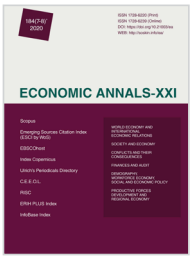

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Time-varying relationship between Ukrainian corn and world crude oil prices

Abstract. Corn belongs to the most important feed and industrial grains in the world being utilized for bioethanol production. Ukraine does not produce biofuels and does not pursue an active renewable energy policy. However, due to significant share of exports, corn prices in Ukraine can be shaped under the influence of biofuel policies pursued by developed countries, as well as under the influence of world energy markets. Therefore, the aim of the paper is to investigate the mechanisms linking Ukrainian export corn prices with Brent oil prices, as well as to quantitatively assess the nature of this relationship. We were especially interested in possible time-varying relationship between the prices. The price analysis was carried out on the basis of monthly data for the period 2001-2020 with the use of rolling correlation technique and rolling causality tests.

The results of this research indicate on time-varying co-movements of Ukrainian corn and Brent crude oil prices. The strongest positive correlations and significant bidirectional causality were observed in 2007-2011. However, in most of sub-periods there were no significant relationships between these prices. Among factors strengthening the price linkages are the low corn-oil price ratios, dynamic increase of corn utilized for ethanol production and depletion of the world corn stocks. The conducted analysis confirmed that changes in biofuel demand in other countries can affect Ukrainian corn market due to horizontal integration of grain markets worldwide. Biofuel policy reforms in the EU aiming at decreasing mandatory blending of conventional biofuels in favor of advanced biofuels can lead to decrease in demand for corn in Ukraine after 2021, leading, in turn, to further weakening of linkage between corn and crude oil prices.

Keywords: Corn; Crude Oil; Brent; Bioethanol; Biofuel; Price Transmission; Time-Varying; Causality; Energy Policy
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Динамічні взаємозв'язки між українськими цінами на кукурудзу та світовими цінами на нафту

Анотація
Насіння кукурудзи використовується як у якості цінного корму, так і для промислових цілей, зокрема виробництва біоетанолу. Україна не виробляє біопальне та не проводить активної політики у сфері відновлювальних джерел енергії. Однак через значну частку експорту ціни на кукурудзу в Україні

можуть формуватися під впливом політики щодо біопалива, яка проводиться розвиненими країнами, а також світових енергетичних ринків. У цьому контексті метою нашої статті є дослідження механізмів, що пов'язують українські експортні ціни на кукурудзу з цінами на нафту марки Brent у світі, а також кількісна оцінка характеру даного взаємозв'язку. Особливу увагу нами приділено оцінці можливого зв'язку між цінами в залежності від часу. Аналіз цін проводився на основі щомісячних даних за період 2001–2020 рр. із застосуванням методики ковзної кореляції та ковзних тестів на виявлення причинно-наслідкових зв'язків.
Результати проведеного нами дослідження свідчать про динамічні сумісні рухи українських цін на кукурудзу та світових нафтових цін марки Brent. Найсильніша позитивна кореляція і значна двонаправлена причинність взаємозв'язків спостерігалась у 2007–2011 рр. Однак у більшості періодів не спостерігалося суттєвих зв'язків між даними цінами. Серед чинників, які посилюють цінові зв'язки, можна відмітити низьке співвідношення цін на кукурудзу та нафту, динамічне зростання використання кукурудзи для виробництва етанолу, а також зниження світових запасів кукурудзи.
Проведений аналіз підтвердив те, що зміни в попиті на біопаливо в інших країнах можуть вплинути на український ринок кукурудзи через горизонтальну інтеграцію ринків зерна в усьому світі. Політичні реформи щодо біопалива в ЄС спрямовані на зменшення обов'язкової домішки звичайного біопалива на користь біопалива другого покоління. Така ситуація може призвести до зменшення попиту на кукурудзу в Україні після 2021 року, що в свою чергу сприятиме подальшому послабленню зв'язку між цінами на кукурудзу й сиру нафту.
Ключові слова: кукурудза; сира нафта; нафта марки Brent; біоетанол; біопаливо; цінова реакція; динамічність; причинний зв'язок; енергетична політика.

