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ORIGINAL ARTICLE

The Impact of Fruit Production and Trade on Global Climate Change: The Case of EU-27 Countries

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Abstract
Global climate change is a crucial issue of the third millennium. The discussion of food security and access risks has become widespread worldwide. Countries are developing policies and making agreements at the regional and global levels. Agricultural production is one of the many sectors affected by global climate change. The agricultural sector contributes to CO2 emissions through tillage, fertilizer and pesticide use, agricultural waste, and transportation. Fruit growing is one area where these factors are used intensively. The production and foreign trade of these products using intensive agricultural methods contribute to annual temperature increases on Earth. This study analyzes the impact of total fruit production, imports, and exports on annual temperature changes in EU-27 countries between 2000 and 2021 using advanced econometric models. The results indicate that both total fruit production and imports contribute to annual temperature increases. Policies at the local, national, and international levels should be reorganized to consider the impact of global climate change on production and transportation systems.

Keywords Fruit Production · Fruit Foreign Trade · EU-27 · Global Warming · Climate Change

Introduction

CO_2 emissions increased from an annual average of 280 ppm (parts per million) in the late 1700s, when the industrial revolution began, to 401 ppm in 2019. Therefore, the global temperature increase in the same period was approximately 1.5 °C (EPA 2021). Energy input from fossil fuels increases the emission of CO_2 and other greenhouse gases (Yılmazer and Karabiber 2022). While the CO_2 emissions created on a global scale were 9413 megatons in 1960, they increased approximately fourfold to 36,441 megatons in 2019. Since the Industrial Revolution, developed countries are currently considered the most important countries responsible for CO_2 emissions. However, since 1990, the emissions of rapidly industrializing developing countries with high energy consumption have tripled (Global Carbon Atlas 2021). The first signs of global climate change are increases in precipitation regimes and average temperatures. These changes, such as floods, storms and droughts, can cause serious economic damage in both the short and long term. One of the most important causes of climate change is the intensive consumption of fossil fuels in parallel with the increasing world population. Fossil fuels such as coal, natural gas and oil are increasingly consumed every year to meet the demands of people (Bal et al. 2017). The process of global climate change is caused by increasing greenhouse gases in the atmosphere. Emissions consist of major gases such as CO_2, CH_4, N_2O and F. These gases formed entirely anthropogenicly. Anthropogenic emissions are emitted to the atmosphere through various sectors. These include industry, transport, agriculture, energy, electricity and heat generation, industrial processes and waste. Among these emission sources, N_2O is a gas whose effect on global warming is 265 times stronger than that of CO_2 (IPCC 2013). Globally, 40% of total N_2O emissions are caused by human activities (IPCC 2021), and agricultural activities, land use, transport, and industry are important emitters (EPA-United States Environmental Protection Agency 2023). Agricultural activities are considered important factors in N_2O formation. Figure 1 shows that

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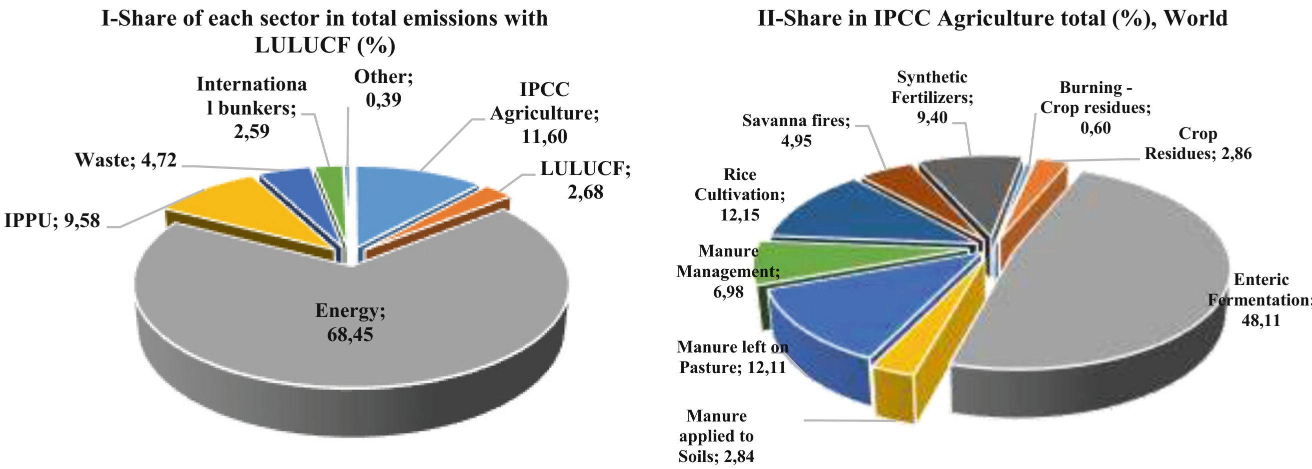

