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INTERNATIONAL MARKET INTEGRATION FOR BIOETHANOL

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WORLD bioethanol fuel production reached 19.5 billion gallons in 2009 (RFA, 2010). The biggest producers of bioethanol are Brazil and USA, their joint production accounts for 89 percent of the world's bioethanol fuel production in 2009. Our focus is to identify and measure how prices of individual economies (Brazil, USA, and Europe) converge in the bioethanol market. This purpose necessitates the use of a time-series based approach. We evaluate the inter-relationship among the variables in a Vector Autoregression (VAR) and Impulse Response Function (IRF). To achieve our goal, we first collected weekly data for bioethanol prices in Europe, USA, and Brazil from January, 2000 to October, 2009. The results provide evidence of cointegration relationship between US bioethanol prices and Brazil bioethenal prices, but no cointegration between the prices of bioethanol in Europe and Brazil or Europe and USA. As a result, we used a VAR model on first differences. With the help of Impulse Response Function, we found out that the impact of the price shock of one variable on the other variables is small and the prices of bioethanol in analyzed countries seem to go back to their initial level in a five-week period.

Key Words: Bioethanol Price, Market Integration, Vector Autoregression.

Inroduction

World biofuel production reached 62 billion liters in 2007. Of this amount around 85 percent of liquid biofuels represents bioethanol, while remaining 15 percent is biodiesel[1]. In 2009 annual production of biofuels has already exceeded 100 billion liters. Incentives motivating the rise of biofuel production come mainly from government support programs. Different instruments are used by governments in the USA, EU, Brazil as well as in other developed but also developing countries to support the production of biofuels. Among the most important instruments belong consumer excise-tax exemptions, mandatory blending of biofuels and fossil fuels, import tariffs on biofuels, production subsidies for biofuel feedstock (e.g., energy crops) and biofuels themselves (grants, loan guarantees, tax incentives, etc.), subsidies for R&D of new technologies (Rajcaniova and Pokrivcak, 2010).

Beside other factors influencing the price of bioethanol (prices of fossil fuels, biofuel policy, production costs…) bioethanol price in one country may be dependent on the price development in another country. Economic theory suggests that price of bioethanol as a homogenous product from different suppliers

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should follow the same pattern over time in an integrated market. The prices may differ in the short run only if there are differences in transportation costs or quality (Asche et al., 2001).

The goal of this study is to investigate the market integration of world bioethanol market with focus on three main markets: EU, USA, and Brazil. The essential principal of market integration is the "Law of One Price". Price convergence tends to result in efficiency gains in an integrated market (Qin et al., 2007).

Empirical studies of price convergence focus on different markets. Similar analyses have been conducted for different energy markets: the European natural gas market has been analyzed by Asche, et al. (2001), the European, Japanese, and North American natural gas markets by Siliverstovs, et al. (2005), the U.S. natural gas market by Cuddington and Wang (2006), the U.S. retail gasoline market by Paul, et al. (2001), the U.S. petroleum market by Asche, et al. (2003) and U.S. natural gas, fuel oil, and electric power markets by Serletis and Herbert (1999). However, there are only a few studies focusing on biofuel market that we are aware of.

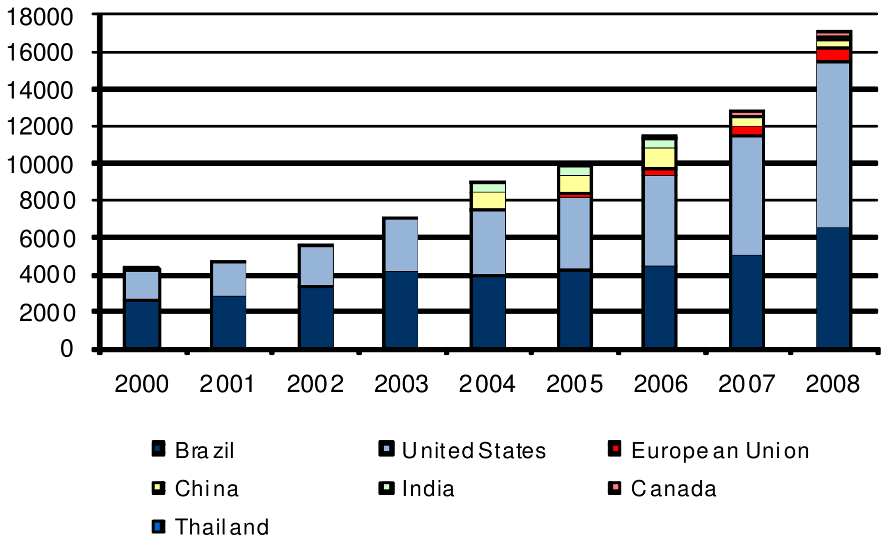

Figure 1: World Bioethanol Production by Country (Millions of U.S. liquid gallons per year)

Source: RFA Industry Statistics.

