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Asymmetric relationship between global and national factors and domestic food prices: evidence from Turkey with novel nonlinear approaches

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Abstract

This study investigates the asymmetric relationship between global and national factors and domestic food prices in Turkey, considering the recent rapid and continuous increase in domestic food prices. In this context, six global and three national explanatory variables were included, and monthly data for the period from January 2004 to June 2021 were used. In addition, novel nonlinear time-series econometric approaches, such as wavelet coherence, Granger causality in quantiles, and quantile-on-quantile regression, were applied for examination at different times, frequencies, and quantiles. Moreover, the Toda-Yamamoto (TY) causality test and quantile regression (QR) approach were used for robustness checks. The empirical results revealed that (i) there is a significant relationship between domestic food prices and explanatory variables at different times and frequencies; (ii) a causal relationship exists in most quantiles, excluding the lowest quantile, some middle quantiles, and the highest quantile for some variables; (iii) the power of the effect of the explanatory variables on domestic food prices varies according to the quantiles; and (iv) the results were validated by the TY causality test and QR, which show that the results were robust. Overall, the empirical results reveal that global and national factors have an asymmetric relationship with domestic food prices, highlighting the effects of fluctuations in global and national variables on domestic food prices. Thus, the results imply that Turkish policymakers should consider the asymmetric effects of global and national factors on domestic food prices at different times, frequencies, and quantiles.

Keywords: Domestic food prices, Global factors, National factors, Nonlinear approaches, Turkey

JEL Classification: C32, Q13, Q18

Introduction

Countries aim to provide better living conditions and a higher quality of life for citizens by achieving sustainable economic growth and development. For this purpose, macroeconomic and financial indicators, such as the consumer price index (CPI), economic growth, foreign exchange (FX) rates, gross domestic product (GDP), interest

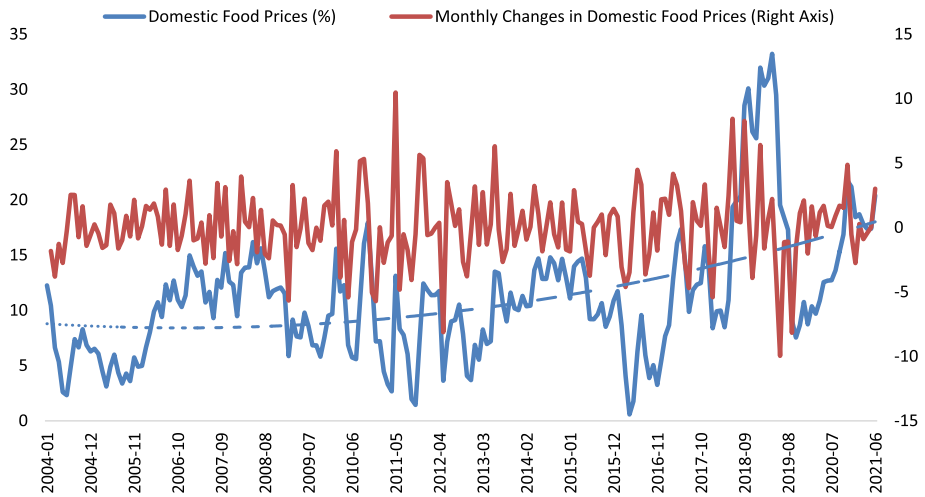

Fig. 1 Developments in domestic food prices in Turkey. The Central Bank of the Republic of Turkey (CBRT), 2021

rates, producer price index (PPI), stock market indices, are the main topics that regulatory authorities focus on to monitor the progress of economies (Ayhan & Kartal 2021; Depren et al. 2021; Kirikkaleli et al., 2021; Aydoğmuş et al. 2022) and the well-being of societies over time, although GDP is not considered a better indicator of societal well-being (Organization for Economic Cooperation and Development-OECD 2018). Nevertheless, such indicators are highly correlated with the stability of economies and the well-being of societies.

Achieving stability in macroeconomic indicators improves economies and society's well-being by reducing uncertainty and volatility. However, there are still some basic needs for people, such as food. Although economies and economic indicators remain important, they come after people's main needs (e.g., food). Therefore, achieving a stable food supply by making food accessible is important, as it directly affects the quality of life and well-being of citizens. In a highly volatile environment, governmental interventions in domestic food prices are generally required to provide stability so that negative impacts on households, inflation, and inflation expectations can be prevented. Hence, price stability is not adversely affected by such volatility or increases in domestic food prices (Food and Agriculture Organization-FAO 2011).

Domestic food prices are a significant component of price baskets. For example, domestic food prices had a 25.94% share in the Turkish CPI basket as of July 2021 (Turkish Statistical Institute-TSI 2021). For this reason, changes in domestic food prices can significantly affect price and financial stability via the price stability channel. Hence, food prices are crucial from a social perspective. Moreover, domestic food prices have been increasing rapidly and continuously, and this increase has caused a high CPI in some countries, such as Turkey. Thus, domestic food prices are more important in these countries. Unfortunately, in such a situation, both the CPI and producer price index have increased. Figure 1 shows the trends in domestic food prices in Turkey.

As Fig. 1 shows, Turkey has a high and volatile trend in terms of developments in domestic food prices. Specifically, domestic food prices increased significantly, with

an increase of 33.23% in some periods, such as 2019/4, whereas they increased slightly, with an increase of 0.58% in other periods, such as 2016/4. These figures show that the changes are not linear, and are the same for all levels of domestic food prices. Although domestic food prices have shown a slight increase in some periods, it can be generalized that domestic food prices have an increasing trend in Turkey.

According to the extant literature, domestic food prices have been examined in various studies. These studies examined the relationship between domestic food prices and different global and national factors, such as energy prices, FX rates, and global warming (İslam & Wong 2017). In addition, other factors such as interest rates (Kara 2017) and oil prices (Kirikkaleli & Darbaz 2021) have been considered when examining domestic food prices. Global and national factors can impact domestic food prices by affecting the cost of production as well as the demand and supply of food products. Global and national factors can have either direct effects on domestic food prices, such as increasing production costs, or indirect effects, such as increasing domestic prices of production materials due to rising FX rates. Based on the current literature, there is no doubt that global and national factors influence domestic food prices. Moreover, current studies show the effects on domestic food prices by applying classical approaches such as regression (e.g., Letta et al. 2021), vector autoregressive models (e.g., Li & Li 2021), and vector error correction models (e.g., Khatun et al. 2016). Thus, such a determination requires the consideration of multiple factors when examining domestic food prices. Although the extant literature includes some studies on Turkey that used classical approaches (e.g., Ertuğrul & Seven 2021), the asymmetric relationship between global and national factors and domestic food prices has not been comprehensively investigated for Turkey using novel nonlinear methods and the longest and most accessible data that contain price increases and high volatility. Hence, it can be stated that there is a literature gap.

Considering the literature gap and developments in domestic food prices in Turkey, a new study can investigate the asymmetric effects of global and national factors on domestic food prices at different times, frequencies, and quantiles using novel nonlinear time series methods. It is also important to examine domestic food prices at different times, frequencies, and quantiles because they follow asymmetric changes rather than linear trends. Such a new study can contribute to the literature by enabling policymakers in emerging countries such as Turkey, which has been faced with increasing domestic food prices, to develop and implement best-fit policies to manage domestic food prices and reduce the negative effects of global and national factors. Hence, they can achieve price stability by controlling domestic food prices.

