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RELATIONSHIP BETWEEN THE PRICES OF GRAINS, CRUDE OIL AND REAL EFFECTIVE EXCHANGE RATES: EVIDENCE FROM FOURIER TODA-YAMAMOTO CAUSALITY TEST

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Abstract
This study focuses on grain prices and their determinants in the case of Turkiye. The sustainability of grain prices matters for Turkiye since it is a significant grains importer due to the nutrition habits of its population and its significant processed grain products sector. Therefore, it is vital to portray the relationship between grain prices and their determinants. We employed a detailed causality analysis between wheat, durum wheat, corn, rye, rice, and barley prices and their significant determinants: crude oil and reel effective exchange rates (REER) between January 2003 and December 2020. We first examined unit root properties of the variables with traditional tests and more advanced Fourier ADF and Lagrange Multiplier (LM) tests; then continued with the Fourier Toda-Yamamoto (TY) causality test. The long-term causality results suggest a unidirectional causality from REER to crude oil, wheat, corn, and rye prices; from wheat, barley, and rice prices to Brent oil prices; an ongoing bidirectional causality between REER and barley, rice, and durum wheat prices.
Keywords: Turkiye, Grains Prices, Crude Oil Prices, Real Effective Exchange Rates, Fourier Toda-Yamamoto Causality
JEL Codes: C22, F31, O13

TAHIL FİYATLARI, HAM PETROL FİYATLARI VE REEL EFEKTİF DÖVİZ KURU İLİŞKİSİ: FOURİER TODA-YAMAMOTO NEDENSELLİK TESTİNDEN KANITLAR

Öz
Bu çalışma Turkiye örneğinde tahıl fiyatları ve belirleyicileri üzerine odaklanmaktadır. Beslenme alışkanları ve önemli büyüklükte bir işlenmiş tahıl ürünleri sektörüne sahip olması nedeniyle tahıl fiyatlarının sürdürülebilirliği Turkiye için önemlidir. Bu nedenle buğday, durum buğdayı, mısır, çavdar, pirinç ve arpa fiyatları ile bu ürünlerin belirleyicileri olan Brent petrol fiyatları ve döviz kuru değişkenleri arasındaki ilişkiyi detaylı bir nedensellik analizi ile Ocak 2003 ve Aralık 2020 dönemini kapsayan aylık veri seti ile inceledik. İlk olarak değişkenlerin birim kök özelliklerini geleneksel testlerle ve daha gelişmiş Fourier ADF ve Lagrange Çarpanı (LM) testleri ile inceledik; daha sonra ise Fourier Toda-Yamamoto (TY) testi ile devam ettik. Uzun dönemli nedensellik analizi sonuçları Brent petrol fiyatlarındaki değişmelerin yalnızca pirinç ve durum buğday fiyatlarına yansıdığını ve döviz kuru ile tahıl fiyatları arasında bir geri besleme ilişkisi olduğunu ortaya koymaktadır. Ayrıca tahıl fiyatlarındaki değişmelerin birbirini etkilediğini tespit ettik. Bulgulara göre mısır ve pirinç fiyatlarındaki değişmeler diğer tahılları etkilerken, durum buğday, çavdar ve arpa fiyatları ise geri besleme ilişkisi içerisindedir.
Anahtar Kelimeler: Türkiye, Tahıl Fiyatları, Ham Petrol Fiyatları, Reel Efektif Döviz Kuru, Fourier Toda-Yamamoto Nedensellik
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Introduction

Production of the agricultural commodities has a vital role in the economy of Turkiye. In the early era, agriculture accounted for 40 to 50 percent of the annual GDP and close to 90% of the total exports (Pamuk, 1988: 20). Even against the country's industrial development, its share in annual GDP was still a respectable 6.2 percent in 2021 (TOB, 2022), making it the seventh-largest agricultural producer (FAO, 2022). Historically, a large part of agricultural production consists of various grains. As of 2020, 71 percent of the arable land was reserved for grain cultivation (TMO, 2021). This reserved land is mainly used for wheat (62%), barley (28%), and corn (6.2%) production. Turkiye also has a large-scale processed cereals industry and exports these products to the degree that it is a net importer of cereals. In this context, grain prices and their determinants have been a crucial topic for governments, researchers, and the public.