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Динамические взаимосвязи между украинскими ценами на кукурузу и мировыми ценами на нефть

Аннотация
Семена кукурузы используются как в качестве ценного корма, так и направляются для промышленных целей, в частности производства биоэтанола. Украина не производит биотопливо и не проводит активной политики в сфере возобновляемых источников энергии. Однако из-за значительной доли экспорта цены на кукурузу в Украине могут формироваться под влиянием политики в отношении биотоплива, проводимой развитыми странами, а также мировых энергетических рынков. В этом контексте целью нашей статьи является исследование механизмов, связывающих украинские экспортные цены на кукурузу с мировыми ценами на нефть марки Brent, а также количественная оценка характера данной взаимосвязи. Особое внимание нами уделено оценке возможной связи между ценами в зависимости от времени. Анализ цен проводился на основе ежемесячных данных за период 2001–2020 гг. с применением методики скользящей корреляции и скользящих тестов на выявление причинно-следственных связей.
Результаты проведенного нами исследования свидетельствуют о динамических совместимых движениях украинских цен на кукурузу и мировых нефтяных цен марки Brent. Наиболее сильная положительная корреляция и значительная двунаправленная причинность взаимосвязей наблюдалась в 2007–2011 гг. Однако же в большинстве периодов не наблюдалось существенных связей между этими ценами. Среди факторов, которые усиливают ценовые связи, можно отметить низкое соотношение цен на кукурузу и нефть, динамичный рост использования кукурузы для производства этанола, а также снижение мировых запасов кукурузы.
Проведенный анализ подтвердил то, что изменения в спросе на биотопливо в других странах могут повлиять на украинский рынок кукурузы через горизонтальную интеграцию рынков зерна во всем мире. Политические реформы относительно биотоплива в ЕС направлены на уменьшение обязательной примеси обычного биотоплива в пользу биотоплива второго поколения. Такая ситуация может привести к уменьшению спроса на кукурузу в Украине после 2021 года, что в свою очередь будет способствовать дальнейшему ослаблению связи между ценами на кукурузу и сырую нефть.
Ключевые слова: кукуруза; сырая нефть; нефть марки Brent; биоэтанол; биотопливо; ценовая реакция; динамичность; причинная связь; энергетическая политика.

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Zmienna w czasie zależność między ukraińskimi cenami na kukurydzę a światowymi cenami ropy naftowej
Streszczenie
Kukurydza należy do najważniejszych zbóż paszowych i przemysłowych na świecie wykorzystywanych do produkcji bioetanolu. Mimo tego, że Ukraina nie produkuje biopaliw i nie prowadzi aktywnej polityki w zakresie energii odnawialnej, ze względu na znaczący udział eksportu, ceny kukurydzy na Ukrainie mogą kształtować się pod wpływem polityki biopaliwowej krajów rozwiniętych, a także pod wpływem światowych rynków energii. W tym kontekście celem naszych badań jest ocena mechanizmów łączących eksportowe ceny ukraińskiej kukurydzy z cenami światowymi ropy Brent, a także ilościowa ocena charakteru tego związku. Szczególnie interesuje nas możliwa ewolucja tej zależności w czasie. Analizę cen przeprowadzono na podstawie danych miesięcznych za lata 2001-2020 z wykorzystaniem techniki korelacji kroczącej oraz kroczących testów przyczynowości.
Wyniki badań wskazują na zmieniającą się w czasie współzmienność cen ukraińskiej kukurydzy i ropy Brent. Najsilniejsze dodatnie korelacje i istotna dwukierunkowa przyczynowość zostały zaobserwowane w latach 2007-2011. Jednak w większości podokresów nie było istotnych zależności między tymi cenami. Czynnikami wzmacniającymi powiązania cenowe są niskie relacje cen kukrurydzy do ropy naftowej, dynamiczny wzrost wykorzystania kukurydzy do produkcji etanolu oraz niski poziom światowych zapasów kukurydzy.
Przeprowadzona analiza potwierdziła, że zmiany popytu na biopaliwa w innych krajach mogą wpłynąć na ukraiński rynek kukurydzy ze względu na przestrzenną integrację światowych rynków zbóż. Reformy polityki biopaliwowej w UE zmierzające się do obniżenia udziału biopaliw konwencjonalnych na rzecz biopaliw zaawansowanych mogą doprowadzić do spadku popytu na kukurydzę na Ukrainie po 2021 r., prowadząc do dalszego osłabienia powiązań między analizowanymi cenami.
Słowa kluczowe: kukurydza; ropa naftowa; ropa Brent; bioetanol; biopaliwo; transmisja cen; zmienna w czasie przyczynowość; polityka energetyczna.