The main motivation of this study is to close the literature gap and analyze the case of Turkey with a comprehensive approach because of its outlier condition in terms of developments in domestic food prices. Turkey also has a negative outlier condition in terms of macroeconomic indicators such as FX rates, inflation (both CPI and PPI), and interest rates (Alola et al. 2019; Yıldırım et al. 2021). In line with the current literature, the hypotheses are that (i) there is a positive relationship between domestic food prices and explanatory (i.e., global and national) factors; (ii) the relationship is a causal; and (iii) the relationship changes according to different times, frequencies, and quantiles. In this context, Turkey was considered because it is an outlier country in terms of developments in domestic food prices. Selected global and national explanatory variables

were included, and monthly data from January 2004 to June 2021 were used to test the hypotheses. Moreover, novel nonlinear time-series methods, such as the wavelet coherence (WC), Granger causality in quantiles (GCQ), and quantile-on-quantile regression (QQR) approaches, were applied because data characteristics are not linear based on the linearity test results, and classical (i.e., regression and autoregressive-based) models have mostly been applied in the current literature. In addition, the Toda-Yamamoto (TY) causality test and quantile regression (QR) were performed as robustness checks in this study. The findings indicate that the effects of global and national factors on domestic food prices are asymmetric and vary according to different times, frequencies, and quantiles.

This study makes the following contributions: First, it uncovers the asymmetric effects of global and national factors on domestic food prices in Turkey at different times, frequencies, and quantiles, which, to the best of the authors' knowledge, have not been explored. Additionally, focusing on Turkey is important because it is an outlier country in terms of recent developments in domestic food prices (TSI 2021). Although various studies have examined domestic food prices in Turkey (e.g., Ertuğrul 2021), none have examined domestic food prices at different times, frequencies, and quantiles. Second, this study used novel nonlinear time-series methods, such as WC, GCQ, and QQR. To the best of our knowledge, this is the first study to employ GCQ and QQR as well as WC approaches to examine domestic food prices in Turkey. Hence, the asymmetric effects of global and national factors on domestic food prices have been comprehensively investigated in terms of correlation, causality, and effects at different times, frequencies, and quantiles.

The rest of the paper is organized as follows. Section "Literature review" presents the literature review. Section "Data and methodology" explains the data and the methodology used. Section "Empirical Analysis "presents the empirical results, a discussion, and policy implications. Section "Conclusion" concludes the paper.

Literature review

Empirical literature

In some studies, in the current literature, researchers uncovered food prices using various explanatory variables, which can be classified into two groups: global and national. Global variables were considered in the first group of studies. Economic policy uncertainty, energy (oil) prices, fertilizer prices, temperature, raw material prices, and volatility were included.

Xiao et al. (2019), Li and Li (2021), and Wen et al. (2021) examined the relationship between economic policy uncertainty and food prices. Xiao et al. (2019) uncovered the influence of economic policy uncertainty on food prices in China by applying the time-varying parameter vector autoregression (TVP-VAR) method and argued that economic policy uncertainty affects grain futures prices significantly. Li and Li (2021) investigated the effect of economic policy uncertainty in China using the time-varying parameter stochastic volatility (TVP-SV-VAR) method and determined that uncertainty results in an increase in food prices by reducing total imports and increasing trade costs. Similarly, Wen et al. (2021) examined China using the nonlinear autoregressive distributed lag (NARDL) method and found that negative economic policy uncertainty shocks have

a stronger effect than positive shocks on food prices. Considering these studies, food prices are expected to increase when economic policy uncertainty increases because increasing economic policy uncertainty causes a decrease in agricultural production by affecting the predictability, costs, investments, and prices of agricultural products. As an economic policy uncertainty indicator, we used the United States (US) Economic Policy Uncertainty Index. There are two main reasons for selecting this index as a proxy for economic policy uncertainty. First, Turkey has no economic policy uncertainty index. Second, the US is the leading partner with an important influence on Turkey in terms of strategic alliances in a variety of areas, such as trade, defense, direct investments, and portfolio investments.

Recent studies have examined the correlation between energy and food prices (Wen et al. 2021; Kartal 2021; Kirikkaleli & Darbaz 2021; Taghizadeh-Hesary et al. 2019; Pal & Mitra 2019; Salisu et al. 2017; Zhang & Qu 2015). Pal and Mitra (2019) investigated whether energy (crude oil) prices drive agricultural crops in the US using the dynamic conditional correlation (DCC) method. In addition, Taghizadeh-Hesary et al. (2019) focused on eight Asian countries by applying the panel VAR method and found that energy (i.e., oil) prices have an important effect on food prices. Similarly, Osman et al. (2019), Makena (2020), and Wen et al. (2021) investigated Saudi Arabia using the ARDL approach, Zimbabwe using the error correction model (ECM), and China using the NARDL method, respectively; they all determined that oil prices increase food prices. High energy (i.e., oil) prices increase costs, leading to an increase in food prices, which follows an increase in agricultural product prices. Consistent with these studies, food prices are expected to increase when energy prices increase. We used Brent crude oil prices as an energy price indicator because energy prices are affected mainly by oil prices.

Abbott et al. (2008), Baltzer et al. (2008), Mitchell (2008), and Ott (2012) studied the relationship between fertilizer prices and food prices. For instance, Mitchell (2008) stated that higher fertilizer prices cause an increase in food prices in the US by affecting production costs. Ott (2012) examined the role of fertilizer prices on global food prices by applying the VAR method and found a positive relationship. Similar results were obtained by other researchers such as Abbott et al. (2008) and Baltzer et al. (2008). An increase in fertilizer prices causes an increase in food prices by increasing the costs and prices of agricultural products. Hence, food prices are expected to increase when fertilizer prices increase. We used the World Bank (WB) fertilizer price index as a fertilizer price indicator.

Dercon (2004), Schlenker and Roberts (2006), Quiggin (2007), Schnepf (2008), D'Agostino and Schlenker (2016), Hirvonen (2016), and Letta et al. (2021) considered whether the effect of weather and climate conditions on food prices is significant. For example, Quiggin (2007) determined that global warming affected grocery prices in Australia. Schnepf (2008) studied global food prices and found that adverse weather conditions affected food prices by reducing supply and stocks. Similarly, Letta et al. (2021) examined the case of India using a regression method and stated that weather (drought) conditions increase agricultural prices by affecting production. Moreover, Dercon (2004), Schlenker and Roberts (2006), D'Agostino and Schlenker (2016), and Hirvonen (2016) showed a causal relationship between food prices and weather

anomalies. A deteriorating climatic condition causes an increase in food prices by decreasing the productivity of agricultural crops, thereby increasing the cost of agricultural crops per unit. Thus, food prices are expected to increase when weather and climate conditions worsen. As a weather and climate indicator, we used temperature changes because increasing temperatures cause droughts that reduce food production.

In addition to the global variables explained above, we included raw material prices in line with Makena (2020) and volatility as independent variables because food prices are likely to increase when raw material prices increase and markets are volatile. Fluctuations in raw material prices and volatility affects predictability and certainty, consequently affecting the costs of agricultural crops and investments. We used the WB raw material price index as a raw material price indicator and the Chicago Board Options Exchange (CBOE) volatility index as a volatility indicator.