Globally, governments subsidize agricultural production with varying policies considering long-term strategies. These policies aim to ensure food security and minimize price fluctuations, and they have direct and indirect effects on prices. Thus, the long-term policy changes should be carefully considered in any research scenario. Earlier agricultural development policies were generally implemented through the state-owned Agricultural Bank, Turkish Grain Board, and several cooperatives. Policies were usually built around price support, support purchases, and input, product, or credit subsidies. The inefficiency of these policies eventually led to a new agricultural program planned along with the World bank. Agricultural Reform Implementation Project (ARIP) was aimed to reduce the burden of inefficient policies on the budget while promoting growth through privatization of state-owned government operations, direct income support, and gradual removal of price and input supports (Olhan, 2012: 146). While the other two parts of ARIP were successfully implemented, the direct income support program eventually failed in 2006 and was phased out by the government. Following the early attempts, Agriculture Strategy Paper was published in 2006 to set the main aims of a new, sustainable, and highly competitive agricultural development policy. The Agricultural Law was adopted along with the paper to define the aims, scope, and subjects of the agricultural policies. Privatization of public economic enterprises and other state-controlled entities has continued, and Agriculture Bank has started allocating resources to fund non-agricultural entities in this era. These structural changes removed subsidies, strategic government entities, and barriers. Therefore, agricultural product prices became more exposed to global factors such as oil prices and currency exchange rates.

Moreover, grain imports started to increase since Turkiye is a significant exporter of cereal end-products, and its population is growing rapidly. Even though there were some late attempts like the "National Unity in Agriculture Project" to regulate the agricultural policies to fight against food inflation, still there are no well-tailored policies to restructure the sector and protect against global fluctuations.

Literature offers several empirical attempts on the topic, and especially the nexus of crude oil prices and various grains prices are widely discussed. The debate is generally shaped around four hypotheses. First, the neutrality hypothesis is supported by Campiche et al. (2007), Reboredo (2012), and Fowowe (2016) among others. Second, the input hypothesis suggests a one-way causality from crude oil prices to prices of agricultural commodities through the input channel. It is supported by the findings of Nazlıoğlu (2011), Gözgör and Kablamacı (2014), Pal and Mitra (2017), and Zaferiou (2018) among others. Third, the bioenergy hypothesis, which is supported by Enders and Jones (2014) among others, claims that the causality is oppositely running from the prices of agricultural commodities to prices of Brent or WTI crude oil due to bioenergy sources emerging as an alternative to petroleum. Lastly, the feedback hypothesis debates that the relationship depends on both the bioenergy and input channels. Thus, the supporting findings debate on a bidirectional causal relationship between the prices of crude oil and agricultural

commodities. The hypothesis is mainly supported by Bayramoğlu and Yurtkur (2015), Rezitis (2015), Fasanya et al. (2018), Gökmenoğlu et al. (2018), Paris (2018), Su et al. (2019) among others.

Even though the topic is widely discussed, a comprehensive revisit is necessary since no conclusive argument is coming forward. More importantly, the recent conflict between Russian Federation and Ukraine can impact grain prices by increasing oil prices, decreasing grain production in both countries, and possible strategic export restrictions in Russia. Also, worldwide economic measures to sustain the well-being of the population in the wake of Covid-19 led to inflation in global prices. Both FED and ECB have recently started to follow anti-inflationist policies, which have implications on the Turkish Lira and purchase power in Turkiye. Therefore, we believe it is vital to portray the relationship between agricultural product prices and their global determinants. As Turkiye is one of the largest importers of Ukrainian and Russian grains and is exposed to global monetary policy changes, the results of the study will be crucial for policymakers to take anti-inflationist measures against upcoming shortages, possible import shocks, and exchange rate fluctuations.

The remainder of the study is structured as follows: The second part provides a brief review of the recent literature; the third part presents the data and methodology for the analysis; the fourth part reveals the results; and the fifth part finally sums up with a discussion and policy recommendations.