1. Introduction

Agriculture plays an important role in providing raw materials not only for food and feed but also for industrial sectors. A relatively new direction of utilization of agricultural commodities is for production of renewable energy, biofuels among them. Fast expansion of ethanol and biodiesel production was enhanced by active government policies. Developed countries implemented various biofuel policies based on such incentives as mandatory blending, tax reductions, and investment subsidies. Rationale for biofuel policies is quite manifold and includes such elements as increased world demand for energy, energy security concerns, alternative use of crop production surpluses and environmental arguments such as reduction of greenhouse-gas emissions (HLPE, 2013; Wright, 2014).

The increasing share of biofuels in liquid fuels is evident over time. Expanded biofuel production and its use have created an additional demand for grains, sugar cane and oilseeds. This led to concerns that agricultural markets, even in countries that don't produce biofuels, could be more closely linked to the oil market. However, this problem is less and less discussed in the literature, which may indicate that the impact of biofuels on agri-food prices is decreasing over the time.

Therefore, the goal of the research is to find the nature of mentioned linkages and theirs strength over time in Ukraine. Ukraine's choice is dictated by two factors. First of all, Ukraine does not apply any effective biofuel supportive policies and is not significant consumer of biofuels. Secondly, there is practically no research in this regard for the Ukrainian market.

2. Brief Literature Review

Most of studies suggest that biofuel policies shifted world agricultural prices upward. Along with introduction of biofuels agro-food prices started to be more correlated with crude oil prices (HLPE, 2013; Tyner, 2009). Gozgor and Kablamaci (2014) using panel model confirmed positive impact of crude oil prices on agricultural commodity prices. Saghaian (2010) indicates that crude oil prices Granger cause corn, soybeans, and wheat prices. Empirical evidence of Katrakilidis et al. (2015) also supports the existence of significant causal effects revealing strong interdependencies among the examined markets. Findings of Zafeiriou et al. (2018) confirm that crude oil prices affect the prices of agricultural products used in the production of biodiesel, as well as of ethanol, validating the interaction of energy and agricultural commodity markets. Still, they indicate that biofuels cannot be substituted for crude oil and protect economies from energy volatility.

However, some of researchers indicate that introduction of biofuels had only a slight impact on agro-food prices. In the case of Zilberman et al. (2013) biofuels have not been the most dominant

contributor to the recent food price inflation and different biofuels have different impacts on food prices. Therefore, the literature review does not give a clear answer, whether biofuels production has impact on agricultural commodity prices and whether there is a substantial linkage between crude oil and agricultural markets. The nature of the mechanism linking agricultural markets with crude oil market and results of empirical research in this domain are ambiguous. They depend heavily on the period analyzed and methodology used. This was partially confirmed by Hamulczuk et al. (2019) who showed time-varying relationship between Ukrainian grain prices and world crude oil prices.

The majority of research in this field concerns countries directly involved in the production and use of biofuels. In contrast, Ukraine, one of the leading producers of grains worldwide, doesn't use biofuels in domestic market. It has not own policy supporting biofuel production but due to possible international trade connections we can expect the positive linkage of Ukrainian grain prices with world crude oil prices. Theoretical basis of price transmission process is explained by the Law of One Price (LOP). The level of grain prices in Ukraine mostly depends on external factors however. Ukraine is a price taker of the world wheat prices (Goychuk & Meyers, 2014). Arnade and Hoffman (2016) found a similar evidence for corn prices. Due to horizontal price transmission mechanism, biofuel policies implemented in the US, the EU or Brazil may indirectly influence grain prices in countries which do not implement their own policy instruments, like Ukraine.

3. Purpose

The objective of this paper is to investigate time-varying nature of relationship between Ukrainian export corn prices with world crude oil prices. The specific objectives of the study include: the characteristics of corn and bioethanol markets, the presentation of theoretical premises of links between corn and crude oil markets and empirical assessment of the nature of price linkages between world oil prices and Ukrainian export corn prices.

In the empirical part we have focused on potential time-varying relationships. The examination of monthly price series in 2001-2020 was carried out with the use of rolling correlation and rolling causality test. The empirical research is one of the very few which focuses on linkage between crude oil and grains prices in Ukraine.