In the second group of studies, national variables were considered. These included FX rates, interest rates, and country risk. Kornher and Kalkuhl (2013), Khatun et al. (2016), Al-Jafari and Altaee (2019), Makena (2020), Demeke and Tenaw (2021), and Verbicki (2021) examined the relationship between FX rates and food prices. Kornher and Kalkuhl (2013) examined whether there is a significant relationship between FX rates and food prices in selected countries using the generalized method of moments (GMM) and determined that this relationship is statistically significant. In addition, Khatun et al. (2016) considered the effect of FX rates on food prices in Bangladesh using a vector error correction model (VECM) and found a positive relationship. Al-Jafari and Altaee (2019) studied the case of Iraq using the ARDL approach; Makena (2020) investigated Zimbabwe using the ECM approach, and Demeke and Tenaw (2021) investigated Ethiopia via the dynamic ordinary least squares (DOLS) and TY causality approach. They determined a long-term asymmetric effect on the inflationary process. In contrast, Verbicki (2021) found that FX rates do not affect food prices in the European Union (EU). An increase in FX rates also increases the cost of agricultural production by affecting the prices of imported components used in agriculture, such as raw materials and oil. Thus, food prices are expected to increase when FX rates increase, considering the general results of these studies. As an FX rate indicator, we used the US dollar (USD)/Turkish lira (TRY) FX rates.

Arango et al. (2012), Baffes and Dennis (2013), Kara (2017), and Campos (2020) examined the relationship between interest rates and food prices. Arango et al. (2012) determined that interest rates are strongly related to commodity prices. In addition, Baffes and Dennis (2013) examined the relationship in Thailand using the ordinary least squares (OLS) regression method and pointed out the importance of interest rates for food prices. Kara (2017) found that there is an interaction between interest rates and food prices in the US, considering developments in food prices during monetary policy processes. Moreover, Campos (2020) argued that there is a U-shaped relationship between interest rates and agricultural commodity prices. An increase in interest rates causes an increase in agricultural production costs owing to an increase in the costs of funds used in agricultural production. Hence, food prices are expected to increase when interest rates increase. We used TRY-denominated credit interest rates as an interest rate indicator.

Table 1 A Summary of Empirical Literature

Authors	Year	Country	Method	Results
Arezki & Bruckner	2011	120 Countries	Panel Data	There is a positive relationship between food prices and political instability
Ott	2012	The US	VAR	There is a positive relationship between fertilizer prices and global food prices
Baffes & Dennis	2013	Thailand	OLS	Interest rates are important for food prices
Kornher & Kalkuhl	2013	53 Developing Countries	GMM	There is a significant relationship between FX rates and food prices
Khatun et al	2016	Bangladesh	VECM	There is a positive relationship between FX rates and food prices
Pal & Mitra	2019	The US	DCC	Energy (crude oil) prices drive agricultural goods
Taghizadeh-Hesary et al	2019	Eight Asian Countries	Panel VAR	Energy (oil) prices have a significant effect on food prices
Xiao et al	2019	China	TVP-VAR	Economic policy uncertainty affects grain futures prices
Ertuğrul	2021	Turkey	DCC	There is a dynamic correlation between oil price and food prices
Ertuğrul & Seven	2021	Turkey	DCC-GARCH	FX rates significantly affect the growing gap between Turkish and international food prices, while oil prices reduce this gap
Letta et al	2021	India	Regression	Weather (drought) conditions increase agricultural prices by affecting production
Li & Li	2021	China	TVP-SV-VAR	Uncertainty results in a rise in food prices by reducing total imports and raising trade costs
Verbicki	2021	EU	Panel Data	FX rates do not affect food prices
Wen et al	2021	China	NARDL	Negative economic policy uncertainty shocks have a greater impact on food prices than positive shocks. Oil price shocks have an increasing effect on food prices

Note: DCC-GARCH denotes the dynamic conditional correlation generalized autoregressive conditional heteroscedasticity

In addition to the national variables explained above, we included country risk as an influencing variable because it is possible for food prices to increase when country risk increases. For instance, Arezki and Bruckner's (2011) study of panel data for 120 countries identified a positive relationship between food prices and political instability proxied by the deterioration of democratic institutions. An increase in country risk causes the deterioration of all macroeconomic indicators by negatively affecting the predictability, certainty, and riskiness of the country. Thus, food prices are expected to increase when country risk increases. We used credit default swap (CDS) spreads as a country risk indicator. In this context, we considered the 5-year USD CDS spreads of Turkey because this maturity has the highest liquidity (Kartal 2020). Table 1 presents a summary of the empirical literature on food prices.

.Nine global and national explanatory factors were included in this study following the literature review. Table 2 summarizes the variables included in the empirical analysis.

Table 2 Variables

Variables	Symbol	Description	Expected Relationship	Sources
Domestic Food Prices*	FOOD	Domestic Food Prices	N/A	CBRT (2021)
Economic Policy Uncertainty	UNCERT	US Economic Policy Uncertainty Index	+	Bloomberg (2021)
Volatility Index	VIX	CBOE Volatility Index	+	Bloomberg (2021)
Oil Price	OIL	Brent Crude Oil Price (USD per Barrel)	+	Bloomberg (2021)
Fertilizer Price	FERTILIZER	Fertilizer Price Index	+	WB (2021)
Raw Material Price	RAW	Raw Material Price Index	+	WB (2021)
Temperature	TEMPERATURE	Global Temperature Change	+	Berkeley (2021)
FX Rate	USD/TRY	USD/TRY FX Rates	+	Bloomberg (2021)
Interest Rate	INTEREST	TRY Denominated Credit Interest Rates	+	CBRT (2021)
Country Risk	CDS	Turkey 5-Year USD CDS Spreads	+	Bloomberg (2021)

* Denotes the dependent variable

Evaluation of literature

As can be seen from the literature review, various studies have addressed food prices considering various explanatory variables that were grouped as either global or national. The explanatory variables included in this study mainly affect food prices through different channels, such as production amount (economic policy uncertainty, oil price, fertilizer price, raw material price, and temperature) and price shocks (FX rates, interest rates, and country risk). While some of these variables, such as temperature and exchange rates, may have long-term effects, others, such as oil and fertilizer prices, may have short-term effects on food prices if they fall again after a while.

Moreover, different econometric methods such as ARDL, causality (Granger, TY), DCC, DOLS, ECM, GARCH, GMM, NARDL, regression (OLS), panel VAR, TVP-VAR, TVP-SV-VAR, and VECM were applied to examine food prices in these studies. In addition, some recent studies have applied group decision-making, TRIZ-based problem solving, and machine k-means algorithms (e.g., Zhang et al. 2019; Li et al. 2021; Kou et al. 2022). However, novel nonlinear approaches can still be used in new studies to contribute to the literature, because few studies have employed nonlinear methods to examine food prices. Moreover, to the best of our knowledge, no study has focused on food prices in Turkey as an example of a developing country by including a variety of global and national explanatory variables and employing such novel nonlinear time series econometric approaches.

