Modelling the Symmetrical and Asymmetrical Effects of Global Oil Prices on Local Food Prices: A MENA Region Application

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Modelling the symmetrical and asymmetrical effects of global oil prices on local food prices: A MENA region application

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Abstract: This paper explores the complex nexus between the global oil prices and the food prices of Middle East and North Africa (MENA) region during the period 2000–2020. Both linear and nonlinear models of the autoregressive distributed lag (ARDL) approach are adapted into panel data form to investigate the symmetrical and asymmetrical influence of oil prices on food prices. The key results are summarized: i) The effect of oil prices on food prices is significantly positive including both oil-exporting and oil-importing nations are verified in the long-term. The positive impact on oil-exporters—due to higher oil revenues—is greater than importing nations, leading to an increased demand for food. Additionally, the effect on oil-exporters is negative and significant in the short-term but not significant for importers. ii) The panel analysis for the MENA sample confirms the presence of negative short-term asymmetric behaviour, while in the long-term, the asymmetric effect is positive, indicating that food prices increase regardless of fluctuations in oil prices. iii) Wald test results support asymmetric co-integration for the whole sample of the MENA due to the heterogeneous response within the oil-importing and exporting samples. Specifically, the non-linear ARDL test results affirm the absence of an asymmetric nexus among oil and food prices for oil-exporting group (including Saudi Arabia, Saudi Arabia, United Arab Emirates) and Tunisia within the oil-importing group. Although there are differences in the direction and degree, the food prices of other countries

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are asymmetric to the oil price. This study provides recommendations that are useful to MENA countries to establish a stable mechanism for oil and food prices to ensure food security in the region.

Keywords: Oil prices; Food prices; MENA region; Panel ARDL; Symmetry and Asymmetry.

Introduction

As important strategic resources, food and oil have been widely studied by scholars (Dalheimer et al., 2021; Mokni and Ben-Salha, 2020; Sarwar et al., 2020). In recent years, international food prices have continued to rise. Many reasons contribute to rising prices of food; however, high oil prices are a major factor. The expansion of biomass energy—such as biodiesel and bioethanol—in response to climate change has caused a crowding-out effect on food production for people, while high oil prices have increased agricultural costs incurred in the production and transportation processes (Gardebroek and Hernandez, 2013; Sarwar et al., 2020; Dalheimer et al., 2021). Rising food prices have posed a substantial threat to food security especially for countries that rely heavily on importing food. The UN Secretary-General Ban Ki-Moon noted that global food prices rose by more than 50% in 2007 alone. This severe situation, and the double crisis caused by rising energy prices, threatened the international community's plan to achieve their Millennium Development Goals in 2015. It is estimated that if food prices increase 50–80%, many people will face malnutrition and hunger. Consequently, recognizing the internal relationship among food oil and oil prices is an important prerequisite to stabilizing food prices and establishing an early warning mechanism. However, due to the huge differences in terms of resource endowment, agricultural productivity, and economic status among regions of the world, the relationship between the two prices can have distinguish mechanism. For example, countries rich in agricultural products will be much less affected by high oil prices than countries with poor supply capacity of agricultural products. Therefore, the internal relationship between food and oil prices should be analysed according to the research objective.

As for the region of Middle East and North Africa (MENA), researching how oil prices affects food prices is even more important. The main reasons are: 1) Most countries are net importers of food commodities as food crops are difficult to cultivate due to insufficient water supply and limited access to arable land. They are particularly vulnerable to fluctuations in international commodity markets and are most seriously affected by rising prices. Therefore, stable food prices and reliable sourcing of imports are the basis for food security in these countries; 2) Some countries that are rich in oil resources but lacking in food have implemented the strategy of the 'Oil for Food programme'. The rising oil price will attract great economic benefits, but more will have to be spent on buying food. Thus, the social welfare of these countries is uncertain given the volatility of oil and food prices; 3) Although MENA countries are geographically concentrated, the resources and economic conditions of these countries are vastly different. Only certain countries are rich in oil products. Therefore, for oil-importing countries (*oil-importers*) and oil-exporting countries (*oil-exporters*), international oil prices can exhibit differing impact mechanisms on local food prices. Researching the influence of oil prices on the MENA region's food prices—where food is primarily dependent on imports—is of great significance in establishing a stable food price mechanism and to ensure regional security.

Consequently, this study will focus on exploring the distinctive mechanisms impacting oil and food prices in the MENA region by comparing *oil-exporters* to *oil-importers*. This research is among the first to focus on examining this from a MENA perspective. Previous studies often using time series which cannot capture inter-group information and eliminate the individual fixed effect; this study explores such relationship using a panel data sample. Considering food prices may appear similar or dissimilar as oil prices fluctuate, the research builds linear and non-linear Autoregressive distributed lag (ARDL) modelling method to address symmetrical and asymmetrical inter linkage between the price food and oil. The contributions of this study are: i) focusing on a specific group of countries in the MENA region to determine the impacts of the oil price on their food prices; ii) Focusing on a comparative exploration on the subject by comparing oil exporters with oil importers. iii) Simultaneously, the symmetrical and asymmetrical interactions in the food-oil price nexus are captured by applying panel data from oil-exporters and importers of the MENA region. The remainder of this paper has the following structures: in section 2 the research literature relating to food-oil prices nexus is summarized; Section 3 highlights the panel symmetric and asymmetric ARDL models; in section 4 the data and indicators used for the study are presented; Section 5 discusses the empirical application for MENA countries from 2000 to 2020; and the paper concludes with Section 6, which discusses policy implications.

Literature review

Substantial research on food and oil markets was stimulated by the 2008 global food crisis. The volatility of the crude oil price affects food commodities through increasing fertilizer costs, transportation costs, and fuels for agricultural machinery and so on (Chen et al. (2019). The existing studies contends that food prices are significantly and positively related to the oil price. For instance, Chen et al. (2010) using the ARDL model, detected that crude oil fluctuations and other grain market fluctuations have a significant impact on the price of grain. Esmaeili and Shokoohi (2011) using a principal component analysis to investigate the nexus between the global oil price, world prices of food and other macroeconomic variables. Their findings revealed that the price of oil influences food prices in an indirect way, as confirmed by Pal and Mitra (2018), Gohin and Chantret (2010), and Ciaian and Kancs (2011). However, some scholars have found that the food prices is not influenced by oil price fluctuations. For example, Reboredo (2012) examined co-movements among the global oil price and those of wheat, corn, soybeans by applying copulas. His results indicated that the increase in food price was not caused by volatility in oil prices. Therefore it supports neutrality against oil price fluctuations in agricultural markets. Baumeister and Kilian (2014) confirmed that shocks in oil prices are not linked to food prices in the United States due to the small contribution of agricultural commodities to total food prices. Another analysis containing the volatility transmission of corn, oil and ethanol prices was performed by Gardebroek and Hernandez (2013). They found there is no major fluctuations in the energy market that boost price variability on the corn market.

Due to the differences in the selected samples and the complexity of the relationships between them, it is difficult to reach a consensus from the literature. Increasingly, scholars believe this is a complex nonlinearity relationship. Using Malaysia as a case, Ibrahim (2015) reported the presence of short- and long-run asymmetries in food prices behaviour when oil price increases led to increasing food prices— but there was no association between the decline in oil prices and food prices. The potential asymmetry for transit from the price of oil to food is also analysed in an Indian context (Pal and Mitra, 2016).For an oil-dependent emerging economy as Nigeria, Nwoko et al. (2016) investigated the causal link between food and oil prices volatility and concluded that the causality from oil prices to aggregate food price fluctuations is unidirectional. Olayungbo and Hassan (2016) examined the symmetric interactions between food and oil prices between oil and food prices of *oil-exporters* by applying a panel ARDL approach. The long-run finding indicated that oil prices affected food prices positively and significantly while the short-term impact was similarly positive and significant. These results were verified by Meyer et al. (2018).