Materials and Methods

The article examines the degree of bioethanol market integration in Europe, USA, and Brazil. We aim to evaluate the relationship among the following variables: German bioethanol prices, US bioethanol prices, and Brazil bioethanol prices. We analyze the strength and direction of a possible linear relationship among the variables. We conduct a series of statistical tests, starting with tests for unit roots, estimation of cointegrating relationships between price pairs, estimation of linear cointegration and evaluating the inter-relationship among the variables in a Vector Autoregression (VAR) and Impulse Response Function (IRF). The direction of causation in the variables is investigated by means of Granger causality tests.

In order to achieve our goal, we first collected weekly data for each variable from January, 2000 to October, 2009. The total number of data points is 446. Prices are expressed in USD per gallon. German prices are used because Germany has been one of the most important bioethanol producers in Europe during the observed period (Figure 2). To attain stationarity, we have transformed the time series. A common way of achieving stationarity is to take logarithms and then first differences. Logarithmic transformation of the prices is used due to the assumed multiplicative effect. Because of the use of the logarithm of the variables, the corresponding coefficients are now interpreted in percentage terms.

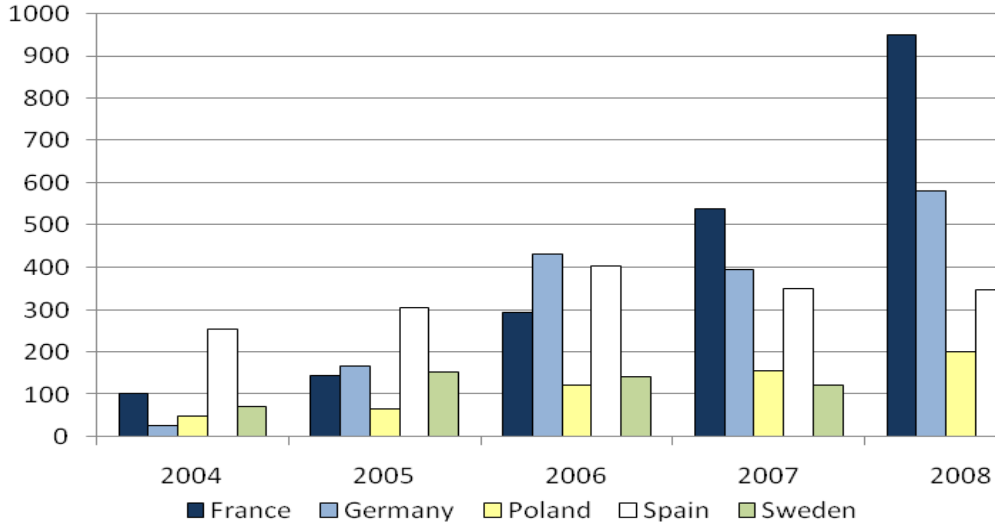

Figure 2: Production in Europe's Largest Bioethanol-Producing Countries (in mln litres)

Source: European Bioethanol Fuel Associations.

Results

Development of Bioethanol Prices

Since early 2000 ethanol prices in analysed countries have widely fluctuated (Figure 3, Table 1). While the most stable was the situation in bioethanol market in Brazil, varying between 0.49 and 2.19 USD per gallon, the biggest fluctuations were observed in Europe. The highest price in the period reached $4.39 per gallon of bioethanol produced in Europe in March 2008, while the lowest price at the amount of $1.63 per gallon was observed in September 2000. The ethanol market in Europe was growing slowly in 1990s. It took almost 10 years for production to grow from 60 million liters in 1993 to 525 million liters in 2004. High increase in production has been driven by the combination of EU biofuel policy, reduction of production costs, and increase in oil prices (Rajcaniova, Pokrivcak, 2010).