1. Literature Review

The literature on the nexus has expanded over the last decade. Studies have especially focused on energy prices since crude oil prices increased significantly (see Nazlıoğlu and Soytas, 2011; Enders and Jones, 2014; Koirala et al., 2015; Fowowe, 2016; Hung, 2021 among others) and alternatives such as biofuel and electricity started to emerge as reliable energy sources (see Kilian, 2009; Lucotte, 2016; Su et al., 2019 among others). In a similar manner, agricultural commodity prices and their relationship with exchange rates have been widely investigated (see Gilbert, 2010; Nazlıoğlu and Soytas, 2012; Bayramoglu and Yurtkur, 2015; Burakov, 2016 among others).

Recent studies mainly concentrated on causalities. Campiche et al. (2007) investigated the cointegrating relationship between the prices of the crude oil and several agricultural items between 2003 and 2007. They suggested that there is a cointegrating relationship between the prices of corn, soybean, and crude oil. Zhang and Reed (2008) investigated the interaction between the prices of crude oil, grains, and pork in China between January 2000 and October 2008. They found no evidence of a causal relationship among the price series according to Granger causality test results. Balcombe and Rapsomanikis (2008) used a generalized form of the nonlinear bivariate ECM. For the Brazilian sample between July 2000 and May 2006, they found nonlinearities in the adjustment process of sugar and ethanol prices to oil price.

Nazlıoğlu (2011) revealed that capturing the nonlinearities between the prices of crude oil and agricultural commodities was a vital part of capturing the causal relationship. The findings from a weekly dataset suggested a unidirectional nonlinear causality running from crude oil prices to the soybean and corn prices for the 1994 – 2010 period. In contrast to earlier research on nonlinearities by Balcombe and Rapsomanikis (2008) and Nazlıoğlu (2011), Enders and Jones (2014) argued that Flexible Fourier Form equation can correctly include effects of the smooth mean shifts in the estimations. Their estimations regarding the maize prices and crude oil prices reveal that the maize prices increase the price of petroleum due to the upswing in the recent biofuel usage. However, they found no evidence of a unidirectional causal effect from crude oil prices to maize prices.

Reboredo (2012) studied co-movements between global wheat, corn, and soybean prices and Brent crude oil prices for the weekly dataset between 1998 and 2011. They found evidence of a weak

relationship between world oil prices and food prices. Estimated copula models that use different conditional dependence structures supported the earlier literature defending the neutrality hypothesis.

Gözgör and Kablamacı (2014) studied the nexus in detail, using price data belonging to 27 different commodities for the dataset spanning between January 1990 to June 2013. Their findings indicate that a weak USD has a positive effect on the prices of 25 out of the 27 commodities. Wang et al. (2014) claimed that the previous studies did not separately focused on the oil-specific shocks and aggregate demand shocks. The study covers between January 1980 and December 2012, consists of two subsamples to consider the food crisis between 2006 and 2008. The findings from the impulse-response analysis reveal that responses of the prices of the agricultural commodities to oil supply shocks or other oil-specific demand shocks were insignificant in the pre-crisis era, yet in the post-crisis period oil-specific demand shocks statistically significantly responded. Bayramoğlu and Yurtkur (2015) tested the effect of global economic indicators on agricultural producer prices and food prices in Turkiye between February 1999 and June 2014. VAR analyses reveal a feedback relationship between the food industry price index and the USD/TRY rate; one-way causalities are running from the USD/TRY rate and food industry price index to Euro exchange, food industry price index and international food prices to oil prices, agricultural producer prices to international food prices, and food industry price index to agricultural producer prices.

Rezitis (2015) studied the nexus between the exchange rates, prices of a panel of 30 international agricultural commodities, crude oil, and five international fertilizer commodities for a large dataset between June 1983 to June 2013 using a panel VAR approach. The findings indicate a bidirectional causality running between the prices of crude oil and cereals and a unidirectional causality from exchange rates to cereal prices. Moreover, individual-level Granger causality analyses reveal a one-way causality running from wheat and soft red winter wheat prices to crude oil prices and from barley prices to exchange rates. The study also provides findings regarding causality running between the exchange rates, prices of crude oil, and other agricultural commodities such as vegetable oils, protein meals, cotton, bananas, oranges, sugar, meat, and seafood under three subgroups. The results belonging to these subgroups reveal that there is a one-way causality running from crude oil prices to each subgroup. At the same time, there are one-way causalities running from exchange rates to vegetable oils and protein meals subgroup and cotton, bananas, oranges, and sugar subgroup.