The literature review shows that although there is rich literature on food prices, there is still a gap in the literature as the relationship between food prices and explanatory variables has not been examined at different times, frequencies, and quantiles in a single study. Accordingly, emerging countries that are outliers, such as Turkey, where domestic food prices have recently been increasing, can be examined. Thus, this study uncovered the effects of selected global and national explanatory variables on domestic food prices by focusing on Turkey and employing novel nonlinear approaches to test the following hypotheses developed by considering theories and studies in the current literature:

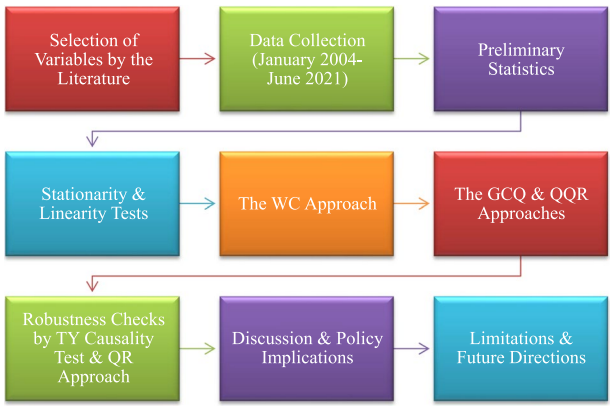

Fig. 2 Methodology followed in the study

Hypothesis 1: There is a positive relationship between food prices and explanatory (global and national) variables.

Hypothesis 2: The relationship between food prices and explanatory (global and national) variables is a causal one.

Hypothesis 3: The relationship between food prices and explanatory (global and national) variables changes according to different times, frequencies, and quantiles.

Hence, this new study fills a gap in the literature by uncovering the relationship between food prices and explanatory variables at different times, frequencies, and quantiles. Moreover, the results of this study provide policy implications for Turkey and other emerging countries.

Data and methodology

Data

This study covers the period from January 2004 to June 2021 because a national crisis occurred in 2000 and 2001, and its negative effects continued in 2002 and 2003. Hence, the data cover the period from the beginning of 2004, which can be considered a relatively normal year.

Data on domestic food prices and interest rate variables were collected from the CBRT (2021). Data for the economic policy uncertainty index, volatility index, oil prices, USD/TRY FX rates, and CDS spread variables were collected from Bloomberg (2021). Data for the temperature variable were collected from Berkeley (2021). Data for the raw material price index and fertilizer price index variables were collected from the WB (2021). In this study, monthly data for the variables were considered because domestic food prices in Turkey are published monthly.[1]

Methodology

Figure 2 illustrates the methodology used in this study.

[1] Data will be made available on request.

In the context of empirical analysis, the following methodology was applied:

- In the first and second steps of this study, the dataset was determined, and data were collected based on the literature.
- In the third step, preliminary statistics were given and interpreted.
- In the fourth step, stationarity tests were applied to the variables to examine the unit root test. In this context, the Augmented Dickey-Fuller (ADF) test and Philip & Perron (PP) test were performed (Dickey & Fuller 1979; PP, 1988). Besides, the linearity conditions of the variables were investigated. In this context, the BDS test was performed (Broock et al. 1996).
- In the fifth step, the WC approach was applied. The WC approach captures the relationship between variables considering both times and frequencies in the fifth step (Goupillaud et al. 1984; Torrence & Compo 1998).
- In the sixth step, the GCQ and QQR approaches were performed to investigate the relationship between the variables at various quantiles (Sim et al., 2015; Troster 2018).
- In the seventh step, the TY causality test (Toda & Yamamoto 1995) and QR approach were performed to check the robustness of the WC and QQR results, respectively (Koenker 2005).
- Finally, a discussion and policy implications are presented. Moreover, limitations and future directions for research are discussed.

When variables have nonlinear characteristics, nonlinear techniques should be applied (Kirikkaleli 2021; Kartal et al. 2022). The main advantages of nonlinear techniques are that they do not have any presumptions and require that all variables be stationary in the same order (Torrence & Compo 1998; Kartal et al. 2021). By considering the data characteristics of the variables, including stationarity and linearity conditions, nonlinear time-series econometric models, namely, the WC, GCQ, and QQR, were applied, and the TY causality test and QR approach were used for robustness checks. In line with the current literature, domestic food prices were considered as a dependent variable, and nine global and national factors were used as explanatory variables. Following the methodology explained, the following main empirical model was used:

$$\begin{aligned} FOOD = {} & \alpha + \beta_1 UNCERT_t + \beta_2 VIX_t + \beta_3 OIL_t \\ & + \beta_4 FERTILIZER_t + \beta_5 RAW_t + \beta_6 TEMPERATURE_t \\ & + \beta_7 USD/TRY_t + \beta_8 INTEREST_t + \beta_9 CDS_t + \varepsilon_t \end{aligned} \tag{1}$$

where α, *FOOD*, *UNCERT*, *VIX*, *OIL*, *FERTILIZER*, *RAW*, *TEMPERATURE*, *USD/TRY*, *INTEREST*, *CDS*, ε, and t denote intercept, domestic food prices, economic policy uncertainty index, volatility index, crude oil price, fertilizer price index, raw material price index, global temperature change, USD/TRY FX rates, TRY denominated credit interest rates, Turkey 5-Year USD CDS spreads, error-term, and time, respectively.

In line with the current literature, when other conditions remain stable, an increase in *UNCERT* causes an increase in FOOD ($\beta_1 = \frac{\partial CO_2}{\partial UNCERT} > 0$); an increase in *VIX* causes an increase in FOOD ($\beta_2 = \frac{\partial CO_2}{\partial VIX} > 0$); an increase in *OIL* causes an increase in FOOD ($\beta_3 = \frac{\partial CO_2}{\partial OIL} > 0$); an increase in *FERTILIZER* causes an increase in FOOD

($\beta_4 = \frac{\partial CO_2}{\partial FERTILIZER} > 0$); an increase in *RAW* causes an increase in FOOD ($\beta_5 = \frac{\partial CO_2}{\partial RAW} > 0$); an increase in *TEMPERATURE* causes an increase in FOOD ($\beta_6 = \frac{\partial CO_2}{\partial TEMPERATURE} > 0$); an increase in *USD/TRY* causes an increase in FOOD ($\beta_7 = \frac{\partial CO_2}{\partial USD/TRY} > 0$); an increase in *INTEREST* causes an increase in FOOD ($\beta_8 = \frac{\partial CO_2}{\partial INTEREST} > 0$); an increase in *CDS* causes an increase in FOOD ($\beta_9 = \frac{\partial CO_2}{\partial CDS} > 0$).

The empirical methods used were not explained in detail to avoid unnecessarily extending the article because this study is not mainly an econometric model development article. Rather, econometric approaches were used to examine the asymmetric relationship between global and national factors and domestic food prices. Hence, more information could be obtained from the original studies of Dickey and Fuller (1979) for the ADF unit root test, Philip and Perron (1988) for the PP unit root test, Broock et al. (1996) for the BDS test, Goupillaud et al. (1984) and Torrence and Compo (1998) for the WC approach, Sim et al. (2015) for the QQR approach, Troster (2018) for the GCQ approach, Toda and Yamamoto (1995) for the TY causality test, and Koenker (2005) for QR.

Empirical analysis

Preliminary statistics

Table 3 summarizes the descriptive statistics of the study variables.

Stationarity and linearity tests

After examining the preliminary statistics of the variables, their stationarity was examined in the context of empirical analysis. Table 4 presents the results of ADF and PP unit root tests.

The ADF test results in Table 4 show that UNCERT, VIX, INTEREST, and CDS are stationary at I(0), and FOOD, OIL, RAW, FERTILIZER, TEMPERATURE, and USD/TRY are stationary at I(1) in Turkey. The PP test yielded similar results.

A linearity test was performed to determine the characteristics of the variables used in the analysis. Table 5 presents the linearity test results.