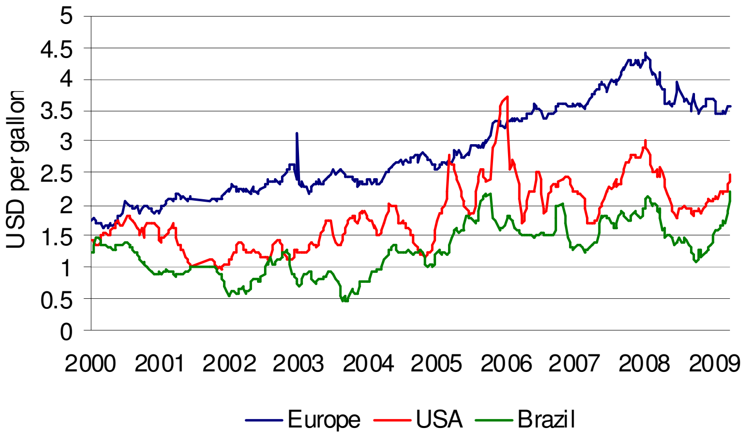

Figure 3: Development of Bioethanol Prices by Country

Source: Bloomberg - bioethanol prices in Europe and USA, – bioethanol prices in Brazil.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Europe	446	2.848006	0.733165	1.625997	4.393175
USA	446	1.840511	0.520700	0.968300	3.729000
Brazil	446	1.272792	0.399953	0.488639	2.194334

Source: Own Calculation.

Around September 2005, ethanol price dropped below the gasoline price and bioethanol became competitive with substitutable gasoline fuel. The same situation was observed in the US ethanol market as well. Hart (2005) attributes this fall in price to the expansion of ethanol production and to the expansion of ethanol products that directly compete with gasoline, such as E85. There was tremendous increase in production in 2005 and 2006 with double-digit growth rates.

Ethanol prices were growing in the observed period, however. This was (especially after 2004) in line with the growth of oil prices.

Correlation analysis confirms high and positive correlation (76.57 %) between bioethanol in Brazil and USA (Table 2). There is also a positive correlation between bioethanol prices in European and US market, as well as between Europe and Brazil (RFA, 2010).

Table 2: Correlation Matrix

Variable	Europe	USA	Brazil
Europe	1.0000	–	–
USA	0.7167	1.0000	–
Brazil	0.6998	0.7657	1.0000

Source: Own Calculation.

However, before making any judgment, we have to analyze the characteristics of time series. Using non-stationary time series can lead to statistically significant results due to spurious correlation. We therefore tested for the stationarity of the bioethanol price series. To test the stationarity we use two unit root tests: augmented Dickey Fuller (ADF) test and Phillips Perron (PP) test. The lags of the dependent variable were determined by Akaike Information Criterion (AIC).

Both tests (Table 3) indicate that all the time series (bioethanol price in Europe, USA, and Brazil) are integrated of order 1, i.e. non-stationary. Order of integration refers to the number of times a variable is differenced before becoming stationary. To make them stationary we, therefore, take the first differences. All the differenced time series were found to be stationary.

Cointegration

According to the above stationarity tests all the original time series are non-stationary and could be used for cointegration test. While individual time series may be non-stationary a combination of two non-stationary time series may be stationary (Engle and Granger, 1987). In this special case, individual time series are said to be cointegrated. Cointegration of time series means, that there exists a long-run equilibrium relationship between them and we may use the ordinary least squares to estimate parameters of their relationship.

Johansen Cointegration Test allows for testing the cointegration of several time series. This test furthermore does not require time series to be in the same order of integration. In the Johansen

Table 3: Unit Root Tests

	Level			First Differences		
Time Series	**None**	**Constant**	**Constant & Trend**	**None**	**Constant**	**Constant & Trend**
ADF – Europe	1.312	-1.413	-1.503	-12.801***	-12.931***	-12.964***
ADF – USA	-0.625	-2.792*	-4.035***	-8.978***	-8.992***	-8.984***
ADF – Brazil	-1.163	-1.657	-3.171*	-10.570***	-10.575***	-10.576***
PP – Europe	1.124	-1.506	-2.168	-27.202***	-27.340***	-27.362***
PP – USA	-0.259	-2.064	-2.846	-10.902***	-10.911***	-10.897***
PP – Brazil	-0.860	-1.357	-2.650	-12.319***	-12.321***	-12.319***

*Notes: * significance at the 10% level, ** significance at the 5% level, *** significance at the 1% level*

Source: Own Calculation.

Cointegration Test, the cointegration rank (number of cointegration relationships) is obtained through the trace test.

The null hypothesis of the trace test statistics of Johansen (1991) is that there are at most r cointegrating vectors.

In Johansen cointegration test we used the 1% level of significance because the power of this test is low. As shown in the Table 4, US and Brazilian bioethanol prices are cointegrated, while other time series are not cointegrated. There is a weak cointegrating relationship between European and US bioethanol prices and European and Brazilian bioethanol prices statistically significant at 5% significance level.