Fig. 1 Share of sectors in total GHG emissions (I) (%) and share of agricultural activities in climate change (II) (%) (FAO 2023a)

11.60% of the total greenhouse gas emissions among the sectors are caused by the agricultural sector, and more than 30% of the emission sources in the agricultural sector are centered on crop production.

Crop production activities in agriculture can be expressed as a process that covers all activities that are planted, grown and harvested using horticultural methods. As of 2022, fruit production was carried out on 5,368,242 ha, and 65,917,611 t of fruit were produced in EU-27 countries (FAO 2023b). When the contribution of crop production to emission emissions within agricultural activities is considered in this framework, factors such as the use of fuel-powered farm equipment, pumping water for irrigation, the use of nitrogen-rich fertilizers (Okumuş 2020), soil cultivation, chemical fertilizer use, pesticide use, transport and product waste explain the high greenhouse gas emissions caused by agriculture. In general, emission increases in the world peaked in 2019 with the combined impact of all sectors. Therefore, at the end of 2019, the European Commission developed the European Green Deal as an EU climate action plan and declared a zero carbon target by 2050. While setting this target, a comprehensive assessment of the gains and risks has been proposed in various studies (Catuti et al. 2020). This agreement is designed to take into account the welfare of all living beings as a human-oriented action of the EU. The zero carbon target by 2050 is seen as important in terms of making the world a more livable area. The agreement, which focuses on fairer, livable, transparent, cleaner production processes, covers all sectors, but also includes important regulations, especially in the agricultural sector. It is considered very important to determine the emissions in terms of production branches and to develop policies to be implemented for them (European Commission 2019). In terms of enterprise typologies in the agricultural sector, fruit production is one of the most important areas where intensive agriculture is intensive and accordingly, emission increases are observed. Fruit production processes can also be considered an important part of climate change processes because of their contributions to greenhouse gas emissions and annual temperature changes since they are considered to occur within intensive agricultural systems and involve input-intensive processes.

On the other hand, world trade in agricultural products has grown remarkably in the last few decades (FAO 2022). Agricultural products ranked first in world merchandise exports, with an average annual increase of 2.2% between 2010 and 2022 (WTO 2022). Agricultural trade has indirect environmental impacts on climate change. The increase in export products leads to deforestation and soil erosion with the opening of new production areas and creates the problem of energy use and emissions associated with transport (Harris 2004). Good transport can be associated with cross-border pollution and the relocation of manufacturing industries. Agricultural trade also has various environmental impacts, such as the intensification of food production, deforestation, soil degradation and the displacement of local farmers (Balogh and Jámbor 2020). The increase in agricultural production triggered by the expansion of trade and the increase in exports and imports caused by the increase in agricultural production are among the important causes of global pollution and loss of biodiversity (Balogh and Jámbor 2020). Among the world countries, EU-27 countries are in the category of developed countries. There are areas where agricultural production is intensive and where fruit growing activities and trade are carried out. The annual temperature change, total fruit production, total fruit imports and total fruit exports in the EU-27 countries between 2000 and 2021 are shown in Fig. 2.