4. Results

Bioethanol and corn markets - trends and figures

One of the key agricultural commodities used for bioethanol production worldwide is corn. In 2010-2017 bioethanol use constituted 17% share in the total corn utilization in the world (feed use was 58%). From 2010 to 2018 the corn production was characterized by an upward trend both in the Ukrainian market and in the largest producer and exporter countries (Figure 1). The annual growth rate of world production of corn in a given period was 3.9%. The highest average annual growth rate of production in the analyzed period was in Ukraine and amounted to as much as 12.8%. For the next decade global maize production is projected to grow by 193 million tons to 1 315 million tons, with the largest increases in China, the United States, Brazil, Argentina, and Ukraine systems (OECD-FAO, 2020). According to OECD-FAO outlook (2020), Ukraine's production will be sustained by the cultivation of high yielding domestic varieties grown in rain-fed systems.

Ukraine is a country with high potential for agricultural production, where agro-climatic conditions and the high quality of land resources favor the cultivation of cereal crops. Corn along with wheat has the biggest shares in grain area and production in Ukraine. In 2005/2006 - 2019/2020 MY the share of the sown area of corn in the total cereal area has doubled. Since 2005/2006 MY production of corn has increased by 3.4 times. Both, the increase in area harvested and the rise in yield have contributed to this growth. Corn productivity has grown by 26% and harvested area around 2.6 times. A further increase in productivity is possible taking into account the quality of soils (The Bleyzer Foundation, 2016).

Ukrainian corn prices are closely linked to the world corn prices. One of the key factors determining the increase in price integration could have been the accession of Ukraine in 2008 to the World Trade Organization (WTO). It allowed for the strengthening the position of the Ukrainian corn market in the world and led to the increase in Ukrainian and international corn price co-movements.

Due to positive price trends on the world markets in analyzed period the Ukrainian corn export has improved significantly. In the last decade it has increased by 7.5 times and in the last five years by 1.2 times. In 2019/2020 MY the share of corn exports in total production constitutes 85% and its self-sufficient ratio was 7.0. The increase in world market demand for grains is connected with good economic situation in the world and development of bioenergy sector. Such a significant growth was, by the way, an effect of implementation of policy tools supporting biofuel production. It should be emphasized that Ukraine has used its potential and the situation that had arisen as a result of the increase in global demand for biofuels, increasing its corn share in the global market, especially to the EU. The key EU policies that have led to increase in the corn imports from Ukraine are duty-free quotas granted to Ukraine, as well as implemented energy policies aiming at maintaining a minimum level of bio-components in transport fuel (Hochman et al., 2017).

Data and methods for the assessment of price linkage

To analyze the linkage between Ukrainian corn prices and world crude oil prices the monthly price series from January 2001 till February 2020 were used (Figure 1). Corn price series (FAOSTAT) express export prices in Ukraine whereas oil price series (World Bank) is for Brent crude oil. The whole analysis was performed on logarithmic data.