As the hub connecting Asia, Europe, and Africa and the most important oil-producing region in the world, the MENA region has garnered much attention. Ek Fälth et al. (2020) explored the impact of nuclear energy, land availability, and the expansion of transmission on the cost of electricity from renewable sources by comparing MENA region to Europe. Kassouri and Altıntaş (2020) examined the trade-off regarding environmental and human well-being issues. Bellakhal et al. (2019) focused on the interaction impact between governance and trade openness on investments in renewable energy in the MENA region over the period 1996-2013. Apergis et al. (2014) investigated the Dutch disease impact of oil rents on added value for the agricultural sector in oil–producers of MENA region, establishing a long-run negative relationship that relatively slowly re-equilibrium with an added agricultural value following a boom in oil rents. Although previous literature has investigated many aspects of the MENA region, the mechanism influencing food and oil prices has been neglected.

In conclusion, although there are considerable researches on the effects of oil price on food price, there are few studies that examine and explore how oil price influences food prices using a sample of MENA nations. Previous studies on this issue have always used time series which cannot capture group information or mitigate individual fixed effects. Consequently, this study explores this relationship using panel linear and non-linear ARDL models to assess both short-term and long-term dynamic interactions between food and oil prices for MENA countries.

Indicators and data

To explore the association of food and oil prices in MENA countries, this study employs panel data of food prices (*FDP*) from 2000 to 2020 for 14 countries of the MENA region and annual time series data of the global oil price (*OLP*). Referring to previous literature (e.g. Meyer et al., 2018; Olayungbo and Hassan, 2016; Taghizadeh-hesary et al., 2019), additional panel data such as the inflation rate (*INF*), the degree of trade openness (*TO*), and urbanization levels (*URB*) are chosen as control variables. Given data availability, we only obtain time series annual data for the global oil price (the average of two major types of crude oil: Brent and WTI). Food prices in the MENA region are transformed by consumer prices indices to actual values for the base period (2015 = 100). The degree of trade openness (*TO*) is expressed as a percentage of total imports and exports to Gross Domestic Product (GDP); and the urbanization level (*URB*) is measured as the urban population ratio. The relevant data was derived from the Energy Information Administration (EIA), the (BP) Statistical Review of World Energy, the Food and

Agriculture Organization (FAO), the World Bank database. Specific indicators for variables are shown in Table 1.

Table 1 Specific indicators for variables

Dimension	Indicator	Symbol	Log form symbol	Data source
Local Food prices	Food consumer prices	FDP	LFDP	FAO
Global oil price	The Brent and WTI average	OLP	LOLP	BP,EIA
The degree of trade openness	The percentage of total imports and exports to GDP	TO	LTO	The World Bank Database
Inflation rate	The percentage rate of change in prices level	INF	LINF	The World Bank Database
Urbanization level	The ratio of urban population to the total population	URB	LURB	The World Bank Database

The sample countries were divided into two groups to analyse the data more precisely: Group 1: Oil-exporters group (Algeria, Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and UAE). Group 2: Oil-importers group (Jordan, Lebanon, Tunisia, Morocco, Egypt, West Bank and Gaza).

Table 2 provides descriptive statistics. For the *oil-exporters* sample, the mean of food prices (*FDP*) is greater than for *oil-importers* (81.702). The oil price (*OLP*) has a volatility of 25.704 based on its standard deviation, which denotes some shocks between 2000 and 2020. Inflation rate (*INF*) among the oil-exporting group has a maximum value of 53.231% and minimum of -10.067%, whereas those values for oil-importers reach 29.602% and -3.749%, respectively. The degree of trade openness (*TO*) among the MENA region has a mean of 92.768 %, with a maximum of 191.872%, and a minimum of 30.247%. Finally, the mean of the urbanization level (*URB*) for *oil-exporters* (83.294%) is higher than for *oil-importers* (69.049%). Overall, different connected mechanisms for food and oil prices in the two types of nations are clearly indicated.

Table 2 Statistics of descriptive variables

Variable	Obs.	Min.	Max.	Mean	Std.Dev.
Oil- exporting countries					
FDP	168	33.342	122.646	83.885	19.138
OLP	168	25.325	103.27	63.161	25.704
INF	168	-10.067	53.231	3.616	6.596

TO	168	50.045	191.872	100.244	32.154	
URB	168	59.919	100	83.294	11.606	
Oil-importing countries						
FDP	126	27.717	193.637		81.702	28.467
OLP	126	25.325	103.27		63.161	25.73
INF	126	-3.749	29.602		4.414	5.149
TO	126	30.247	144.881		82.053	24.189
URB	126	42.701	92.203		69.049	15.755
MENA countries						
FDP	294	27.717	193.637		82.95	23.572
OLP	294	25.325	103.27		63.161	25.671
INF	294	-10.067	53.231		3.958	6.022
TO	294	30.247	191.872		92.448	30.335
URB	294	42.701	100		77.189	15.249

Table 3 shows the correlation matrix among variables. For the MENA countries there is a positive correlation between food prices (FDP) and oil prices (OLP). The inflation rate (INF) is positively correlated with food prices (FDP), except for *oil-exporters* where there is a negative correlation. Furthermore, the degree of trade openness (TO) negatively correlated with food prices (FDP) for oil-importers and the MENA region, and the relation between urbanization level (URB) and food prices (FDP) is positive for *oil-exporters*. These results indicate there is no potential multi-collinearity problem.

Table 3 Matrix of correlations among variables

Variable	*FDP*	*OLP*	*INF*	*TO*	*URB*
Oil- exporting countries					
FDP	1.000				
OLP	0.427	1.000			
INF	-0.270	0.063	1.000		
TO	0.001	0.167	0.053	1.000	
URB	0.183	0.062	-0.200	0.298	1.000
Oil-importing countries					
FDP	1.000				
OLP	0.286	1.000			
INF	0.331	0.172	1.000		
TO	-0.046	0.224	-0.297	1.000	
URB	0.128	0.061	-0.458	0.599	1.000
MENA countries					
FDP	1.000				
OLP	0.346	1.000			
INF	0.006	0.102	1.000		
TO	-0.005	0.177	-0.071	1.000	
URB	0.154	0.054	-0.298	0.486	1.000

Methodology

This article specified the recent method proposed by Pesaran et al. (2001) of the autoregressive distributed lag (ARDL) boundary testing to determine the influence of global oil prices on MENA countries' local food prices. This approach has many advantages compared to classical co-integration models (e.g. Engle and Granger, 1987; Johansen and Juselius, 1990), including: i) Estimations of both short- and long-term coefficients can be captured simultaneously; ii) it is practicable even if I(0) or I(1) or combination of any of the regressors are used ; iii) prevent endogeneity issues by taking into consideration a small sample and producing better outcomes over other co-integration methods. All variables are logarithmically transformed to address the potential heteroskedasticity problem. We construct panel linear ARDL and non-linear ARDL models according to Shin et al. (2014) and Salisu and Isah (2017) to detect the existence of symmetrical and asymmetrical relationships among global oil prices and local food prices.

1. The panel linear ARDL Model

Given the assumption that oil prices have a symmetric influence on food prices —the effect is similar if oil prices increase or decrease —and referring to Salisu and Isah (2017), the following formula is expressed by a symmetric form of linear ARDL:

$$\Delta(LFDP_t) = \sum_{i=1}^{q} \beta_{1i} \cdot \Delta(LFDP_{t-i}) + \sum_{i=0}^{p} \beta_{2i} \cdot \Delta(LOLP_{t-i}) + \sum_{i=0}^{p} \beta_{3i} \cdot \Delta(LINF_{t-i}) + \sum_{i=0}^{p} \beta_{4i} \cdot \Delta(LTO_{t-i}) + \sum_{i=0}^{p} \beta_{5i} \cdot \Delta(LURB_{t-i}) + \alpha_1 LFDP_{t-1} + \alpha_2 LOLP_{t-1} + \alpha_3 LINF_{t-1} + \alpha_4 LTO_{t-1} + \alpha_5 LURB_{t-1} + \mu_i + \varepsilon_{it} \quad (1)$$

Where:

Δ is defined as the operator of differences; i =1,2,..., N refers to each country's numbers; t =1,2,…, T denotes the time periods; p and q represent the optimum lag for dependent and independent variables, respectively; and u_i is the group-specific effect. The residuals ε_{it} are assumed to be white noise. $\beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i}, \beta_{5i}$ are the parameters for short-term while $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ are the parameters for long-term.