Figure 2 shows that total fruit production decreased by 9.58%, total fruit exports increased by 59.62% and total fruit imports increased by 52.09% between 2000 and 2021.

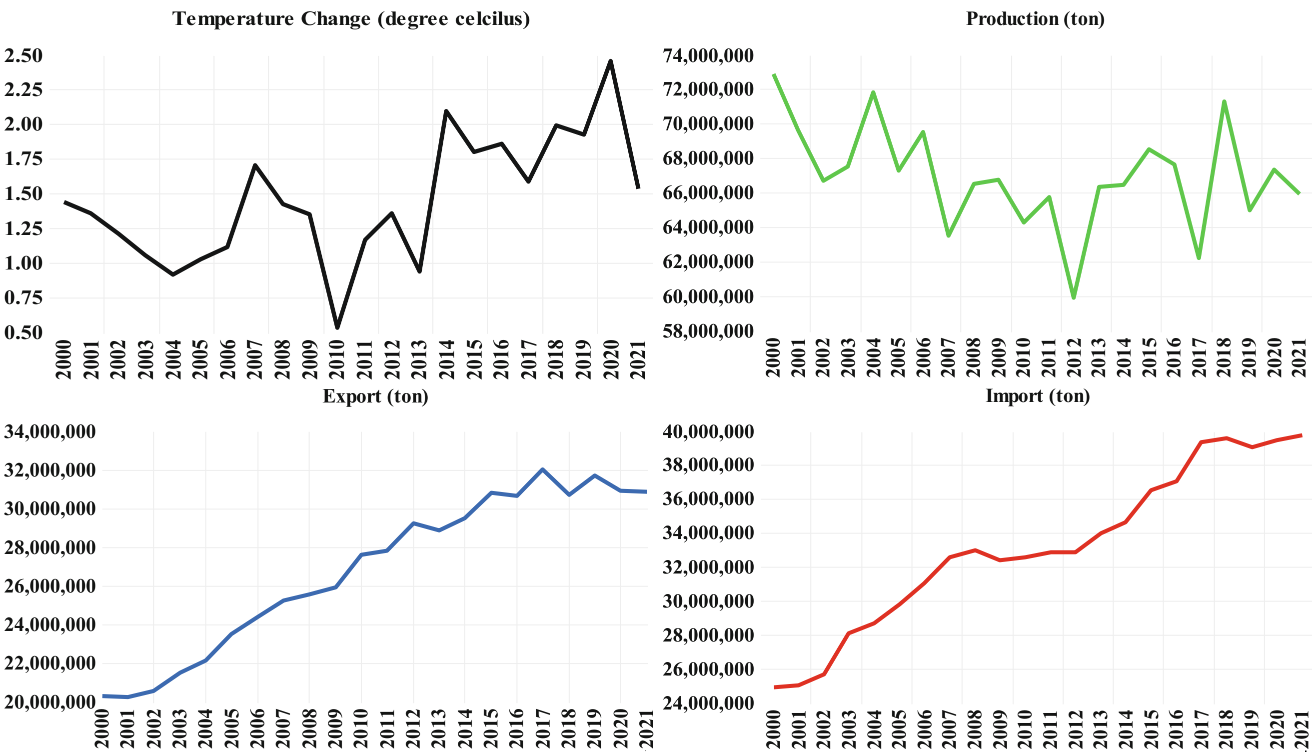

Fig. 2 Annual temperature change, total fruit production, total fruit imports and total fruit exports of EU-27 countries between 2000 and 2021 (FAO 2023b)

As can be understood from this, it can be stated that there are significant increases in foreign trade in fruit production contrary to the decrease in production. On the other hand, the annual average temperature increase was determined to be 1.45 °C during the study period. In this study, the effects of the fruit growing sector, which is considered important for agricultural production due to its production amount, cultivation area and foreign trade, on climate change within the scope of the EU-27 were investigated. Since the climate change process is an issue that concerns the whole world, it should be handled and analyzed meticulously in all aspects. European Union countries play an important role in climate change processes since they are among the most developed countries in terms of intensive production processes and economic performance. Climate change relations, which are mostly handled on the basis of sectors in the literature, may be insufficient for developing detailed policies. For this reason, it is important to analyze the fruit growing sector within the agricultural sector.