Table 4: Johansen Cointegration Test

Rank	**Trace statistic**	**1% critical value**	**5% critical value**
Europe – USA			
0	17.5135	20.04	15.41
1	2.2321	6.65	3.76
Europe – Brazil			
0	19.1708	20.04	15.41
1	1.0783	6.65	3.76
USA – Brazil			
0	22.5925	20.04	15.41
1	2.7930	6.65	3.76
EU – USA – Brazil			
0	43.1316	35.65	29.68
1	18.8866	20.04	15.41
2	1.0818	6.65	3.76

Source: Own Calculation.

These results are in line with Liu (2007) who found out, 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.

Vector Autoregression Model

Not all of the variables presented evidence to be all cointegrated. As a result, we used a Vector Autoregression (VAR) model to estimate the relationships among the variables. Based on the AIC criterion, we fit the VAR (2) model on the first differences of the logarithms of each variable. Table 5 presents the main results of the model (p values are presented in parentheses below the estimates).

Table 5: Vector Autoregression

	Europe	USA	Brazil
Europe L1	-0.3664 (0.000)	0.0866 (0.228)	-0.2534 (0.005)
Europe L2	-0.1808 (0.000)	0.0413 (0.569)	-0.1634 (0.070)
USA L1	0.0239 (0.516)	0.4775 (0.000)	0.1215 (0.058)
USA L2	-0.0324 (0.380)	0.0518 (0.317)	0.0040 (0.950)
Brazil L1	0.0382 (0.199)	0.0599 (0.151)	0.4213 (0.000)
Brazil L2	0.0088 (0.767)	-0.1139 (0.006)	-0.0125 (0.810)

Note: p values in parentheses below the estimate.

Source: Own Calculation.

We found a relationship between the prices of Brazilian bioethanol price in period t-2 and US bioethanol price in t period. The coefficient -0.1139 implies that if the bioethanol price in Brazil in period t-2 goes up by one unit, the bioethanol price in USA in period t would decrease by 0.1582. Both prices are negatively linked.

Second, we found a reverse relationship between the price of bioethanol in USA and Brazil. There is a positive relationship between bioethanol price in period t-1 and the bioethanol price in Brazil in period t. If the price of US bioethanol in period t-1 increases by one unit, the coefficient shows that the bioethanol price in Brazil in period t increases by 0.1215 (Note the p value 0.058).

The strongest is the relationship observed between the bioethanol price in Europe and bioethanol price in Brazil. The model suggests that the increase in European bioethanol price by one unit in period t-1 will lead to a decrease in bioethanol price in Brazil by 0.2534.

Finally, we found that each variable in this period is affected by its own values from the previous periods.

Granger Causality

In order to explore if there is a "Granger causality" among the analyzed variables, we needed to run a causality test. A Wald test is commonly used to test for Granger causality. The test highlights the presence of at least unidirectional causality linkages as an indication of some degree of integration. This implies that each market uses information from the other when forming its own price expectations, while unidirectional causality inform about leader-follower relationships in terms of price adjustments (Arshaad and Hameed 2009). Causality tests answer the question which of the observed country is a price leader and which are the price followers, or that none of the countries is more important than the other (Ciaian and Kancs, 2009). 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.

X Granger causes Y if past values of X can help explain Y. Of course, if Granger causality holds this does not guarantee that X causes Y. This is why we say “Granger causality” rather than just “causality”. Nevertheless, if past values of X have explanatory power for current values of Y, it at least suggests that X might be causing Y (Koop, 2005).

Causality results are reported in Table 6. As seen from the table, we found a Granger casual relationship between USA granger causing the bioethanol prices in Brazil. Later on we found out Brazilian bioethanool prices having Granger caused European bioethanol prices. Similar results were found by Liu (2007), where in the long-run, Brazilian bioethanol price difference has rather bigger impact on the EU market than in USA. The price difference of EU market has very limited effect on either USA or Brazil market. Thus the results of Liu (2007) are in line with our conclusion, that there is only a one-way casualty running from USA to Brazil market to EU market.

Table 6: Granger Causality Wald Tests

Equation	Excluded	Prob > chi2
Europe	USA	0.661
Europe	Brazil	0.287
Europe	All	0.541
USA	Europe	0.474
USA	Brazil	0.023
USA	All	0.071
Brazil	Europe	0.011
Brazil	USA	0.083
Brazil	All	0.010

Source: Own Calculation.

Impulse Response Function

Impulse Response Functions were performed in order to show how a shock in one variable would persist in future periods. The forecast was made considering a ten-week period.