To estimate short-term dynamic coefficients (e.g. Kun et al., 2015), the equation (1) has been re-specificated by using the model of panel error correction model (ECM) as:

$$\Delta(LFDP_t) = \sum_{i=1}^{q} \beta_{1i} \cdot \Delta(LFDP_{t-i}) + \sum_{i=0}^{p} \beta_{2i} \cdot \Delta(LOLP_{t-i}) + \sum_{i=0}^{p} \beta_{3i} \cdot \Delta(LINF_{t-i}) + \sum_{i=0}^{p} \beta_{4i} \cdot \Delta(LTO_{t-i}) + \sum_{i=0}^{p} \beta_{5i} \cdot \Delta(LURB_{t-i}) + \lambda_i ECT_{t-1} + \mu_i + \varepsilon_{it} \quad (2)$$

Where:

The co-integration term: $\mathrm{ECT}_{t-1} = LFDP_{t-1} - \alpha_{1i} LOLP_{t-1} - \alpha_{2i} LINF_{t-1} - \alpha_{3i} LTO_{t-1} - \alpha_{4i} LURB_{t-1}$ is referred to the error correction term (ECT). $??_i$ is the coefficient of speed adjustment in error correction model towards a long-term equilibrium and is required to be significant and negative. $\beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i}, \beta_{5i}$ are short-run coefficients as shown in equation (1).

2. The panel non-linear ARDL Model

In contrast to the symmetric linear ARDL Model, asymmetries are calculated in this case to investigate food price asymmetric reactions to oil prices by decomposing the sum of negative and positive partial following Salisu and Isah (2017) and Shin et al. (2014). According to this model, positive and negative oil price shocks are not assumed to affect the price of food similarly. The ARDL model can therefore be expressed nonlinear in the following form:

$$\Delta(LFDP_t) = \sum_{i=1}^{q} \beta_{1i} \cdot \Delta(LFDP_{t-i}) + \sum_{i=0}^{p} \beta_{2i}^{+} \cdot \Delta(LOLP_{t-i}^{+}) + \sum_{i=0}^{p} \beta_{3i}^{-} \cdot \Delta(LOLP_{t-i}^{-}) + \sum_{i=0}^{p} \beta_{4i} \cdot \Delta(LINF_{t-i}) + \sum_{i=0}^{p} \beta_{5i} \cdot \Delta(LTO_{t-i}) + \sum_{i=0}^{p} \beta_{6i} \cdot \Delta(LURB_{t-i}) + \alpha_1 LFDP_{t-1} + \alpha_2 LOLP_{t-1}^{+} + \alpha_3 LOLP_{t-1}^{-} + \alpha_4 LINF_{t-1} + \alpha_5 LTO_{t-1} + \alpha_6 LURB_{t-1} + \mu_i + \varepsilon_{it} \quad (3)$$

Where:

$LOLP^{-}$ and $LOLP^{+}$ represent the logarithm of partial sums for changes in negative and positive oil prices, indicating respectively negative and positive oil price shocks:

$$LOLP_t^{+} = \sum_{j=1}^{t} \Delta LOLP_{ij}^{+} = \sum_{j=1}^{t} \max(\Delta LOLP_{ij}, 0) \quad (4)$$

$$LOLP_t^{-} = \sum_{j=1}^{t} \Delta LOLP_{ij}^{-} = \sum_{j=1}^{t} \min(\Delta LOLP_{ij}, 0) \quad (5)$$

$$LOLP_t^{+} = \sum_{j=1}^{t} \Delta LOLP_{ij}^{+} = \sum_{j=1}^{t} \max(\Delta LOLP_{ij}, 0) \tag{4}$$

$$LOLP_t^{-} = \sum_{j=1}^{t} \Delta LOLP_{ij}^{-} = \sum_{j=1}^{t} \min(\Delta LOLP_{ij}, 0) \tag{5}$$

Since we added the error correction term of the linear model in Equation (1), we likewise utilize this term for the non-linear version as follows :

$$\Delta(LFDP_t) = \sum_{i=1}^{q} \beta_{1i} \cdot \Delta(LFDP_{t-i}) + \sum_{i=0}^{p} \beta_{2i}^{+} \cdot \Delta(LOLP_{t-i}^{+}) + \sum_{i=0}^{p} \beta_{3i}^{-} \cdot \Delta(LOLP_{t-i}^{-}) + \sum_{i=0}^{p} \beta_{4i} \cdot \Delta(LINF_{t-i}) + \sum_{i=0}^{p} \beta_{5i} \cdot \Delta(LTO_{t-i}) + \sum_{i=0}^{p} \beta_{6i} \cdot \Delta(LURB_{t-i}) + \lambda_i ECT_{t-1} + \mu_i + \varepsilon_{it} \tag{6}$$

The error-correction term ECT_{t-1}captures the long-term equilibrium of the nonlinear panel ARDL is captured by the error-correction term ECT_{t-1} as equation (2). λ_i is an error-correction parameter that determines the speed at which the independent variable adjusts to reach its long-term equilibrium as a result of shocks in the dependent variable.

Results and discussions

1 Data Stationary Test Result

As a prerequisite for selecting an econometric model, panel unit root tests are applied on each variable to ensure that the data used are stationary at levels or first-order differences. With the chosen samples being countries, we suspend the cross-section dependence across them in our model. We utilized the cross-sectional dependence Pesaran CD test to assure this assumption. The CD-test findings indicate the presence of cross-sections in all variables, as shown in Table 4, where the statistical values were significant at 1%, indicating that the sample countries share the same characteristics.

Table 4 Cross-sectional dependence test

Variables	Oil-exporting countries	Oil-importing countries	MENA countries
	CD-test	CD-test	CD-test
lFDP	16.178*** (0.000)	16.842*** (0.000)	34.553*** (0.000)
LOLP	24.249*** (0.000)	17.748*** (0.000)	43.715*** (0.000)

LINF	6.418*** (0.000)	2.239** (0.025)	8.512*** (0.000)
LTO	3.984*** (0.000)	5.29*** (0.000)	8.683*** (0.000)
LURB	19.707*** (0.000)	9.505*** (0.000)	30.881*** (0.000)

Note. (1)The CD test is based upon the null hypothesis of the cross-section independence tends to N (0,1). A p-value near zero indicates the correlation between panel sets.

(2) Parentheses denote probability values, while ***,**,* represent a 1%, 5 and 10%, respectively, of significance.If no special instructions, the following symbols are the same.

Given the cross-section dependencies among countries, first-generation panel unit root tests such as Levin Lin and Chu (LLC), Im Pesaran and Shin (IPS) tests are unsuitable. Hence, we employ the Cross-sectional Augmented Dickey-Fuller (CADF) Pesaran test (Pesaran, 2007) for checking the stationarity levels of the variables in the sample countries. The findings of the CADF tests indicate in Table 5 that the variables considered in our study are not integrated at an order greater than I (1). These levels of integration confirm the convenience of the panel ARDL approach.

Table 5 CADF test results

Variables	Oil-exporting countries		Oil-importing countries		MENA countries	
	Zt-bar		Zt-bar		Zt-bar	
	Level	F.difference	Level	F.difference	level	F.difference
LFDP	-1.675** (0.047)	-2.722** (0.003)	0.861 (0.805)	-3.464*** (0.000)	-0.820 (0.206)	-3.049*** (0.001)
LOLP[2]	12.743 (1.000)	11.918 (1.000)	11.035 (1.000)	10.321 (1.000)	16.895 (1.000)	15.994 (1.000)
LINF	-0.945 (0.172)	-4.753*** (0.000)	0.344 (0.634)	-6.428 *** (0.000)	-1.159 (0.123)	-6.574 *** (0.000)
LTO	0.325 (0.627)	-3.029*** (0.001)	1.225 (0.890)	-1.891** (0.029)	1.547 (0.939)	-3.176*** (0.001)
LURB	1.101 (0.864)	-3.346** (0.002)	-2.317** (0.010)	3.049 (0.999)	-1.723** (0.042)	6.478 (1.000)

Note. The Pesaran's CADF-test is based upon the null hypothesis that series are integrated at I (1).