Fowowe (2016) investigated the causal relationship for South Africa for the daily period between 2 January 2003 and 31 January 2014 under the assumption of possible nonlinearities between oil prices and agricultural commodities prices. The findings show that the prices of oil and agricultural commodities (maize, sunflower, and soybean) are neutral to changes in each other. Pal and Mitra (2017) used the Johansen cointegration test, wavelet analysis, and the TY causality approach to examine the relationship between crude oil prices and global food price indices over the time period between January 1990 and February 2016. Their findings confirmed the cointegrated relationship between the two, and a one-way causality running from crude oil prices to the world food price index. Furthermore, they contended that crude oil prices drive and co-move with cereals, vegetable oils, sugar, and global food prices.

Fasanya et al. (2018) investigated the case in Nigeria for the period from January 1997 to December 2016. They used ARDL and nonlinear ARDL modeling approaches. They aimed to reveal the importance of the nonlinearities in the nexus between the prices of crude oil and agricultural commodities. According to their findings, price of crude oil has a positive statistically significant effect on the prices of the commodities. They further emphasize that the oil price asymmetries are significant and a pre-test for possible asymmetries and structural breaks should

be initiated beforehand, as almost all the agricultural commodities analyzed in the study were under the influence of structural breaks and both short- and long-run asymmetries. Gökmenoğlu et al. (2018) is another study that focused on Nigeria, employing a monthly dataset ranging between January 2006 and December 2015. They used a panel of agricultural commodities to investigate the relationship between exchange rates and crude oil prices. The findings revealed that the variables are cointegrated according to DOLS and FMOLS estimations; the exchange rates and prices of agricultural commodities are unresponsive regarding the changes in each other; there is feedback between the price of crude oil and agricultural commodities; and there was a unidirectional causality moving towards exchange rates from oil prices.

Paris (2018) examined the nexus considering the rise of biofuels. The study utilized a monthly-to-daily interpolated dataset between 2 January 1986 and 28 November 2014. The study argues that there are nonlinear relationships between crude oil prices and prices of all the agricultural commodities; the biofuel production has contributed to agricultural price increases; a rising oil price effect on the agricultural commodities which are essential for biofuel production; and an increase in the price of other agricultural commodities through the substitution effect. The findings of the study contain vital information since they emphasize the importance of using agricultural commodities as alternative energy commodities at the expense of rising food prices. Zafeiriou et al. (2018) also investigated the linkages between crude oil- and agricultural commodity prices. They estimated two ARDL models to investigate corn – oil and soybean – oil prices relationship for the period from July 1987 to February 2015. Their findings confirm that crude oil prices have an impact on the price of agricultural products used in the production of biofuel. Su et al. (2019) is another work that studied the nexus in the bio-energy context. Their time-varying rolling-window approach to the causality testing illustrated a feedback relationship between the two over certain sub-periods spanning between January 1990 to February 2017, supporting the earlier propositions on the interaction between the energy- and agricultural commodity prices directly through the biofuel channel and indirectly through the input channel.

Hung (2021) focused on the impact of the Covid-19 outbreak on the nexus, investigating the pre-Covid-19 period from 2 February 2018 to 30 January 2020 and the Covid-19 period from 31 January 2020 to 14 May 2020. The findings reveal that the directional association from the crude oil market to agriculture commodity returns was lower than in the opposite direction in general, return spillovers increased during the Covid-19 outbreak, and co-movement of crude oil- and agricultural commodity prices was stronger during the Covid-19 outbreak than the pre-Covid-19 period.

2. Data and the Methodology

We used monthly Brent oil spot prices, REER, and various grain prices (wheat, durum wheat, corn, rice, rye, and barley) data spanning between January 2003 and December 2020. We proxied crude oil prices with Brent oil prices because Brent oil prices better reflect the oil price fluctuations in the oil exporter countries geographically closer to Turkiye. Since geographically closer countries trade more frequently (Karacan, 2021), Brent oil spot prices are expected to be a better indicator than the WTI oil spot prices series for the Turkish case. We also used REER series instead of real exchange rates series. Since US dollars and crude oil prices are closely related due to the US being an oil exporter country, using weighted averages of a basket of currency exchange rates will better reflect the comparative advantage of the Turkish Lira in the global grain markets. Seasonally adjusted Brent oil prices and REER data are taken from the Turkish Central Bank database (EVDS, 2022). Grains data are compiled from the Turkish Statistical Institute (TurkStat, 2022), rearranged as US dollars according to monthly USD – TL exchange rates, and used in their natural logarithmic forms.