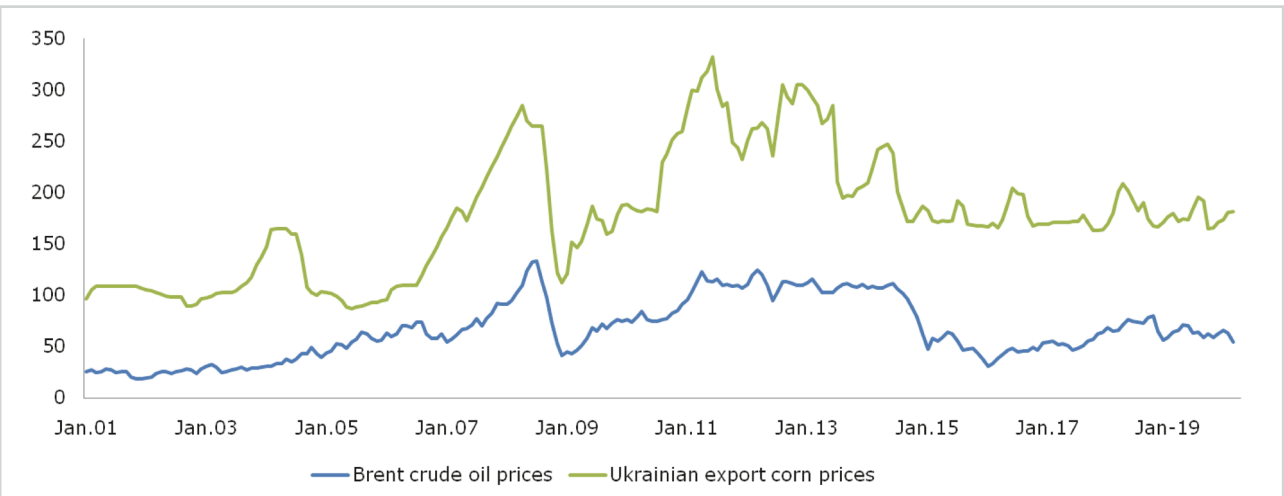

Figure 1:
Monthly price series used in the analysis (USD/tonne and USD/barrel)
Source: Own elaboration based on World Bank and FAO data

Unlike Hamulczuk et. al. (2019) who used the ARDL-ECM model with structural breaks, we focused on rolling techniques. The co-movements of these prices were examined with the use of rolling correlation technique and rolling causality tests. The length of the rolling window in both cases was 48 months.

The value of correlation coefficient according to centered rolling correlation in a period t for a pair of variables x_t and y_t was calculated with use of the following formula:

$$r_t = \frac{\sum_{t=-23}^{t=24}(x_t-\bar{x})(y_t-\bar{y})}{\sqrt{\sum_{t=-23}^{t=24}(x_t-\bar{x})^2 \sum_{t=-23}^{t=24}(y_t-\bar{y})^2}} . \quad (1)$$

Another question we tried to answer was whether world crude oil prices were leading Ukrainian corn prices or vice versa. We have applied Toda-Yamamoto variant of causality test which is insensitive for stationarity and cointegration assumptions (Toda & Yamamoto, 1995). Two variants of causality have been tested: Granger causality and instantaneous causality (Granger, 1969). To test Granger causality two equations were estimated:

$$y_t = \alpha_0 + \sum_{j=1}^{p+d} \alpha_j \, y_{t-j} + \sum_{j=1}^{p+d} \beta_j \, x_{t-j} + \varepsilon_t \, , \quad (2)$$

$$x_t = \gamma_0 + \sum_{j=1}^{p+d} \gamma_j \, x_{t-j} + \sum_{j=1}^{p+d} \delta_j \, y_{t-j} + u_t \, , \quad (3)$$

where:

$\alpha, \beta, \gamma, \delta$ are model parameters, y and x are analyzed variables, j=1,2,..., p is a lag length, ε_t and u_t are white noise residuals, d is maximal order of integration of analyzed processes. For determining number of p lag length we applied AIC. Testing Granger causality comes down to testing significance of first p lagged x variable in equation 2 and first p lagged y variables in equation 3. Null hypothesis, stating that x does not Granger-cause y assumes that $\beta_1 = \beta_2 = \ldots = \beta_p = 0$ against alternative of these coefficients statistically significant. Null hypothesis, stating that y does not Granger-cause x assumes that $\delta_1 = \delta_2 = \ldots = \delta_p = 0$ against alternative of these coefficients statistically significant.

In testing instantaneous causality we used a modified pairs of equations:

$$y_t = \alpha_0 + \sum_{j=1}^{p+d} \alpha_j y_{t-j} + \sum_{j=0}^{p+d} \beta_j x_{t-j} + \varepsilon_t , \quad (4)$$

$$x_t = \gamma_0 + \sum_{j=1}^{p+d} \gamma_j x_{t-j} + \sum_{j=0}^{p+d} \delta_j y_{t-j} + u_t . \quad (5)$$

Null hypothesis, stating that x does not cause y assumes that $\beta_0 = \beta_1 = \ldots = \beta_p = 0$ against alternative of these coefficients statistically significant. Null hypothesis, stating that y does not cause x assumes that $\delta_0 = \delta_1 = \ldots = \delta_p = 0$ against alternative of these coefficients statistically significant. We can see that in instantaneous causality a significance of no-lagged exogenous variable is also tested. This approach is justified by relatively low frequency data (monthly span of our data) and possible efficiency of markets revealing in fast flow of price signals due to application of information and communication technologies (ICT).