2 Food prices symmetrical response to oil prices

The estimated symmetric impact is summarized in Table 6 using equation (1). Here, all the equations are estimated with pooled mean group (PMG) of dynamic heterogeneous panels (Pesaran et al., 1999), Pesaran and Smith's (1995) mean group estimator (MG), and the

[2] Here the oil price variable is non-stationary because oil price only have the time change and no changes across countries.

Dynamic panel model with Fixed Effects (DFE). The Hausman test p-values for MG and DFE are not significant which indicates that the PMG is the adequate estimator in all sample countries for modelling the symmetric nexus among food prices and oil prices. Thus, we accept the estimated results for PMG methods.

Table 6 Symmetric ARDL model results

Variables	Oil-exporting countries			Oil-importing countries			MENA countries		
	PMG	MG	DFE	PMG	MG	DFE	PMG	MG	DFE
Long-run									
$LOLP_{t-1}$	0.334***	-0.0758	0.341***	0.269***	0.166*	-6.390	0.274***	0.027	1.652
	(0.000)	(0.650)	(0.000)	(0.000)	(0.024)	(0.721)	(0.000)	(0.787)	(0.666)
$LINF_{t-1}$	0.0499**	0.245	0.0414	0.0375*	0.268*	-6.011	0.0464**	0.255**	1.729
	(0.012)	(0.092)	(0.687)	(0.062)	(0.072)	(0.709)	(0.002)	(0.011)	(0.679)
LTO_{t-1}	-0.357**	0.295	0.175	-0.416***	-0.293	4.807	-0.369***	0.0430	-0.352
	(0.016)	(0.616)	(0.473)	(0.000)	(0.177)	(0.805)	(0.000)	(0.901)	(0.908)
$LURB_{t-1}$	2.385***	145.9	1.163	2.035***	-4.971	40.37	2.081***	81.22	-10.36
	(0.000)	(0.211)	(0.478)	(0.000)	(0.741)	(0.684)	(0.000)	(0.234)	(0.738)
ECT	-0.314*	-0.529**	-0.107***	-0.442***	0.167	0.00493	-0.244**	- 0.492***	- 0.0111
	(0.062)	(0.013)	(0.000)	(0.000)	(0.177)	(0.666)	(0.015)	(0.000)	(0.646)
Short-run									
$\Delta LOLP_{t-1}$	-0.0435*	-0.00940	0.0105	-0.0370	-0.0659**	-0.0382	-0.0386**	-0.0336 *	0.00553
	(0.014)	(0.715)	(0.547)	(0.250)	(0.013)	(0.158)	(0.014)	(0.085)	(0.757)
$\Delta LINF_{t-1}$	-0.00183	-0.0295	-0.0005	0.00822	-0.0264*	-0.0061	0.00324	-0.0282**	-0.00350
	(0.575)	(0.180)	(0.956)	(0.276)	(0.070)	(0.318)	(0.394)	(0.038)	(0.472)
ΔLTO_{t-1}	-0.317	-0.240	-0.101	0.0396	0.0419	0.0689	-0.125	-0.119	-0.0241
	(0.220)	(0.089)	(0.283)	(0.639)	(0.598)	(0.403)	(0.272)	(0.200)	(0.714)
$\Delta LURB_{t-1}$	867.6	1168.1	-1.102**	-16.53	1.673	-0.0417	387.7	668.2	0.0979
	(0.319)	(0.355)	(0.027)	(0.130)	(0.820)	(0.945)	(0.331)	(0.352)	(0.844)
Hausman test		0.95	5.08		2.15	0.68		1.49	2.35
		(0.9166)	(0.3695)		(0.7077)	(0.8593)		(0.8289)	(0.6582)
Model		PMG	PMG		PMG	PMG		PMG	PMG

Note. The PMG estimator is accepted under the null hypothesis of the Hausman test, while the MG estimator is accepted under the alternative hypothesis.

As shown in Table 6, the long-run finding shows that oil prices impact food prices positively and significantly for all samples. This corresponds to several empirical studies (e.g. Alghalith, 2010; Baumeister and Kilian, 2014; Olayungbo and Hassan, 2016; Taghizadeh-hesary et al., 2019), suggesting that a rising oil price will induce higher food prices in the long-term. Further, we observe that the coefficients of *LOLP* of *oil-exporters* are greater than those for oil-importers which indicate the food prices of *oil-exporters* are rising more than that of *oil-importers* with an increasing oil price. The reason may be that the revenue gains from high oil prices for *oil-exporters* will spur more food demand and increase energy consumption costs in the food production process and ultimately lead to higher local food prices. It is also important to note that the total social welfare of *oil-exporters* may decrease because high food import costs offset the benefits of oil exports. Another phenomenon is that oil prices have a significantly negative short-term influence on *oil-exporters*' food prices, unlike for *oil-importers* where this is not significant. The reason for this is that *oil-exporters* can take short-term measures to mitigate the negative effects on the food system from high oil prices, while oil-importers have greater difficulty in taking effective short-run measures.

The rate of inflation (INF) is similarly affected by food prices for both *oil-exporters* and *oil-importers* positively and significantly in the long-term, while the short-term effect insignificant. This finding is in line with Furceri et al. (2016), indicating that inflation has boosted food prices. However, this effect is larger for *oil-exporters* than *oil-importers*. Specifically, a 1% increase in the inflation rate increases food prices in the long-term by 0.049% for *oil-exporters* while this change is 0.037% for the oil-importing group in the long-term. This indicates that prices of food for *oil-exporters* are more sensitive than for *importers*.

In addition, the trade openness index (TO) affected negatively and significantly the long-run food prices for all samples .This effect can be explained by the competitiveness of food commodities when MENA countries open up to foreign trade, leading to the further long-term declines in food prices. The short-term coefficient of trade openness was found to be negative and insignificant in the MENA region. The reason may be that it takes a long time for the welfare effect of trade freedom to impact food prices.

The long-run results show that urban population (URB) also affects food prices positively and is statistically significant for the sampled countries. This implies that rural migration to cities within the same country—or between MENA countries— this has resulted in a substantial increase in the urban population thereby depriving labour from the agricultural sector in rural areas. As a consequence, the agricultural sector's performance in these areas has deteriorated, leading to higher food prices.

For all sample countries, the error correction coefficients (ECTs) terms are statistically significant, negative, and less than one, demonstrating that short-run fluctuations in the system will converge in a long-run relationship. For oil-exporters, the distortions due to food price shocks can be corrected at a speed of 31.4%. Alternatively, for oil-importers, the speed of long-run equilibrium adjustment is 44.2%— which is faster than for the oil-exporting group.

To test how robust the estimated outcomes are, this study re-estimated the PMG model by gradually adding variables and the panel OLS results are reported (see Appendix Table A, B, and C). The former results show that as the number of variables increases, the coefficients of most variables fluctuated in a small range, verifying that the estimation results are robust. The latter results indicate that, as expected, most of the variables are correctly signed, proving that the long-run result of PMG estimates is reasonable.

3 Food prices asymmetrical response to oil prices

Food prices in MENA countries may have different impact mechanisms in the face of fluctuating oil prices. To explore this asymmetric response, we use panel data samples for country groups and time series for each country to analyse the heterogeneous response of different samples.

(1) Estimation results using panel data

With the null hypothesis that positive and negative changes are not jointly significant, Wald tests are conducted to investigate the existence of an asymmetry relationship with panel data used for both groups of *oil-exporters* and *oil-importers* nations. Table 7 shows that for the entire sample of MENA countries, the null hypothesis is rejected for both short- and long-term, which supports the asymmetrical relationship and implies that oil prices do not have the identical impact on food price as oil prices rise and decrease. From the perspective of country groups, however, the F-statistics of the Wald test are not significant. This result predicts the heterogeneous response within the oil importing and exporting countries groups.

Table 7 Wald Test for Asymmetry

	Oil-exporting countries		Oil-importing countries		MENA countries	
	Long-run	Short-run	Long-run	Short-run	Long-run	Short-run
Wald Statistic	0.95 (0.3301)	1.52 (0.2180)	0.43 (0.5126)	1.51 (0.2190)	3.25* (0.0713)	6.38** (0.0115)
Asymmetric Evidence	No	No	No	No	Yes	Yes

Note. The null hypothesis of Wald's test that positive and negative changes are not jointly significant. Thus, they do not differ from zero, the alternative is that the changes are jointly significant.