The standard procedure for a Granger-type causality test necessitates testing both for both stationarity and for co-integration in the case of higher integration orders as its consistency depends on the asymptotic properties of the Wald test. However, the Toda-Yamamoto (TY) approach (Toda and Yamamoto, 1995) relaxes these shortcomings by estimating a $VAR(p+d)$ model with variables in levels, and d is the maximum integration order (Nazlioğlu et al., 2019).

Nazlıoğlu et al. (2016) proposed a novel TY type approach that also considers breaks in the causality analysis, relaxing the assumption that the constant term α is invariant over time and defining $VAR(p+d)$ model as in equation (1).

$$y_t = \alpha(t) + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} + \epsilon_t \quad (1)$$

where $\alpha(t)$ are considered as the functions of time and denote possible structural shifts in y_t. Here possible structural shifts with unknown date, number, or form of breaks are captured by the following Fourier approximation described in equation (2).

$$\alpha(t) \cong \alpha_0 + \sum_{k=1}^{n} \gamma_{1k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \gamma_{2k} \cos\left(\frac{2\pi kt}{T}\right) \quad (2)$$

where respectively, γ_{1k} and γ_{2k} are coefficients to measure the amplitude and displacement of the frequency and n is the number of frequencies. Hence, Nazlıoğlu et al. (2016) obtain the framework as in equation (3).

$$y_t = \alpha_0 + \sum_{k=1}^{n} \gamma_{1k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \gamma_{2k} \cos\left(\frac{2\pi kt}{T}\right) + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} + \epsilon_t \quad (3)$$

However, they discuss that a large n is possibly associated with stochastic parameter variation and decreases degrees of freedom, eventually leading to an over-fitting issue. Therefore, they suggest adding only a single Fourier frequency that mimics multiple breaks with an unknown form following (Becker et al., 2006). Single-frequency form of equation (3) can be defined as in equation (4).

$$y_t = \alpha_0 + \gamma_1 sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + \beta_1 y_{t-1} + \cdots + \beta_{p+d} y_{t-(p+d)} + \epsilon_t \quad (4)$$

The number of Fourier frequency (k) and optimal lag lengths (p) can be assessed by the information criterion of Akaike or Schwarz. Here, the bootstrap distribution of Wald statistic that includes Fourier terms should be used instead of the asymptotic χ^2 distribution following Becker et al. (2004). Bootstrapping increases the power of the test statistic in small samples, and bootstrapped critical values are robust against possible unit root and cointegration issues (see Hatemi-J, 2002; Konya, 2006; Zortuk and Karacan, 2018; Nazlıoğlu et al., 2019).

3. Results

The TY approach is appropriate when the variables are integrated with different orders. Yet, we first investigate the stationarity properties of the data to determine correct d value. Table (1) offers unit root test results. The variables might have been subject to structural breaks or shifts due to economic shocks in the investigated period. However, traditional unit-root tests do not take these properties of the series into account. For this purpose, we utilized Fourier ADF and Fourier LM tests along with the standard ADF test. A possible difference between common ADF tests and their Fourier variants will be pointing to the importance of utilizing Fourier alternatives to the traditional causality tests as well. According to Fourier ADF results, all variables are stationary at

levels. On the other hand, Fourier LM test results suggest that wheat, barley, rye, and rice prices have unit roots in levels.[2]

Table 1: *Test Results for the Unit Root Process*

	ADF	ADF w/ Trend	Fourier ADF	Fourier ADF w/ Trend	Fourier LM	Lags (p)	Fourier F. (k)
reer	0.276	-1.713	-2.161	-4.849**	-4.584**	4,4,1,1,1	1,1,1
Brent	-2.855*	-2.728	-4.089**	-4.342**	-4.349**	2,3,1,1,1	1,1,1
wheat	0.616	-2.275	-0.963	-4.29*	-3.761	2,2,1,1,1	1,1,1
corn	0.591	-2.558	-0.675	-5.338***	-4.264**	3,2,1,1,1	1,1,1
barley	0.195	-2.555	0.318	-4.045*	-3.359	1,1,1,1,1	4,1,1
rye	-0.025	-2.313	-1.261	-4.138*	-3.317	4,4,1,1,1	1,1,1
rice	-0.312	-2.712	-1.695	-3.558*	-3.698	4,4,1,1,1	1,3,1
durum	0.596	-2.357	-1.118	-4.162*	-3.827*	2,2,1,1,1	1,1,1

