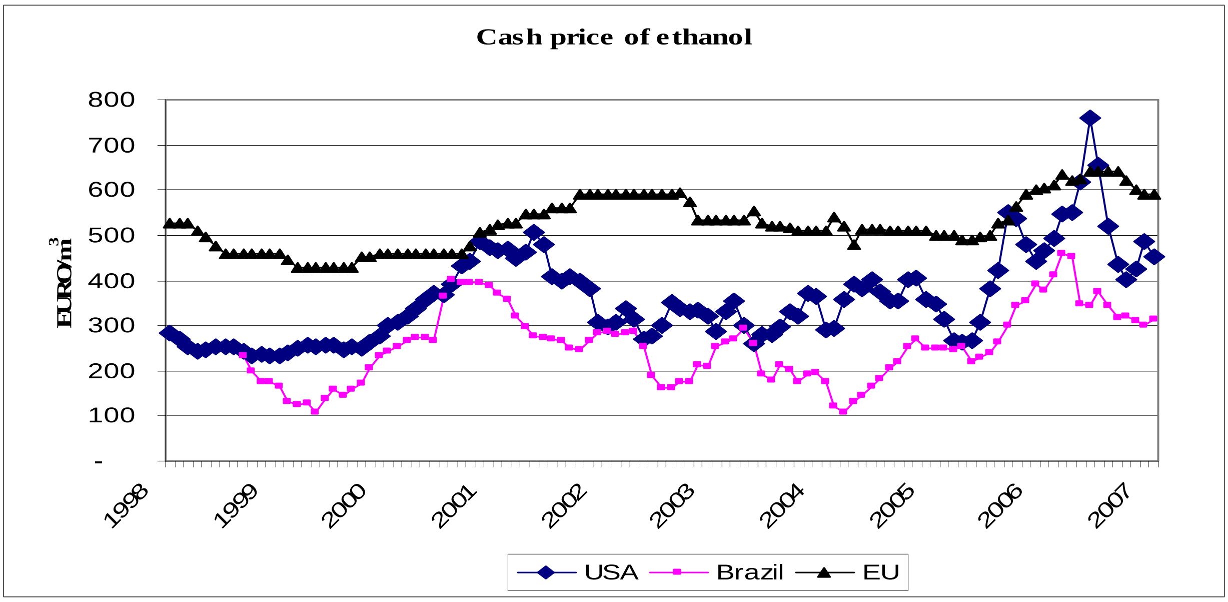

Figure 1. Global ethanol wholesale prices in EU, USA and Brazil.

The summary of statistics of ethanol monthly prices in three major markets is listed in Table1. Obviously, European ethanol price has been highest among the three regions during the last decades, but turned most stable market. Comparatively, the average price of ethanol in USA stays between Europe and Brazil, but it has the biggest volatility figure among three regions. Also the high kurtosis and right skewness presents some evidence of a leptokurtic and asymmetric distribution. Brazilian price series, on the other hand, distribute as normal distribution.

Table 1. Summary of statistics of European, Americal and Brazilian ethanol price series

Descritives	Europe	USA	Brazil
Mean	524.3028	358.3578	253.9406
Median	520.0000	337.0000	252.0000
Maximum	640.0000	761.0000	461.0000
Minimum	430.0000	231.0000	108.0000

5 The Data is provided by Agra Informa. The detailed information could be subscribed from www.agra-net.com
6 The exchange rate is refered to xrate monthly average. Detaled information can be found at www.x-rates.com

Standard Deviation	57.72500	101.4386	81.82112
Skewness	0.246232	1.113112	0.361513
Kurtosis	2.136077	4.509522	2.520680
Normality test (J-B test)	4.491179	32.85775	3.166832
	0.105865	0.000000	0.205273
Observations	109	109	101