The estimated asymmetric impacts of changes in oil price on food price sample groups is presented in Table 8 using equation (3). First, all equations are estimated using PMG, MG, and DFE estimators, and then choose the most appropriate estimator based on the Hausman test in the last line of Table 8. The findings show that the null hypothesis is appropriate, which suggests that all groups are consistent with the PMG estimator.

Table 8 Estimation of NARDL Models.

Variables	Oil-exporting countries	Oil-importing countries	MENA countries
Long-run			
$LOLP^{-}_{t-1}$	0.373***	0.287***	0.296***
	(0.000)	(0.000)	(0.000)
$LOLP^{+}_{t-1}$	0.354***	0.301***	0.302***
	(0.000)	(0.000)	(0.000)
$LINF_{t-1}$	0.0688**	0.0373**	0.0256
	(0.003)	(0.005)	(0.151)
LTO_{t-1}	-0.361**	-0.358***	-0.408***
	(0.032)	(0.000)	(0.000)
$LURB_{t-1}$	2.354***	1.992***	1.915***
	(0.000)	(0.000)	(0.000)
ECT	-0.262*	-0.175	-0.250**
	(0.052)	(0.171)	(0.025)
Short-run			
$\Delta.LOLP^{+}_{t-1}$	-0.0229*	-0.0382	-0.0494**
	(0.051)	(0.326)	(0.021)
$\Delta.LOLP^{-}_{t-1}$	-0.0255*	-0.0360	-0.0470**
	(0.057)	(0.365)	(0.027)
$\Delta LINF_{t-1}$	-0.00333	0.0140	0.00624
	(0.458)	(0.220)	(0.241)
ΔLTO_{t-1}	-0.257	0.0439	-0.183
	(0.141)	(0.619)	(0.265)
$\Delta LURB_{t-1}$	754.2	-18.67*	460.0
	(0.317)	(0.097)	(0.328)
Hausman test	0.37	3.63	0.55
	(0.9961)	(0.6046)	(0.2303)
Model	PMG	PMG	PMG

For the MENA sample, the short-term asymmetrical parameters of a? ? $LOLP^{+}_{t-1}$ and $\Delta LOLP^{-}_{t-1}$ are negative at 5% level of significane, implying that food prices will decline over the short-term, whether oil prices increase or decrease. One possible reason is that in the short-term, governments provide timely food subsidies and other measures to stabilize prices. However, the long-term asymmetric parameters (0.296 and 0.302) are positively significant at the 1% level, which indicates, whether oil prices rise or fall, food prices always rise. This confirms that continuing food price rises is inevitable over the long-term even though it will decline in the short-term. Another observed phenomenon is that when oil prices rise, food prices rise faster than the corresponding decline when oil prices fall. This finding indicates that when the international oil price rises, it exerts more pressure on the domestic food price.

Error correction coefficients (ECTs) terms are negatively significant for the samples of oil-exporting and MENA countries that support a long-term convergence. When a short-term deviation is caused by shocks in food prices, the adjustment to the long-run equilibrium in the long-term is 26.2% and 25% in oil-exporting and MENA countries, respectively. Alternatively, the coefficient of ECT for oil-importing countries is shown to be negative but statistically insignificant indicating no convergence in the long-run relationship.

(2) Estimation results using time series

We estimate the non-linear effects of oil price on each country's food price by employing time series for the two groups (oil-exporters and oil-importers) following the non-linear ARDL model. The Wald test results for asymmetries are summarized in Table 9.

Table 9 Wald Test for Asymmetry in MENA countries

	Wald Statistic		Asymmetric Evidence	
Country	Long-run	Short-run	Long-run	Short-run
Oil-exporting countries				
Algeria	48.39***	0.07652	Yes	No
	(0.000)	(0.788)		
Bahrain	32.93***	0.3956	Yes	No
	(0.000)	(0.543)		
Iraq	15.78**	2.032	Yes	No
	(0.003)	(0.184)		
Kuwait	2.148	7.584	No	No
	(0.173)	(0.979)		
Oman	13.72**	0.0148	Yes	No
	(0.004)	(0.906)		
Qatar	7.02**	0.8604	Yes	No
	(0.024)	(0.375)		

Saudi Arabia	0.08213	0.4131	No	No
	(0.780)	(0.535)		
UAE	0.7371	1.64	No	No
	(0.411)	(0.229)		
Oil-importing countries				
Egypt	529.5***	6.211**	Yes	Yes
	(0.000)	(0.032)		
Jordan	31.55***	0.2005	Yes	No
	(0.000)	(0.664)		
Lebanon	57.7***	1.31	Yes	No
	(0.000)	(0.279)		
Morocco	87.09***	0.0010	Yes	No
	(0.000)	(0.975)		
Tunisia	0.2471	0.2482	No	No
	(0.630)	(0.629)		
West Bank	8.194**	0.3595	Yes	No
& Gaza	(0.017)	(0.562)		

The asymmetry test findings for oil-exporting group—including Algeria, Bahrain, Iraq, Oman, and Qatar—indicated that the Wald test F-statistics are significant in the long-term, suggesting that asymmetrical influence exists in those countries. Alternatively, economies such as Kuwait, Saudi Arabia, and the United Arab Emirates have rejected the null hypothesis regarding the existence of asymmetric linkage in the short- and long-term, which indicates that the oil-food prices relationship is not asymmetric. This evidence supports our observations of the cumulative effects of oil price on food price (see Appendix Figure A), where the asymmetry line shows that food prices in Kuwait, Saudi Arabia, and the UAE do not react differently to shocks in the oil price—whether increasing or decreasing.

Except for Tunisia, all oil-importers pass the long-term Wald test at 5% significance level, indicating how asymmetric the changes in the price of oil are influencing long-term food price. The asymmetry line implies that the impact of oil price on food price in Egypt, Jordan, Lebanon, Morocco, the West Bank, and Gaza is not identical for either a rise or decline in oil price, as seen in the plots of the cumulative effects of oil price on food price (see Appendix Figure B).

The long-run asymmetric effects for each MENA country are shown in Table 10. For the oil-exporting group, the results show that the coefficients associated with increases in the oil price positively affect food prices. Specifically, an increase of 1% in positive oil price changes causes an increase of between 0.24% and 0.59% in food prices. Nevertheless, the coefficients related to decreases in the oil price negatively affect food prices in Iraq, whereas in Algeria, Bahrain, Oman, and Qatar these are insignificant. For oil-importing nations, the outcomes also indicate that food prices are positively influenced by the increasing oil price changes. A 1% rise in oil prices results in a 0.12% to 0.40% increase in food prices. However, the coefficients of oil price reductions have been found to be mixed. Egypt and Lebanon are positively affected, while Jordan is negatively affected, and the impact on Morocco, the West Bank and Gaza are insignificant.

Table 10 Long-run asymmetric effects

Oil exporting countries

	Algeria	Bahrain	Iraq	Kuwait	Oman	Qatar	Saudi Arabia	UAE
$LOLP^{+}_{t-1}$	0.259**	0.239**	0.586***	-	0.379***	0.338**	-	-
	(0.014)	(0.039)	(0.000)		(0.000)	(0. 003)		
$LOLP^{-}_{t-1}$	0.148	-0.015	-0.309**	-	-0.161	-0.159	-	-
	(0.291)	(0.914)	(0.009)		(0.201)	(0.283)		

Oil importing countries

	Egypt	Jordan	Lebanon	Morocco	Tunisia	West Bank & Gaza
$LOLP^{+}_{t-1}$	0.255***	0.403***	0.214**	0.124***	-	0.298***
	(0.001)	(0.000)	(0.003)	(0.000)		(0.000)
$LOLP^{-}_{t-1}$	0.399***	-0.173*	0.153*	0.039	-	-0.143
	(0.000)	(0.067)	(0.097)	(0.296)		(0.140)

By comparing our time-series results with estimates of the panel data, we concluded that due to countries' different economic status, the asymmetric impacts of fluctuations in oil prices on the food price varies. In general, our conclusion is that when oil prices rise, the food prices also rise; but when oil prices drop, food prices do not always decrease. This also proves that, as a necessary commodity, the price of food is sticky—it does not fall easily.