Note: ****, **, and* respectively denote 0.01, 0.05, and 0.10 significance levels.*

Since Fourier ADF and Fourier LM tests pointed to contradicted results, we set $d = 1$. We selected lag lengths (p) and Fourier frequencies (k) according to the Schwarz information criterion. Also, the tests are evaluated with heteroskedasticity robust bootstrap standard errors, and table (2) and (3) represent the results accordingly.

Table 2: *Test results for TY Causality*

	reer	***Brent***	***wheat***	***corn***	***barley***	***rye***	***rice***	***durum***
reer	-	1.705	9.547***	7.674***	7.242**	6.587**	8.796**	8.582**
Brent	3.566	-	3.362	0.055	1.717	1.906	7.521**	3.443
wheat	4.670*	4.074	-					
corn	0.833	2.316		-				
barley	6.936**	5.062*			-			
rye	3.381	4.623				-		
rice	0.649	2.337					-	
durum	3.565	3.283						-
Lag (p)	2	2	2	2	2	2	2	2

Note: *Wald statistics are tested against bootstrapped critical values. Number of bootstrap replications, $R = 1000$. ***, **, and* respectively denote 0.01, 0.05, and 0.10 significance levels.*

Conventional TY findings reported in table (2) presents a one-way causality running from rice prices to Brent oil prices (BRENT); from grain prices to REER; from BRENT to barley prices; and finally, a bidirectional causal relationship between REER, wheat, and barley.

However, when we account for nonlinearities such as smooth breaks and price fluctuations in TY model, results from the table (3) point to a one-way causality running from REER to BRENT, wheat, corn, and rye prices; a one way-causality running from wheat, barley, and rice prices to BRENT; a bidirectional causality between REER and barley, rice, and durum wheat prices.

Exchange rates and crude oil prices are generally closely connected in oil exporting countries and net oil importing countries. Beckmann and Czudaj (2013) suggested that the currencies of oil exporting countries generally appreciate while importing country currencies depreciate in the face

[2] All the variables are stationary in their first differences. To save space, we did not include results belonging to first differences.

of an increase in the crude oil prices. However, effective exchange rates are generally expected to be robust against the fluctuations in the crude oil prices due to being a weighted average of the different exchange rates. Fourier TY test results reveal that this is the case for Turkiye as well. Interestingly though, there is a unidirectional causal relationship running from REER to BRENT. This might be possible through the collective impact of the monetary policies of oil exporter countries on the Turkish Lira. The test results regarding the REER and grain prices draws a clearer picture. Turkish agricultural production largely depends on imported inputs such as combustibles, fertilizers, and seeds. Therefore, the pass-through from REER to grain prices is evident. REER show the average change in the value of Turkish against a basket of foreign currency and can be interpreted as it is. But, more importantly, REER project competitiveness in terms of trade, and we can presume that the changes in the trade competitiveness of the Turkish Lira transmit to grains prices.

Table 3: *Fourier TY Causality Test Results*

	reer	***Brent***	***wheat***	***corn***	***barley***	***rye***	***rice***	***durum***
reer	-	1.714	3.480	0.331	9.152**	4.088	6.487*	11.424**
Brent	7.780**	-	7.334**	3.072	3.730**	2.489	16.366***	7.584
wheat	12.508***	3.648	-					
corn	6.122**	0.629		-				
barley	30.285***	3.705			-			
rye	8.411***	3.532				-		
rice	13.204***	1.685					-	
durum	13.046**	3.436						-
Lag (*p*)	2	2	2	2	3	2	3	4
Fourier f. (*k*)	3	3	3	3	3	3	3	3

Note: *Wald statistics are tested against bootstrapped critical values. Number of bootstrap replications,* $R = 1000$. ****, **, and* respectively denote 0.01, 0.05, and 0.10 significance levels.*

In Turkiye, agricultural production and logistic processes still mostly depend on machinery with combustion engines, which require oil products. Therefore, changes in BRENT are expected to transmit to the grain market through the input channel, and this was the case for barley prices in the findings from the table (2). However, in a riveting manner, our findings from the table (3) assert that the grain prices are unresponsive to changes in BRENT. The unresponsiveness might be due to the increasing (Dedeoğlu and Kaya, 2014) yet still limited price passthrough from global crude oil markets to domestic fuel market in Turkiye.