Research method

Unit root test

The first step is to examine the stationarity properties of the univariate time series. Let $\ln p_t^{EU}$ $\ln p_t^{USA}$ and $\ln p_t^{Brazil}$ represent ethanol prices of European, USA and Brazilian respectively with t = 1, 2, 3,…., T, where T is the sample size. Test for stationarity for price series, denoted by and the order of integration of the individual price series. The series is integrated of order d (denoted I(d) if it attains stationarity after differencing d times. If the series is I(1) it is deemed to have a unit root Stationarity of the price processes is tested using a group of unit roots which include the Augmented Dickey-Fuller (ADF) test (1976), Phillips-Perron test (PP) (1988), and a test developed by Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (1992). While the ADF, PP tests state the null hypothesis of non-stationarity or the presence of a unit root, the KPSS test defines stationarity as the null. The Monte Carlo simulations by Schwert (1989) showed that the ADF tests have low power and are sensitive to the choice of lag-length. The unit root tests are known to have low power problems in small samples, particularly, if the series include structural breaks (Kwiatkowski et al.1992; Leybourne & Newbold 2000). The KPSS tests, on the other hand, have good power properties. PP test is an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root. Since no single unit root test is without some statistical shortcomings, in terms of size and power properties, a group of unit root tests are applied to statistically determine the order of integration of the time-series used in cointegration analyses. The results of the ADF, PP and KPSS are summarized in Table 2.

According to these results, ADF tests indicate non-stationarity, and the KPSS tests confirm it for European and USA ethanol price. Thus, it was concluded that there is strong evidence that these two series are non-stationary. However, ADF and KPSS tests have different results in Brazilian ethanol price, but PP test supports the ADF tests, therefore, it is prudent to conclude that the series of Brazilian ethanol is also nonstationary. For the first difference series, the results of all these unit root tests indicate they are stationary and are not reported here, thus all three series are intergrated of order 1, designated as I(1).

Table 2. Unit Root Tests

Test	European price	USA price	Brazilian price	Critical values
ADF (intercept and trend excluded)	0.46	0.45	0.21	-1.61* -1.94** -2.59***
ADF (intercept included)	0.83	-2.01	-2.37	-2.58* -2.89** -3.49***
ADF (intercept and trend included)	-1.88	-2.47	-2.51	-3.15* -3.45** -4.05***

KPSS (intercept included)	0.56	0.58	0.22	0.34* 0.46** 0.74***
Phillips-Perron (intercept included)	-1.28	-1.82	-2.13	-2.58* -2.88** -3.49***

Notes: ADF is Augmented Dickey-Fuller test, test statistics is according to MacKinnon (1996) critical values for rejection of hypothesis of a unit root. KPSS is the η-test of Kwiatkowski et al. (1992). Phillips-Perron test is Phillips and Perron (1988) nonparametric test of unit root. Asterisk (*), (**) and (***) denote significance level at 10 %, 5% and 1% respectively. [7]

Conitegration test

The second step the Conintegration anaysis will be carried out. Conintegration analysis helps to identify long-run economic relationships between two or several variables and to avoid the risk of spurious regression (Hamilton, 1994). Cointegration analysis is important because if two non-stationary variables are cointegrated, a VAR model in the first difference is misspecified due to the effect of a common tend. If cointegration relationship is identified, the model should include residuals from the vectors (lagged one period) in the dynamic Vector Error Correcting Mechanism (VECM) system. In this stage, Johansen (1988) cointegration test is used to identify cointegrating relationship among the variables. Within the Johansen multivariate cointegrating framework, the following system is estimated:

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{t=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \tag{1}$$

where Δ is the first difference operator, **y** denotes vector of variables, which are $\ln p_t^{EU}$ $\ln p_t^{USA}$ and $\ln p_t^{Brazil}$, $\varepsilon_t \sim niid(0,\Sigma)$, μ is a drift parameter, and Π is a ($p\times p$) matrix of the form $\Pi = \alpha\beta'$, where α and β are both ($p\times r$) matrices of full rand, with β containing the r cointegrating relationships and α carrying the corresponding adjustment coefficients in each of the r vectors. Johansen (1988) proposed two tests statistics to determine the cointegration rank, which are trace statistic denoted by LR_{tr} and maximum eigenvalue statistic denoted by $\lambda_{\max}$. The trace statistics is shown in function (2)

$$LR_{tr}(r\mid k) = -T\sum_{i=r+1}^{k}\ln(1-\hat{\lambda}_i) \tag{2}$$

where $\hat{\lambda}_i$ denote the i-th largest Π eigenvalue of the matrix in function (1). The maximum eigenvalue statistic tests the null hypothesis of r cointegrating relations against the alternative of $r+1$ cointegrating relations. This test statistic is computed as function (3):

$$LR_{\max}(r\mid r+1) = -T\ln(1-\lambda_{r+1}) = LR_{tr}(r\mid k) - LR_{tr}(r+1\mid k) \tag{3}$$

for r=0, 1, 2….., k-1.