Conclusions and policy implications

The linear and nonlinear panel ARDL models are used in this paper to investigate the symmetrical and asymmetrical relationship between world oil prices and local food prices for the MENA region from 2000 to 2020. Findings from the symmetric linear ARDL model show that oil prices have a long-run positive and significant impact on food prices for oil-exporting and importing MENA nations. The positive impact is larger for *oil-exporters* than for *oil-importers*. This outcome concludes oil prices have a greater influence on increases in food prices for those economies that export oil at high prices. This results in increased costs for imported food due to the higher energy cost needed to produce food commodities in the country of origin. Furthermore, we found that the inflation rate and urban population affect positively and significantly on food prices for oil-exporters and importers groups, while trade openness is negative and significant in relation to food prices. These results suggest that expanding trade openness can help these countries source cheaper food resources. Additionally, reducing inflation and controlling the scale of urbanization will foster agricultural development and ensure an adequate food supply.

For the entire sample from the MENA region, outcomes indicate that the oil price effect on food price is asymmetrical in the short- and long-term although this effect is insignificant for the oil-exporters and importers groups. This finding follows Meyer et al. (2018) and Ibrahim (2015). However, the short-term asymmetric effect was negative, while this was found to be positive in the long-term, indicating that—whether oil prices rise or fall—food prices always rise. These results indicate that food products price is sticky: once food prices rise, it is harder to reduce them. Therefore, policymakers should take measures to improve agricultural labour productivity, increase the supply capacity of agricultural products, and develop renewable energy sources (such as photovoltaic cells) to eliminate the dependence of agriculture on oil. For the MENA region, developing biomass energy is discouraged to prevent the reduction in available agricultural land. Thus, while developing biomass energy, the government–should reasonably assess its potential impact on agricultural land and food supply.

Regarding the non-linear ARDL results for each country using time series, we found an absence of asymmetrical behaviour for nations including Kuwait, Saudi Arabia, and the UAE from the oil-exporting group, and Tunisia from the oil-importing group. Except those countries, others have the asymmetrical effects in food prices responses to oil prices in the long-term. Oil prices have a major impact on countries such as Iraq and Jordan, and food price tracked oil price fluctuations. To maintain the stability of food prices, these countries need to make counter-cyclic adjustments; when the oil price is expected to rise, they should stockpile a large amount of food, and when the oil price is expected to fall, they should sell food. For countries such as Egypt and Lebanon, The rate of increase in food prices fluctuates with rising oil prices; hence, these governments need to establish long-term food price stability mechanisms—increasing food production, establishing a stable international food trading partner and other policies regardless of how oil prices fluctuate. Additionally, for countries such as Algeria and Bahrain which are seriously affected by increases in the oil price—but not by its decline—they need to stockpile more agricultural products before forecasting higher oil prices.

As one of the global regions with insufficient food supply, food price stability in the MENA region is an important guarantee of food security. First, MENA governments should review their agricultural policies by providing incentives and implementing effective mechanisms to increase domestic production to avoid the effects of high food prices that result from energy price fluctuations; second, as most MENA agricultural resources (whether water or arable land) are located in oil-importing countries (characterized by a scarcity of financial resources) while *oil-exporters* have enormous oil wealth (matched by a scarcity of arable land and water) cooperation should be strengthened between countries to stabilize oil and food prices. Third, according to the differentiated symmetrical and asymmetrical mechanisms of food and oil prices, MENA countries should establish specific coping strategies. For countries with a relatively large impact on international oil prices, an early warning mechanism could mitigate price spikes in food and oil.

Appendix:

Table A The estimated results of the pooled mean group and panel OLS for oil-exporting countries

Pooled mean group	Panel OLS

Long-run					
LOLP$_{t-1}$	0.578***	0.498***	0.452***	0.334***	0.283**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)
LINF $_{t-1}$		0.0929*	0.112**	0.0499**	-0.0541**
		(0.088)	(0.037)	(0.012)	(0.023)
LTO $_{t-1}$			0.0431	-0.357**	-0.311
			(0.876)	(0.016)	(0.335)
LURB $_{t-1}$				2.385***	3.502**
				(0.000)	(0.002)
	-0.109***	-0.0864***	-0.0833***	-0.314*	
ECT	(0.000)	(0.000)	(0.000)	(0.062)	
Short -run					
Δ.LOLP $_{t-1}$	-0.0135	-0.00907	-0.00223	-0.0435**	
	(0.632)	(0.721)	(0.870)	(0.014)	
Δ.LINF $_{t-1}$		0.00299	0.00122	-0.00183	
		(0.622)	(0.821)	(0.575)	
Δ.LTO $_{t-1}$			-0.0616	-0.317	
			(0.319)	(0.220)	
Δ.LURB $_{t-1}$				867.6	
				(0.319)	

Table B The estimated results of the pooled mean group and panel OLS for oil-importing countries

	Pooled mean group				Panel OLS
Long-run					
LOLP $_{t-1}$	0.594***	0.738**	0.486***	0.269***	0.321**
	(0.000)	(0.039)	(0.000)	(0.000)	(0.022)
LINF $_{t-1}$		1.633**	0.0774*	0.0375*	0.139
		(0.002)	(0.064)	(0.062)	(0.332)
LTO $_{t-1}$			-0.825***	-0.416***	-0.841
			(0.000)	(0.000)	(0.106)
LURB $_{t-1}$				2.035***	2.874
				(0.000)	(0.112)
ECT	-0.0566*	- 0.0241***	-0.0606	-0.167	
	(0.048)	(0.001)	(0.423)	(0.177)	
Short-run					
Δ.LOLP $_{t-1}$	-0.0277*	-0.0416*	-0.0465	-0.0370	
	(0.069)	(0.050)	(0.102)	(0.250)	
Δ.LINF $_{t-1}$		-0.00128	0.0146	0.00822	
		(0.881)	(0.241)	(0.276)	
Δ.LTO $_{t-1}$			0.0200	0.0396	
			(0.790)	(0.639)	
Δ.LURB $_{t-1}$				-16.53	
				(0.130)	

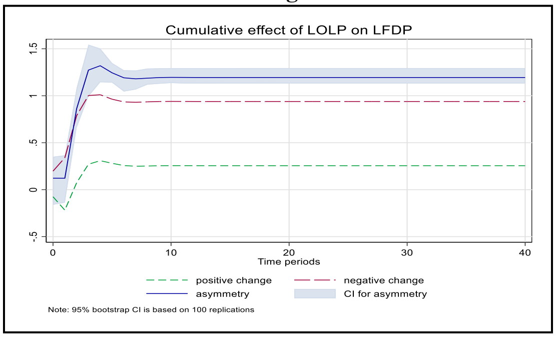
Table C The estimated results of the pooled mean group and panel OLS for MENA countries

	Pooled mean group				panel OLS
Long-run					
LOLP $_{t-1}$	0.584***	0.525***	0.524***	0.274***	0.295***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LINF $_{t-1}$		0.122**	0.176**	0.0464**	0.00979
		(0.016)	(0.005)	(0.002)	(0.835)
LTO $_{t-1}$			-0.0624	-0.369***	-0.626*
			(0.792)	(0.000)	(0.051)
LURB $_{t-1}$				2.081***	3.227***
				(0.000)	(0.000)