Recent works on the biofuel case suggest that the increasing biofuel production significantly impacted the relationship between the crude oil- and agricultural commodity prices. The studies argue that the prices of the commodities used in biofuel production[3] and their substitutes become effective on the crude oil markets. In parallel with the relevant literature, our findings reveal a one-way causality running from wheat, barley, and rice prices to BRENT. Corn and wheat are the primary sources of bioenergy products regarding grains. However, we report that the changes in BRENT are not transmitted to Turkish corn, rye, or durum wheat prices. In Turkiye, bioenergy production is relatively limited, and produced grains are generally used in the food industry. Yet, Turkish grain prices are subject to global changes in food prices. Thus, the well-documented

[3] Biofuels are mainly produced from sugar crops (beet and cane), grains (mainly corn and wheat), and oilseeds (Hervé et al., 2011)

impact of global grain prices on the crude oil market seems to partially transmit to the Turkish case.

The results from tables (2) and (3), in sum, reveal that the linear causality testing approaches are subject to neglected nonlinearities between BRENT, REER, and grain prices. When we account for nonlinearities, transmission between the REER and grain prices becomes apparent. Also, linear modeling completely disregards the unidirectional causality running from wheat and barley prices to BRENT, mitigating the vital role of bioenergy production on crude oil prices.

4. Conclusion

Recent events have drawn attention to a long-going debate on the interlinkages between agricultural commodity prices, energy prices, and exchange rates. Governments employed inflationist policies to sustain the well-being of the public in the wake of the Covid-19 outbreak and started to tighten their food security policies due to the recent war between the Russian Federation and Ukraine, which directly affected the energy and agricultural commodity markets. On the other hand, the Turkish agricultural sector is struggling to find its way in the absence of short- and long-term agricultural policies. Input and import costs are rapidly increasing while the domestic grains production is slowly declining, thus the food security in the short-term and sustainable agricultural production in the long-term are at risk.

Russian Federation is one of the major oil and natural gas producers in the world, and Ukraine has a vital role in the distribution of Russian energy sources to Europe. Both countries also export several agricultural commodities, most notably a variety of grains, and Turkiye is one of their most significant energy and grains importers due to its historical agriculture policies being inefficient. Furthermore, post-pandemic measures of the FED and ECB to suppress the price inflation affected the effective exchange rates in Turkiye due to the Turkish Central Bank's interest rates policy.

Most of the previous literature suggests a link between the three in the global context. Therefore, we investigated the topic using the Fourier TY causality approach to consider existing unit roots, structural breaks, and nonlinearities from January 2003 to December 2020. Emphasizing the importance of the nonlinearities between REER, BRENT, and grain markets, our findings reveal the interlinkages among the three. Changes in REER transmit to BRENT, wheat, corn, and rye prices; changes in wheat, barley, and rice prices transmit to BRENT; and finally, there is transitivity between REER and barley, rice, and durum wheat prices. We also found that the real effective exchange rate of the Turkish Lira and domestic grain prices are neutral to BRENT. We believe that neutrality is due to the low transitivity between global oil prices and domestic fuel prices. Reportedly pass-through of the changes in global oil markets to fuel prices are low in Turkiye and fuel prices are mainly determined by exchange rates. Since changes in the average value of the Turkish Lira and its trade competitiveness transmit to grains prices, it can be said that monetary and trade policies will also impact the grains market. Policies that aim to improve exports by increasing the competitiveness of the Turkish Lira might serve to increase grain prices as the input costs in the sector generally depend on imported sources, jeopardizing food security. Therefore, we suggest short-term policies aimed to reduce input costs in the agricultural sector, which is possible through central bank instruments, and long-term policies aimed to increase the efficiency of the agricultural production and reduce the dependency on the imported inputs.

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