Johansen and Juselius (1990) indicated that trace test might lack the power relative to the maximum eigenvalue test. Based on the power of the test, the maximum eigenvalue test statistic is often preferred. Johansen Cointegration test results are presented in Table 3. Only one trace statistic rejects the hypothesis of no cointegration at the 5% level, which implies that the evidence of cointegration among the prices of ethanol in three market is very weak. Thus, the ethanol prices in Europe, USA and Brazil are very unlikely cointegrated.

[7] Unit root testing and cointegration analysis are conducted using EVIEWS 5.1 (2004).

Table 3. Johansen Cointegration Test Summary

(a) Constant included

Hypothesized No. of CEs	Max-Eigenvalue	5% max	Trace statistic	5% trace
r=0	14.56	22.3	30.40	35.19
r=1	11.27	15.89	15.84	20.26

(b) Constant not included

Hypothesized No. of CEs	Max-Eigenvalue	5% max	Trace statistic	5% trace
r=0	13.75	17.80	25.08**	24.28
r=1	10.58	10.50	11.32	12.32

Note: Critical values based on MacKinnon-Haug-Michelis (1999) ***denotes rejection of hypothesis at 5% level

The fundamental Granger causality method is based on the hypothesis that compared series are stationary or I(0). In the Absence of cointegration vector, with I(1) series, valid results in Granger causality testing are obtained by simply first differentiating the VAR model. Hassapis et al. (1999) show that in the absence of cointegration, the direction of causality can be decided upon via standard F-tests in the first differenced VAR. The VAR in the first difference can be written as:

$$\Delta X_t = c_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta X_{t-i} + \sum_{j=1}^{k} b_{1i} \Delta Y_{t-1} + \mu_{1t} \quad (4)$$

$$\Delta Y_t = c_1 + \sum_{i=1}^{k} \alpha_{2i} \Delta X_{t-i} + \sum_{j=1}^{k} b_{2i} \Delta Y_{t-1} + \mu_{2t} \quad (5)$$

where ΔX_t and ΔY_t represents a pair of ethanol prices among $\ln p_t^{EU}$ $\ln p_t^{USA}$ and $\ln p_t^{Brazil}$. F test is carried out for the null hypothesis of no Granger causality $H_0 : b_{i1} = b_{i2} = b_{ik} = 0$, $i = 1,2$ The pairwise Granger Causality test results are shown in Table 4. Results of Granger-causality tests show the following facts:

1. The USA Granger cause to both EU and Brazil, implying that the change of ethanol price in USA has dominant impact in global ethanol market.
2. Brazil, as the biggest producer of ethanol, its ethanol price difference has rather bigger impact on the EU market than in USA.
3. The price difference of EU market has very limited effect on either USA or Brazil market. Thus there is only a one-way casualty running from USA market or Brazil market to EU market.

Table 4. Granger causality test results

	F - Statistics			
Null hypothesis	Lag 1	Lag 2	Lag 3	Lag 4
USA does not granger cause EU	1.747	7.553***	4.942***	3.91***
EU does not granger cause USA	0.898	2.418	1.809	1.262
EU does not granger cause Brazil	0.08	0.429	0.5320	0.403
Brazil does not granger cause EU	5.363**	2.654*	2.525*	1.911
USA does not granger cause Brazil	12.87***	5.39***	4.04***	3.007**
Brazil does not granger cause USA	4.46**	0.777	1.115	1.455

Note: *, ** and *** represent rejection of the null hypothesis at the 10%, 5% and 1% respectively.

Johtopäätös

In rapid growth of ethanol demand in EU has caused ethanol price to fluctuate much more within recently two years. The dominant ethanol markets in the world, are located in USA and Brazil, where the most production and trading took place. A careful assessment of the relationship between ethanol prices in EU and the prices in USA and Brazil provides significant insights to the greatly expanded linkages among these markets. This study used Johansson cointegration test and Granger Causality test to investigate the price trend and relationship among these three ethanol markets. Our results so far indicate that the ethanol prices in EU, USA and Brazil do not follow the same pattern in the long-term. Thus, the futures market for commodity CBOT in USA may not be the best predictor for the expected price for EU ethanol spot market. However, the study finds there is obvious Granger causality between EU and other markets, which is one-way directional. That is, the ethanol price changes in both USA and Brazil will affect EU market significantly in the short term, but not the other way around. USA, as the major producer and trader for ethanol, its ethanol market has dominant impact in the global ethanol market. Brazil, the biggest producer of ethanol, its ethanol price change gives significant impact only to EU but not to USA market.

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