The results of the Jarque–Bera normality and BDS linearity tests show that there is no significant evidence to accept the null hypothesis, which means that the variables do not meet the normality and linearity assumptions. Therefore, it was decided to perform nonlinear statistical approaches, namely, WC, GCQ, and QQ. In addition, the TY causality test and QR approach were used for robustness checks.

The WC results

The WC approach was evaluated according to the preliminary analyses, which were linearity and normality analyses of variables used in the study, to reveal the bi-directional relationship between domestic food prices and the related variables considering the times and frequencies. The results of this approach are shown in Fig. 3.

Similar to the studies by Xiao et al. (2019), Li and Li (2021), and Wen et al. (2021), a significant relationship between domestic food prices and other variables in different periods was determined in this study using the WC approach. More specifically, FOOD affected UNCERT positively for a very long time until the first quarter of 2012, whereas UNCERT affected FOOD positively for both the long and short terms

Table 3 Descriptive Statistics

Variables	Food	Uncert	Vix	Oil	Raw	Fertilizer	Temperature	Usd/ try	Interest	Cds
Units	%	Point	Point	USD	Point	Point	Degree	Point	%	Point
Mean	11.120	119.506	19.076	72.850	84.996	96.970	0.795	2.776	16.533	261.824
Minimum	0.577	18.150	9.510	22.740	58.382	42.304	0.267	1.164	8.415	117.809
Maximum	33.225	626.030	59.890	139.830	134.555	256.055	1.331	8.708	34.480	593.625
SD	5.801	89.217	8.517	25.769	14.550	37.833	0.193	1.919	5.353	107.272
CV	52%	75%	45%	35%	17%	39%	24%	69%	32%	41%
JB	125.415	898.191	377.889	12.828	46.522	208.857	4.802	86.308	20.999	60.772
JB Prob	0.000	0.000	0.000	0.002	0.000	0.000	0.091	0.000	0.000	0.000
Observations	210	210	210	210	210	210	210	210	210	210

CV denotes the coefficient of variation; JB denotes Jarque–Bera; Prob. Denotes the probability; SD denotes the standard deviation. The average value of FOOD was 11% with a standard deviation of 5.801. Based on Jarque–Bera test statistics, the variable FOOD does not meet the normality assumption. In addition, none of the variables used in the analysis, except TEMPERATURE, met the assumption of normality. When the coefficient of variation statistics was examined, it was observed that the volatilities of the UNCERT and USD/TRY variables were relatively higher (also higher than 50%) than those of the others. However, the volatilities of RAW and TEMPERATURE were lower than those of the others

Table 4 Stationarity test results

Variables	ADF Test		PP Test		Results
	I(0)	I(1)	I(0)	I(1)	
FOOD	0.4130	0.0000	0.0078	0.0000	I(1)
UNCERT	0.0000		0.0000		I(0)
VIX	0.0048		0.0002		I(0)
OIL	0.0552	0.0000	0.0880	0.0000	I(1)
RAW	0.1644	0.0000	0.2428	0.0000	I(1)
FERTILIZER	0.0899	0.0000	0.1067	0.0000	I(1)
TEMPERATURE	0.0696	0.0000	0.0005	0.0000	I(0)
USD/TRY	1.0000	0.0000	1.0000	0.0000	I(1)
INTEREST	0.0316		0.0375		I(0)
CDS	0.0109		0.0109		I(0)

Lag length is automatically selected based on Akaike information criterion in the ADF test and Bartlett kernel in the PP test. The figures in the table show the probability values

Table 5 Linearity Test Results

Variables	Dimensions				
	2	3	4	5	6
FOOD	0.0000	0.0000	0.0000	0.0000	0.0000
UNCERT	0.0000	0.0000	0.0000	0.0000	0.0000
VIX	0.0000	0.0000	0.0000	0.0000	0.0000
OIL	0.0000	0.0000	0.0000	0.0000	0.0000
RAW	0.0000	0.0000	0.0000	0.0000	0.0000
FERTILIZER	0.0000	0.0000	0.0000	0.0000	0.0000
TEMPERATURE	0.0000	0.0000	0.0000	0.0000	0.0000
USD/TRY	0.0000	0.0000	0.0000	0.0000	0.0000
INTEREST	0.0000	0.0000	0.0000	0.0000	0.0000
CDS	0.0000	0.0000	0.0000	0.0000	0.0000

Values denote the *p*-values. The null hypothesis is that a variable is linearly distributed

after the first half of 2015. By contrast, UNCERT negatively affected FOOD for a long term after the beginning of 2004. In addition, the analysis of the bidirectional effect between FOOD and VIX and RAW shows that VIX and RAW negatively affected FOOD for a short term from 2010 to 2013. This relationship was reported in a study by Makena (2020).

Unlike the relationship between FOOD and RAW, there was a significant negative relationship between FOOD and VIX over the long term, beginning in 2004. During this period, VIX affected FOOD negatively. In summary, because an increase in raw material prices and volatility has a negative impact on predictability and certainty, which affects the costs of agricultural crops and investments, food prices increase.

When the relationship between FOOD and OIL was examined, it was observed that FOOD negatively affected OIL for a short period of time in 2016. This relationship was determined in the opposite direction by Pal and Mitra (2019). However, in the long term, similar results were obtained by Osman et al. (2019), Pal and Mitra (2019), Makena (2020), and Wen et al. (2021).