Empirical results

In the first step we have tested for a unit root in the analyzed price series with the use of ADF. The estimate of δ parameter for corn price series is -0.027 with tau test statistic on the level -2.38 (model with one lag). Therefore, null hypothesis (assuming non-stationarity of series) cannot be rejected at 5% and 10% significance levels (p = 0.15). ADF test applied for first differences of corn price series clearly indicated on stationarity of such transformed data (tau = -9.10 and δ = -0.654). Crude oil price series have similar properties. The null hypothesis for levels was not rejected (tau = -2.12, δ = -0.039) and it was rejected for first differences (tau = -11.44, δ = -0.736). Therefore, we can conclude that both variables are integrated in order 1 (d = 1) in the whole sample.

Keeping in mind that factors underlying strength of linkage between corn and crude oil markets may evolve over time, in the next step we calculated centered rolling correlations between a pairs of variables (Eq. 1). It allows us to examine the co-movements of prices series over the analyzed period, as well as to assess the stability of their relationships. Since our series are not stationary we have computed such correlations both or logarithmic levels and for first differences of logarithmic series (Figure 2).

The relationship between corn and crude oil prices is not constant over time. Correlations between levels (l) and first differences (d l) have similar shape but different values. Till 2006 correlations were close to zero or even negative indicating the weak co-movement of corn and crude oil prices. A substantial increase in correlation could be visible on the graph since 2007 (in fact since 2005 because each period covers 48 month window), the period when a strong demand for biofuels has occurred. The highest positive correlation coefficients for prices are for 2007-2011. Since 2013 we can observe weakening relationship between corn and oil prices in reaction to the decrease in crude oil prices and fulfilling mandatory blending levels of biofuels with conventional fuels in the EU and USA.

In the next step we tried to investigate whether crude oil prices are leading Ukrainian corn price or vice versa. The total number of lags was 3 ($p + d$) and restrictions were imposed on first two of them (p = 2). Taking into account that price relationships may vary over time a rolling version of Granger-causality test was applied. Figure 3 includes centered F statistic for four year windows. Each value shows output of testing the null hypotheses of no Granger causality for a period of two years before and two years after a given point. In most of sub-periods there is no significant Granger causality between Ukrainian corn and world crude oil prices. The only exceptions are years between 2007 and 2010 (the null: corn prices are not a Granger cause for crude oil prices) and from mid-2015 (the null: crude oil prices are not Granger cause for corn prices). Surprisingly in the years of the biofuel boom the Ukrainian corn prices were leading world crude oil prices.

Obtained results for instantaneous rolling causality coincide with rolling correlations and Granger causality and are much significant than in Granger causality case. Significant bidirectional causality is observed in 2007-2011. Moreover, the strength of such linkage is higher than in case of Granger causality.

The study confirms that strength of the linkage between corn and agricultural prices strongly depends on period being analyzed. Our conclusions are in line with research of Tyner (2009), de Gorter et al., (2013) or Paris (2018). These authors also indicated the possible time-varying relationships between crude oil and agricultural commodity prices. Hamulczuk et al. (2019) analyzing linkage of Ukrainian procurement (not export) corn prices with crude oil prices indicate on possible structural breaks in 2008 and 2013. They found a strong evidence for co-movements of crude oil and corn prices only in 2008-2013. In that period, a 1% change in crude oil prices leads to 0.85% change of corn prices in 12 month horizon. The shape of rolling correlation coefficients and F-statistics of causality tests (Figures 2-3) strongly confirm the above mentioned research results.

To explain such price relationships we need to refer to mechanisms linking crude oil and corn market. In Figure 4 on the left panel corn demand for biofuel, as well as stock to use ratio in the