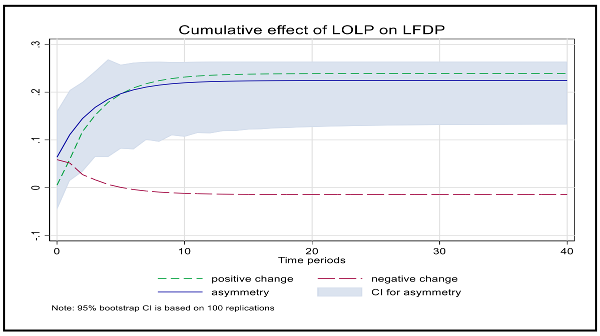
ECT	-0.0863***	-0.0636***	-0.0572***	-0.244**
	(0.000)	(0.000)	(0.000)	(0.015)
Short -run				
Δ.LOLP $_{t-1}$	-0.0196	-0.0212	-0.0156	-0.0386**
	(0.247)	(0.195)	(0.250)	(0.014)
Δ.LINF $_{t-1}$		0.00730	0.00579	0.00324
		(0.201)	(0.328)	(0.394)
Δ.LTO $_{t-1}$			-0.0393	-0.125
			(0.307)	(0.272)
Δ.LURB $_{t-1}$				387.7
				(0.331)

Figure A The cumulative effect of oil price on food price in oil-exporters group

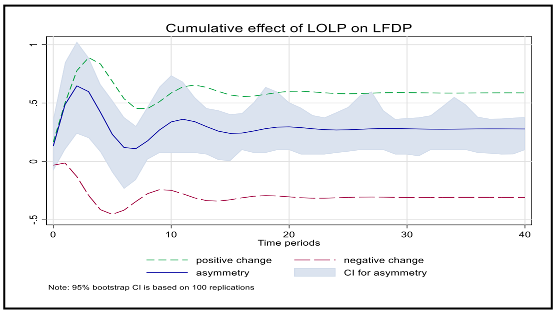
Algeria



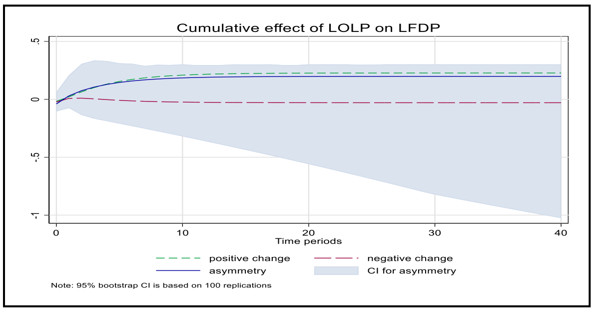
Bahrain



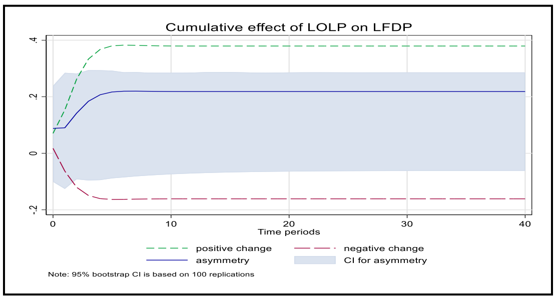
Iraq



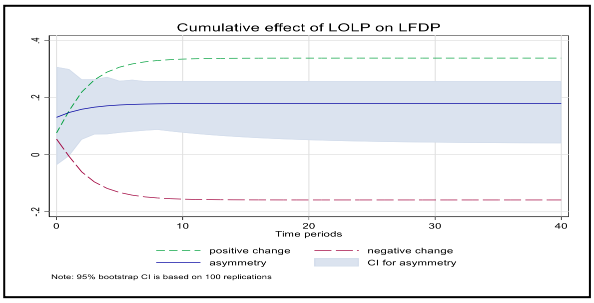
Kuwait



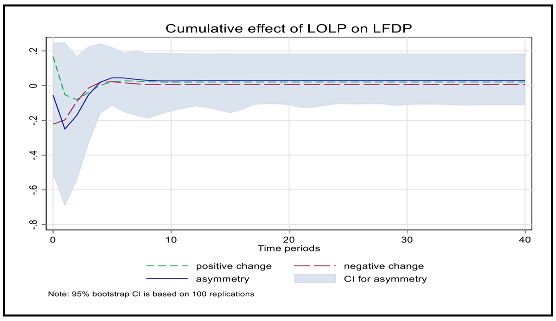
Oman



Qatar



Saudi Arabia



UAE

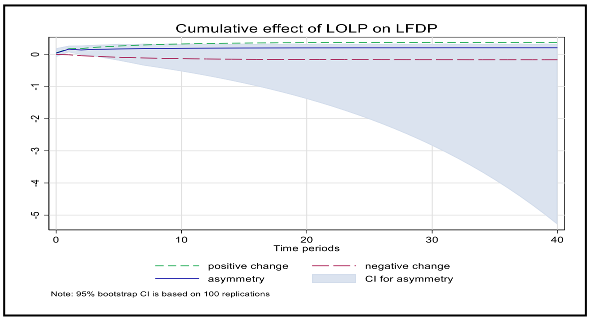
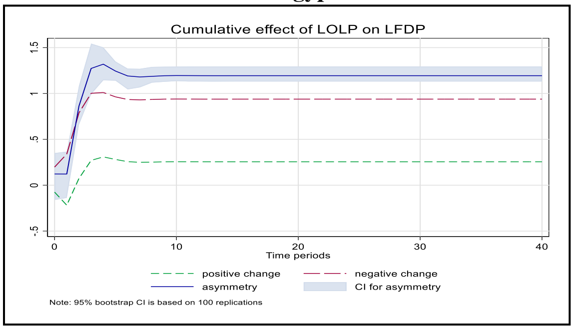
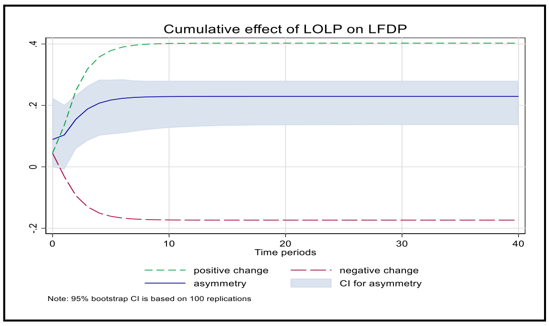