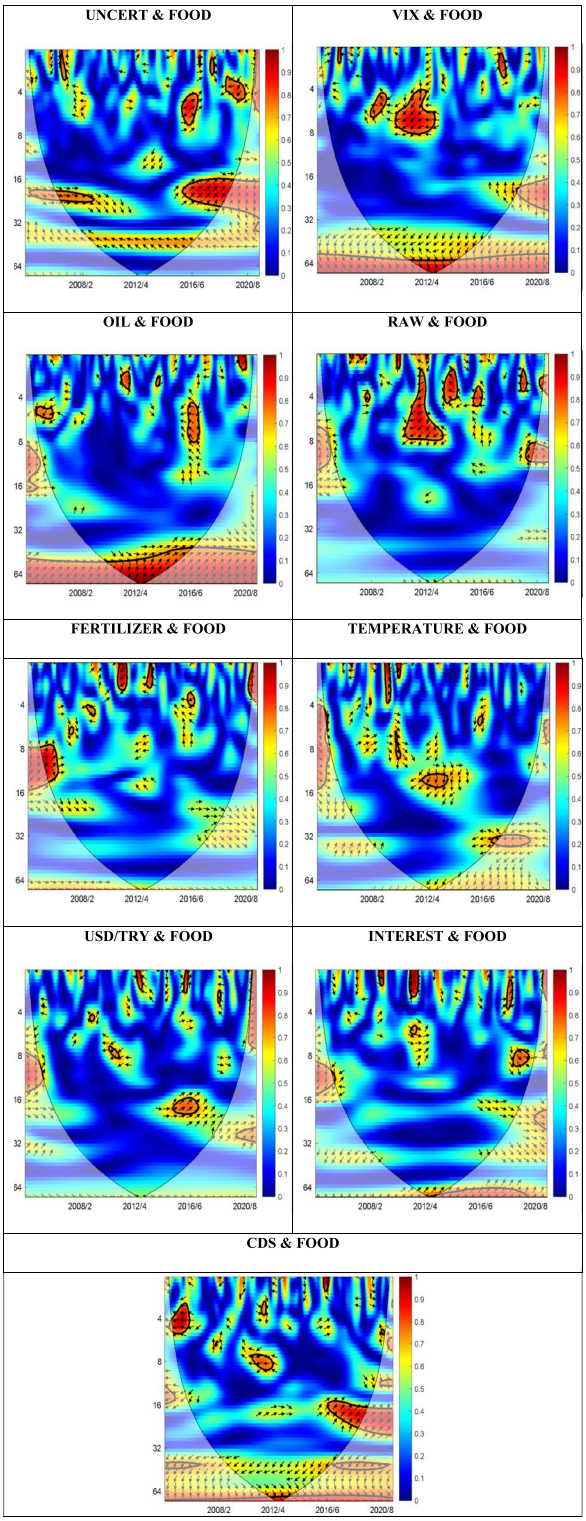

Fig. 3 The WC Results. Notes: The vertical axis shows the frequencies, while the horizontal axis shows time. The black cone shows the influence area. The warmer colors show a higher degree of dependence between the two variables. 0–8 scale shows short term, 8–16 scale shows medium-term, 16–32 scale shows long-term, and 32–64 scale shows very long term. 0–0.4 shows low-frequency, 0.4–0.6 shows medium-frequency, 0.6–1.0 shows high-frequency. Left arrows show a negative correlation while right arrows show a positive correlation. Right-down and left-up arrows show that the first variable causes the second variable. Also, right-up and left-down arrows show that the second variable causes the first variable

The bidirectional relationship of FOOD versus USD/TRY shows that USD/TRY affected FOOD negatively in the short term from 2010 to 2012. However, this effect turned positive in the long term after 2012; these results were given in the studies by Kornher and Kalkuhl (2013), Khatun et al. (2016), and Makena (2020) as well. Consequently, as expected, an increase in FX rates causes an increase in agricultural production costs by affecting the prices of imported components used in agriculture such as raw materials and oil. In both the short and long terms, FOOD affected INTEREST positively.

Analysis of the relationship between TEMPERATURE and FOOD revealed that TEMPERATURE significantly affected FOOD after 2008. This finding has been emphasized by different researchers in the literature (Schnepf 2008; Letta et al. 2021). However, this significant interaction changed from short-to long-term effects from 2008 to 2020. As a result, it can be said that deteriorating climatic conditions cause an increase in food prices, decreasing the productivity of crops and hence increasing the costs of crops per unit. Unlike the relationship between TEMPERATURE and FOOD, contrary to the literature (Mitchell 2008; Ott 2012), FOOD affected FERTILIZER over the long term.

The relationship between CDS and FOOD is more complex than that between FOOD and the other variables. In contrast to Arezki and Bruckner (2011), there is a negative correlation between FOOD and CDS, and FOOD affected CDS in the short-term before mid-2012. However, after 2012, CDS positively affected FOOD in the long term. This effect was especially strong after 2017. Additionally, in the very long term, CDS negatively affected FOOD from 2004 to 2020.

The GCQ and QQR results

The analysis of the bilateral interaction between FOOD and other relevant variables shows a significant bidirectional effect between the variables. Causality was measured in quantiles using the GCQ approach to understand which quantiles had a significant effect. Table 6 presents the results of the GCQ approach.

Based on Table 6, the Granger causality from the independent variables to domestic food prices is statistically significant at the 5% level of significance, except for the 0.05, 0.35, 0.45, 0.50, 0.55, and 0.95 quantiles. This result means that the causal relationship between the relevant independent variables and food prices is significant, except for the highest, lowest, and middle quantiles (from 0.45 to 0.55 quantiles).

The GCQ results imply that global and national factors have an important effect on domestic food prices at all levels, except for the highest, lowest, and middle levels. The findings of the GCQ approach are consistent with the results of Xiao et al. (2019) and Li and Li (2021) for economic uncertainty, Kirikkaleli and Darbaz (2021) and Wen et al. (2021) for oil prices, Mitchell (2008) for fertilizer prices, Letta et al. (2021) for temperature changes, Makena (2020) for raw material prices, Demeke and Tenaw (2021) for FX rates, Kara (2017) for interest rates, and Arezki and Bruckner (2011) for country risk.

After applying the GCQ approach, the QQR approach was applied to determine the relationship between the relevant study variables and food prices at different quantiles. This relationship is illustrated in Fig. 4. In the figures, the x- and y-axes represent the tth quantile coefficient of food prices and the qth quantile coefficient of the relevant variables.

Table 6 The GCQ Results

Causality path	Quantiles																		
	0.05	**0.10**	**0.15**	**0.20**	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**	**0.80**	**0.85**	**0.90**	**0.95**
UNCERT FOOD	0.17	0.01	0.01	0.01	0.01	0.01	0.09	0.02	0.22	0.60	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.29
VIX FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.10	0.01	0.28	0.67	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.29
OIL FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.13	0.01	0.32	0.64	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
RAW FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.09	0.01	0.26	0.66	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
FERTILIZER FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.11	0.01	0.26	0.67	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
TEMPERATURE FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.11	0.01	0.25	0.70	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
USD/TRY FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.10	0.01	0.26	0.66	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
INTEREST FOOD	0.28	0.01	0.01	0.01	0.01	0.01	0.10	0.01	0.26	0.66	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28
CDS FOOD	0.30	0.01	0.01	0.01	0.01	0.01	0.12	0.01	0.31	0.77	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.28

Numbers represent the p-values. The null hypothesis is that the first (explanatory) variable does not granger cause the second (domestic food prices) variable