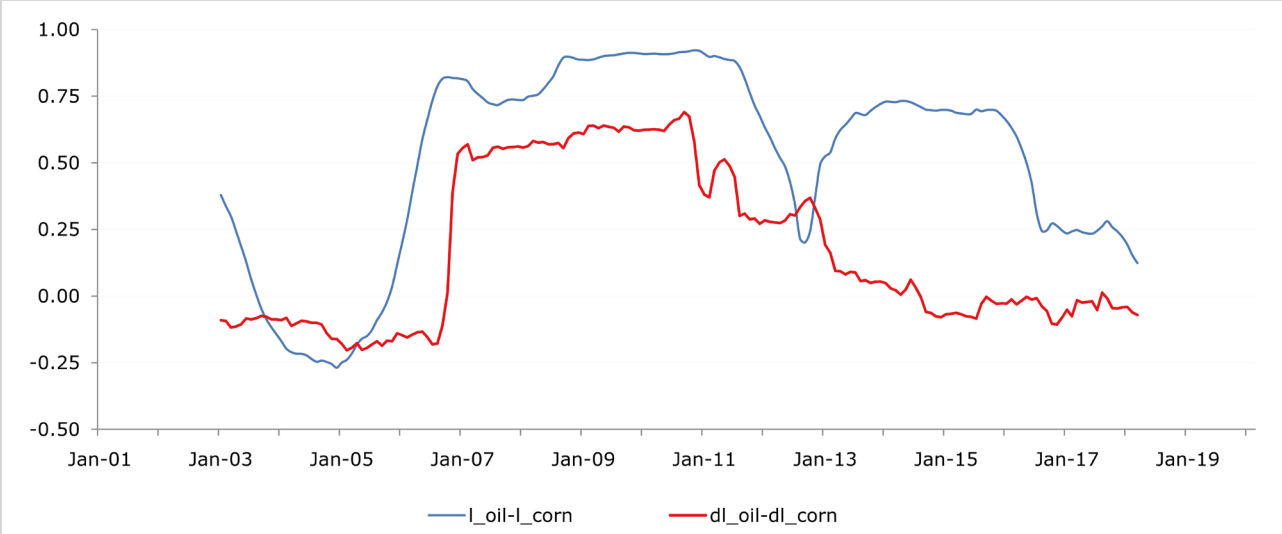

Figure 2:
Rolling correlations (48 months)
Source: Own elaboration based on World Bank and FAO data

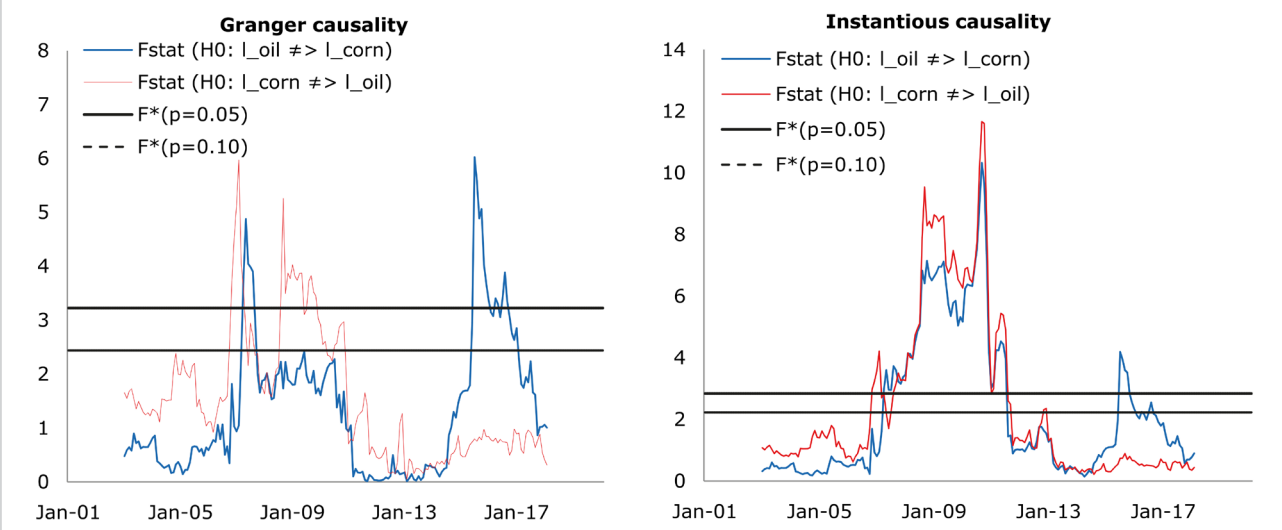

Figure 3:
Rolling Granger causality and instantaneous causality test results
Source: Own elaboration based on World Bank and FAO data