Figure B The cumulative effect of oil price on food price in oil-importers group

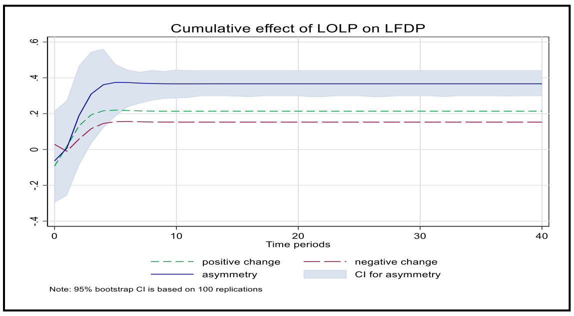
Egypt



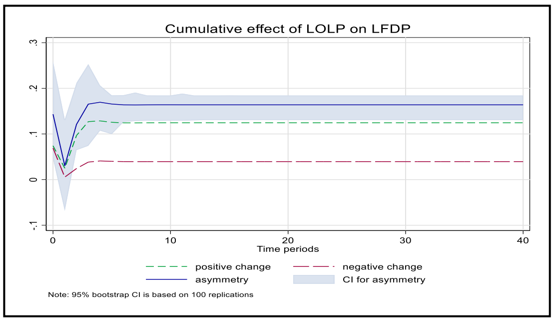
Jordan



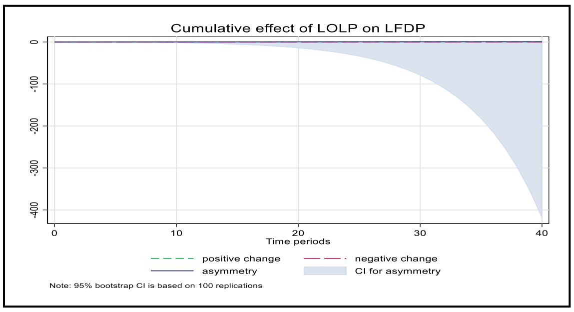
Lebanon



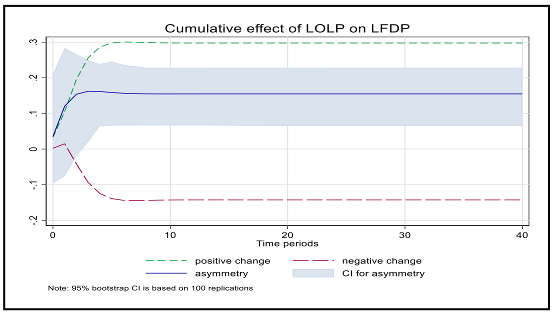
Morocco



Tunisia



West Bank & Gaza



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Figures

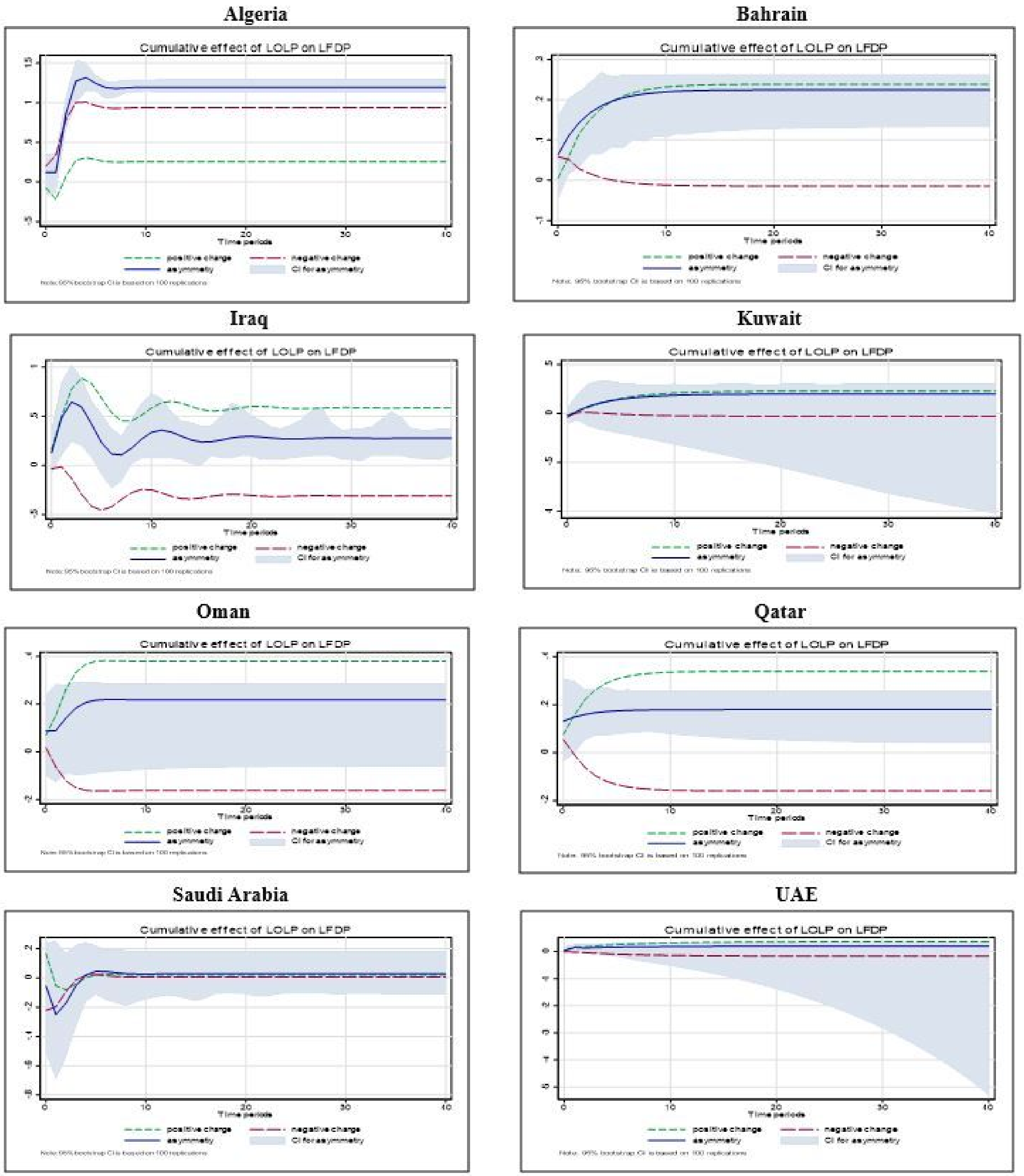

Figure 1

The cumulative effect of oil price on food price in oil-exporters group

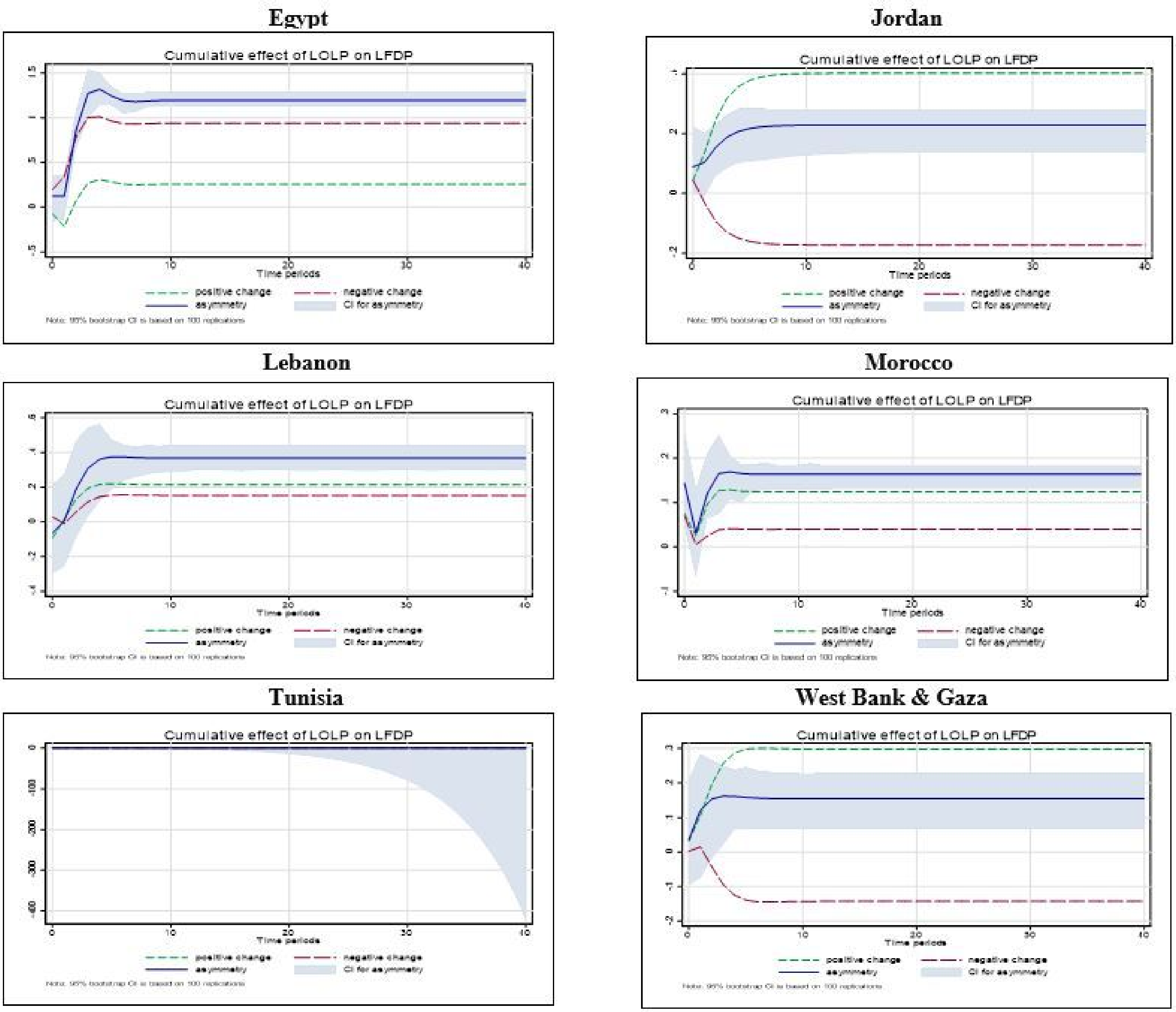

Figure 2

The cumulative effect of oil price on food price in oil-importers group