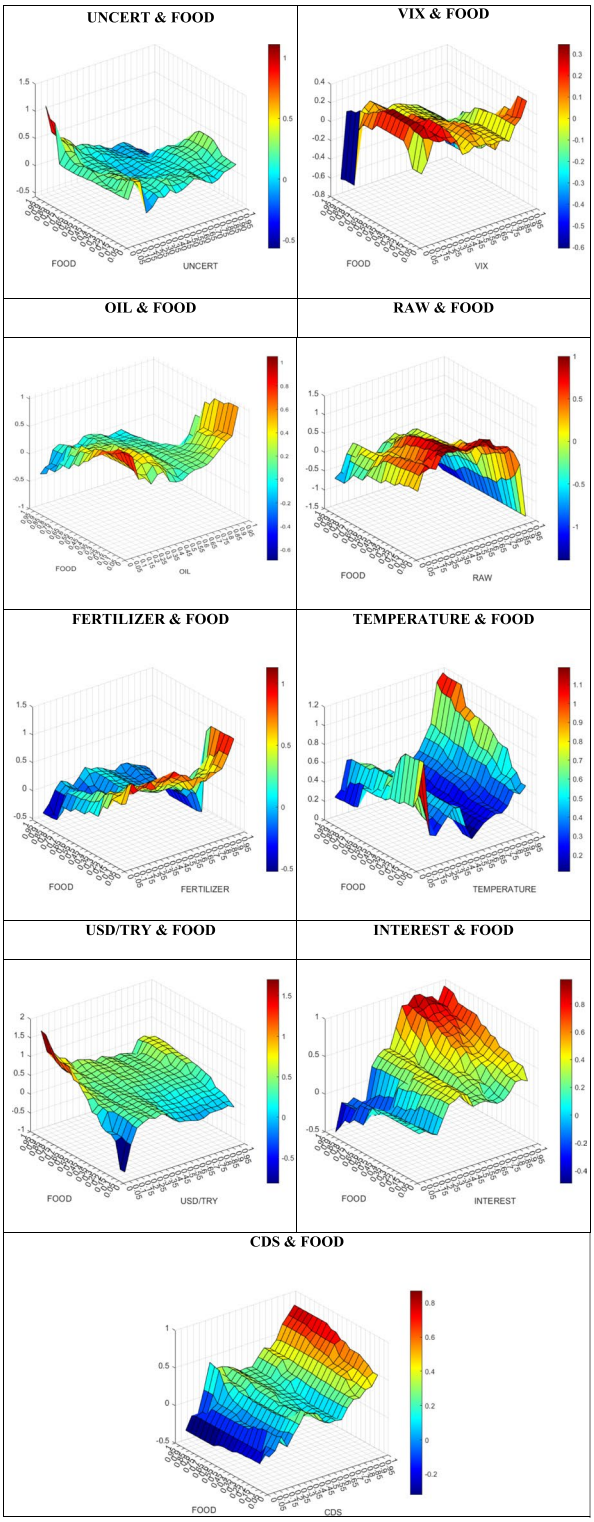

Fig. 4 The QQR results

The effect of UNCERT on FOOD is generally positive but weak in all areas, except for the area combining the highest quantile of FOOD and the lowest quantile of UNCERT. In addition, the effect of UNCERT on FOOD in the area where the quantiles are higher than 0.8 for both factors is strongly negative. Similar to the relationship between UNCERT and FOOD, the effect of VIX on FOOD is generally negative, and this effect becomes stronger from low to high quantiles.

It was ascertained that the characteristics of the effects of OIL and FERTILIZER on FOOD are quite similar, but the magnitude of the effects of these factors on FOOD is differentiated. Specifically, the negative effect of OIL on FOOD from the low to high quantiles of OIL increases in areas where the quantiles of FOOD are higher than 0.5. However, in quantiles of FOOD lower than 0.5, and in the low and high quantiles of OIL, the effect of OIL is positive and strong. It was revealed that the magnitude of the effect of FERTILIZER on FOOD was more dissociative than the relationship between OIL and FOOD.

Once the relationship between RAW and FOOD was analyzed, it was revealed that the effect of RAW on FOOD was positive, and this effect became stronger from the low to the high quantiles of RAW in each quantile of FOOD. Unlike the relationship between RAW and FOOD, the relationship between TEMPERATURE and FOOD has a "U-shape" characteristic, which means that the effect of TEMPERATURE on FOOD is strong and positive in the area with the lowest and highest quantile of TEMPERATURE, while it is weak in the middle of the quantiles.

The relationship between USD/TRY and FOOD is generally weak in all areas, except for the lower (below 0.4) and upper quantiles (above 0.6) of FOOD. On the other hand, the relationships between INTEREST and FOOD and CDS and FOOD have similar characteristics. The effect of INTEREST and CDS on FOOD increases from the low to high quantiles of INTEREST and CDS, and its effect becomes stronger up to the highest quantile.

The QQR results imply that global and national factors have a significant effect on domestic food prices in various quantiles based on each explanatory indicator. The findings of the QQR approach are consistent with the results of Wen et al. (2021) for economic uncertainty, Taghizadeh-Hesary et al. (2019) and Kirikkaleli and Darbaz (2021) for oil prices, Ott (2012) for fertilizer prices, Letta et al. (2021) for temperature changes, Makena (2020) for raw material prices, Verbicki (2021) for FX rates, Campos (2020) for interest rates, and Arezki and Bruckner (2011) for country risk.

Overall, the GCQ and QQR results reveal that global and national factors have an asymmetric and significant effect on domestic food prices. Hence, it is important that policymakers consider these findings in the policy development and implementation process regarding domestic food prices and effective factors classified into global and national.

Robustness checks

In this section, the TY causality test is first applied for robustness checks of the WC approach. Table 7 presents the results of TY causality tests.

According to the TY causality test results, there is a causal relationship between domestic food prices and the global and national explanatory variables, except for

Table 7 Robustness checks of the WC by the TY causality test

Causality Path	Estimation Degree ($k + d_{max}$)	X^2 Statistics	*p*-value	Result
UNCERT FOOD	3	3.530127	***0.0856	Causality
VIX FOOD	3	9.691675	*0.0046	Causality
OIL FOOD	3	9.360580	*0.0046	Causality
RAW FOOD	3	3.803780	***0.0746	Causality
FERTILIZER FOOD	3	2.418177	0.1482	No Causality
TEMPERATURE FOOD	3	4.940688	**0.0423	Causality
USD/TRY FOOD	3	21.992910	*0.0000	Causality
INTEREST FOOD	3	1.965224	0.1872	No Causality
CDS FOOD	3	4.279903	***0.0588	Causality

The maximum cointegration is 1. Lag length is defined as 2 based on Akaike Information Criteria. Hence the estimation degree is determined as 3. *, **, *** denote %1, %5, %10 significance, respectively

fertilizer and interest rate factors. Hence, the results of the WC and TY causality test are mainly similar.

Moreover, the coefficients of the QR and QQR results were compared to confirm the robustness of the results. A comparison of the coefficients for different quantiles of the QR and QQR approaches is shown in Fig. 5.

Based on Fig. 5, the correlation between the QR and QQR approaches is similar and statistically significant. In addition, the slope correlation coefficients for the effects of VIX, RAW, TEMPERATURE, USD/TRY, INTEREST, and CDS on FOOD are higher than 0.80.

Discussion & policy implications

Considering the objectives of this research, three hypotheses were proposed. The evaluation of these hypotheses can be summarized as follows: (i) an increase in explanatory variables causes an increase in domestic food prices; (ii) the relationship between explanatory (global and national) variables and domestic food prices is a causal one; and (iii) the relationship between explanatory variables and domestic food prices changes according to different times, frequencies, and quantiles. Specifically, there is a relationship between explanatory variables and domestic food prices in almost all quantiles, excluding the lowest quantile, some middle quantiles, and the highest quantile for some variables, when variable-based results change. Hence, it can be concluded that the results of the novel nonlinear approaches validate the hypotheses. The outcomes gathered from the nonlinear approaches are generally consistent with our expectations and the results of current studies (e.g., Campos 2020; Kirikkaleli & Darbaz 2021; Letta et al. 2021; Wen et al. 2021; Verbicki 2021).

In line with the results of the empirical examination, policymakers in Turkey should consider global and national explanatory variables in their policy development and implementation process. Thus, Turkey can benefit from stable domestic food prices, especially in terms of the course of inflation, because food prices constitute a relatively high proportion of the inflation basket (25.94%) (TSI 2021). Furthermore, other emerging countries can benefit from Turkey by considering the empirical results obtained and the policy implications proposed in their policy development processes.