As we can see from Figure 4, a shock in the bioethanol price in Brazil would result in a temporary response in bioethanol prices in Europe and USA. It seems that the response disappears after about two weeks in Europe and 5 weeks in USA. This is also true for the response of Brazilian bioethanol price to the shock in bioethanol prices in Europe and USA. The response of Brazilian bioethanol price to European price shock would lead to decrease and then starts increasing after 5-7 days following the shock. After about three weeks the response to European price shock would disappear while the response to US prices would persist two weeks longer. However all the responses would eventually approach zero within a ten-week period, which proves to be a temporary response.

Discussion

The main purpose of this paper is to examine the degree of bioethanol market integration in Europe, USA, and Brazil. In order to achieve our goal, we first collected weekly data for each variable from January, 2000 to October, 2009. The results provide evidence of cointegration relationship between US and Brazilian bioethanol prices, but no cointegration between European and US bioethanol prices and European and Brazilian bioethanol prices. As a result, we used a VAR model on first differences. We

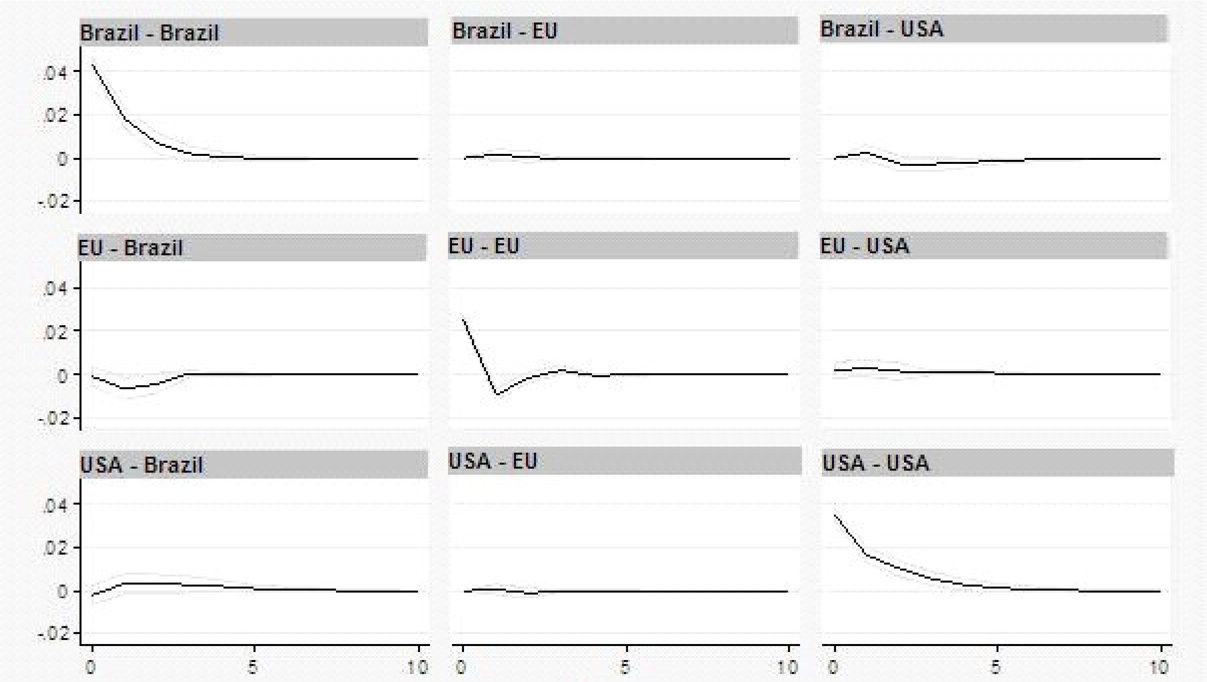

Figure 4: Impulse Response Function

Note: Graphs by impulse variable and response variable.

Source: Own Calculation.

found a relationship between the price of Brazilian bioethanol price in period t-2 and US bioethanol price in t period, reverse relationship between the price of bioethanol in USA and Brazil, the bioethanol price in Europe and bioethanol price in Brazil and finally, we found that each variable in this period is affected by its own values from the previous periods.

After running an Impulse Response Function, we found out that a shock in the bioethanol price in Brazil would result in a temporary response in bioethanol prices in Europe and USA. It seems that the response disappears after about two weeks in Europe and 5 weeks in USA. This is also true for the response of Brazilian bioethanol price to the shock in bioethanol prices in Europe and USA. The response of Brazilian bioethanol price to European price shock would lead to decrease and then starts increasing after 5-7 days following the shock. After about three weeks the response to European price shock would disappear while the response to US prices would persist two weeks longer. However all the responses would eventually approach zero within a ten-week period, which proves to be a temporary response.

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