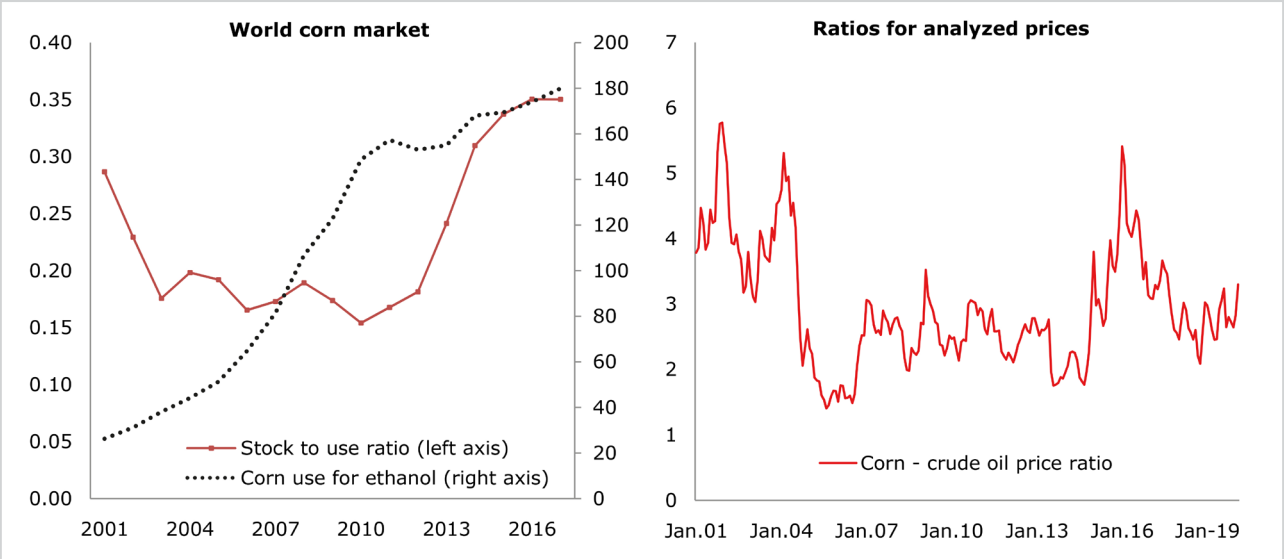

Figure 4:
Statistics for world corn market and price ratios for the analyzed prices
Source: Own elaboration based on World Bank, FAO and OECD data

world corn market are presented. The highest correlation coefficients between Brent crude oil and Ukrainian corn prices are in periods when the highest increase in bioethanol production was observed. In the same time a low stock to use ratio was visible. Right panel in the Figure 4 includes corn-crude oil price ratio which is an inverse indicator of a free market profitability of bioethanol production based on Ukrainian corn. The highest co-movements and causality of analyzed price series are for years when the price ratios were the lowest. Generally high profitability of ethanol production, low stock to use ratios in corn market and high dynamic of corn use for ethanol have positive impact on strength of linkage between Ukrainian export corn prices and world crude oil prices.

5. Conclusions

The goal of the paper was to present the potential links between Ukrainian export corn prices and Brent crude oil prices, as well as to verify the strength of price co-movements over time. The results of application of the rolling window correlation technique and rolling causality tests indicate time-varying co-movements of Ukrainian corn and Brent crude oil prices. The strongest positive correlations and significant bidirectional causality were observed in 2007-2011. In this period market and institutional factors favored bioethanol productions. Low stock to use ratios in the world corn market, high dynamic of corn use for ethanol, depletion of world corn stocks and low corn-oil price ratios were reflected in strong positive linkage between Ukrainian export corn prices and world crude oil prices. In the remaining years, correlations between analyzed prices were much weaker, or even negative. Since 2012, a gradual decrease in co-movements of Brent crude oil and Ukrainian export corn prices has been observed. Lowering price linkage might be caused by reaching planned mandatory blending levels of first generation biofuels in most countries promoting biofuel policy. Moreover, relatively low crude oil prices do not constitute the motivation to increase the use of cereals for biofuel production.

Performed analysis confirmed that changes in biofuel demand in other countries might affect Ukrainian corn market due to horizontal integration of grain markets worldwide. Biofuel policy reforms in the EU aiming at decreasing mandatory blending of conventional biofuels in favor of advanced biofuels can lead to decrease in demand for corn in Ukraine after 2021. This in turn may lead to further weakening of linkage between corn and crude oil prices.

The performed analysis has also some limitations related to data used and methods applied. Especially the quality of monthly corn series in Ukraine is frequently questioned by market experts. The study might be extended by direct inclusion of ethanol quotations in Europe which is intermediate link between crude oil and corn markets. The extension of these studies may include also the application of more sophisticated method such as non-linear cointegration or switching regime models.

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