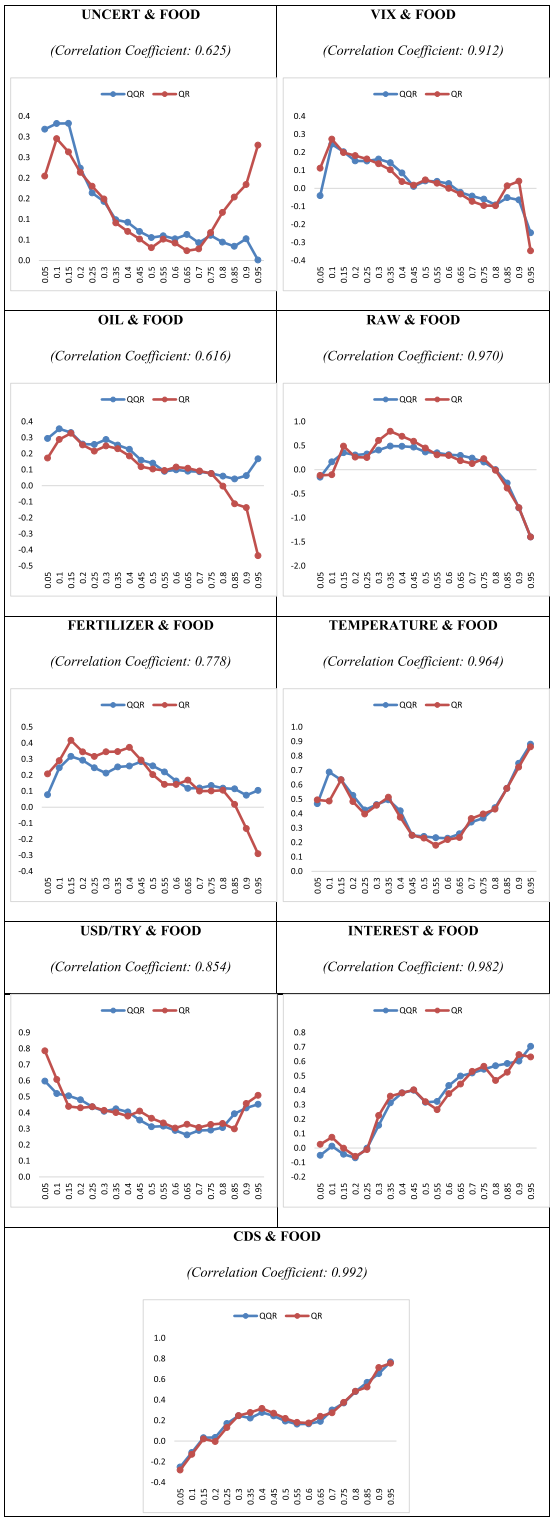

Fig. 5 Robustness checks of the QQR by the QR

Based on the results of the empirical examination, some policy proposals are recommended. The main issue is that Turkey should first deal with factors that are both national and highly influential on domestic food prices because national factors can mostly be kept under control. Turkey should focus on how food prices are handled. Therefore, it is highly recommended that Turkey considers developments in domestic food prices as a macro-prudential concern and manage them at the top level in terms of country management.

Second, Turkey must deal with CDS spreads. By implementing necessary measures such as structural reform, Turkey can reduce the country risk that arises in economic, political, and financial areas. Thus, the adverse effects of country risk on domestic food prices can be eliminated. Moreover, reduced country risk contributes positively to the stability of FX rates, inflation, and interest rates.

Third, Turkey can focus on dealing with other national factors such as interest rates and FX rates. If Turkey can reduce its country risk, foreign (portfolio and direct) investments will increase. In such cases, stability of FX rates can also be achieved. By stabilizing country risk and FX rates, Turkey can lower food prices, inflation, and interest rates. Hence, it can be argued that positive developments in country risk, FX rates, and interest rates maintain the stability of food prices and control inflation.

Fourth, fertilizer prices, especially in the high quantiles, significantly affect domestic food prices. Turkey should therefore consider producing organic fertilizers and increasing domestic fertilizers during the food production process. This way, Turkey may be less affected by international developments in fertilizer prices.

Fifth, raw-material prices also significantly affect domestic food prices. In addition to fertilizers, Turkey should consider domestic production of raw materials to be used in food production to minimize the impact of negative developments in international raw material prices.

Sixth, considering the negative effects of global warming, proxied by temperature change in this study, it is crucial to make efforts to limit greenhouse gas emissions. In this context, climate agreements, such as the Kyoto Protocol and Paris Climate Agreement, could be highly effective. Therefore, participation in and implementation of such climate agreements are very important, and Turkey's participation in the Paris Agreement is highly appreciated. It is expected that the necessary rules will be implemented such that global warming can be limited by the efforts of Turkey and other countries.

Seventh, Turkey must consider uncertainty and volatility. Turkey does not have much power in terms of international uncertainty and volatility. However, Turkey can reduce the uncertainty and volatility arising from domestic issues.

Finally, although consistent, different econometric models, such as the WC, GCQ, and QQR approaches, provide different information about the effects of explanatory variables on domestic food prices. Therefore, it is highly recommended to apply multiple methods to analyze data for use in policy development and implementation processes. Hence, more detailed information can be obtained from different models and more comprehensive policies can be developed.

The development and timely implementation of appropriate policies considering the economic structure and realities of the country can contribute to achieving stable domestic food prices in Turkey by mitigating the adverse effects of the explanatory

variables. Naturally, other emerging countries can benefit from the case of Turkey as well as the findings and recommendations of this study.

Conclusion

This study examined the effects of global and national factors on domestic food prices in Turkey by applying novel nonlinear time-series econometric models. For this purpose, a total of nine variables were included and the most probable monthly data between January 2004 and June 2021 were used. A comprehensive examination was performed to investigate the effects of explanatory variables on domestic food prices in Turkey at different times, frequencies, and quantiles.

The results of the empirical analysis show that there is a relationship between domestic food prices and explanatory variables at different times and frequencies in most quantiles, excluding the lowest quantile, some middle quantiles, and the highest quantile for some variables; the power of the effect of explanatory variables on domestic food price changes according to the quantiles. In addition, the results of the TY causality test and the QR approach confirm the robustness of the study findings, which are generally consistent with pre-expectations and current literature. To the best of our knowledge, this is the first study to use WC, GCQ, and QQR approaches to analyze domestic food prices in Turkey.

The results highlight the effects of fluctuations in global and national variables on domestic food prices. Based on the empirical results obtained from the novel nonlinear time series econometric models, this study discusses the following policy implications: focusing primarily on domestic factors; positioning food prices as a macro-prudential concern due to their impact on macroeconomic indicators, such as inflation and interest rates; and reducing country risk so that FX rates can be stabilized by encouraging foreign investment inflows and implementing the Paris Agreement. Naturally, Turkey's economic realities and structure should be considered in policy development and implementation. This is also an important point for other emerging countries that would like to benefit from Turkey's experience as well as the findings and recommendations of this study because each country has its own specific characteristics that must be considered. Hence, this study aims to contribute to the development and implementation of policies in Turkey, as well as other emerging countries, to ensure domestic food price stability.

Although this study contributes to the extant literature in many ways, it also has some limitations. This study focuses solely on Turkey. Accordingly, other emerging and developed countries that face increasing domestic food prices can be included in new studies. Moreover, like the studies of Zhang et al. (2019), Li et al. (2021), and Kou et al. (2022), future studies can apply other statistical and econometric techniques, such as group decision-making, TRIZ-based problem solving, deep learning, and machine learning algorithms (i.e., k-means).

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Author contributions
MTK: The design of the study, Conceptualization, Investigation, Methodology, Data collection, Econometric Analysis, Writing—review & editing; ÖD: Conceptualization, Methodology, Data collection, Econometric Analysis, Writing—review & editing. Both authors read and approved by the final manuscript.

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Availability of data and materials
The data that support the findings of this study are available in Bloomberg Terminal, in the Central Bank of the Republic of Turkey at https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket., and in World Bank Commodity Prices at https://www.worldbank.org/en/research/commodity-markets.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
The authors are willing to permit the Journal to publish the article.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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