Materials and Methods

The research covers the period between 2000 and 2021 for the EU-27 countries. The annual temperature change, total fruit production amount, total fruit export amount and total fruit import amount for the region analyzed are given in Table 1.

Time series were created in light of the information obtained from the data source. For the series in the data set to have the possibility of calculation and interpretation, they were transformed into full logarithmic form. The following equation was utilized for the annual temperature change and the variables assumed to affect it and is expressed in Table 1:

$$ln\Lambda = f(lnP, ln\mathcal{E}, lnT) \quad (1)$$

Based on the functional relationship in Eq. 1, the following advanced econometric analyses were used in this study to determine the effect of the total amount of fruit produc-

Table 1 Variables, symbols and data sources used in the study

Variable	Symbol	Unit Data	Source
Annual temperature change	⅄	°C	FAOSTAT
Total fruit production	P	Ton	FAOSTAT
Total amount of fruit exports	$\mathcal{E}$	Ton	FAOSTAT
Total amount of fruit imports	T	Ton	FAOSTAT

tion, total amount of fruit exports and total amount of fruit imports on the change in average annual temperature in EU-27 countries.

- Unit root test (ADF)
- Johensen Cointegration test
- Full modified ordinary least squares (FMOLS) method
- Canonical Cointegrating Regression (CCR)

Unit Root Test

An ADF unit root test was conducted in this study. A unit root test is applied to analyze the stationarity of the series. Stationarity is investigated to prevent the problem of spurious regression that may arise because the series are affected by past values due to the trend effect or other reasons in the long run and, accordingly, to prevent the emergence of biased results. Many theories have been proposed for unit root testing (Fisher 1932; Maddala and Shaowen 1999; Kao and Chiang 2000; Hadri 2000; Choi 2001; Levin et al. 2002; Im et al. 2003). Most of these theories are based on the Augmented Dickey-Fuller (ADF) unit root test. In this study, the ADF test statistic is used for the unit root test. The notation for the ADF unit root test can be expressed as follows:

$$\Delta X_t = \beta_0 + \beta_1 t + \beta_i X_{t-1} + \sum_{j=1}^{n} \theta_i \Delta X_{t-j} + e_t \tag{2}$$

The results of the ADF test statistic are tested with the Mac Kinnon critical value (MacKinnon 1996). The stationary series are then tested with the Johansen cointegration test, FMOLS test and CCR test.

Johensen Cointegration Test

The Johansen Cointegration Test (JCT) is a test applied to determine whether a series moves together in the long run. The notation for the JCT test is given in Eq. 3:

In Eq. 3, Xt and Yt are nonstationary at the I(0) level and stationary at the I(1) level. If the notation for the differenced series is expressed again:

$$\Delta Y_t = \pi Y_{t-1} + \sum_{i=1}^{p-1} \delta_i Y_{t-i} + \beta X_t + v_t \tag{3}$$

can be expressed as $\pi = \alpha\beta'$. Here, it is expressed as $\pi = \alpha\beta'$. α and β' are two matrices of size (kxr) and rank (R) (Göçer et al. 2013; Akpolat and Altintas 2013; Dogan and Kan 2018). α is the speed of adjustment, β is the matrix of long-run cointegration coefficients, and r is the rank of the matrix (Tarı 2010).

Full Modified Ordinary Least Square

The FMOLS test was developed by Pedroni (2000) and Pedroni (2001). It is one of the next generation of cointegration tests that allows us to reveal long-run relationships. This study provides important contributions to the verification and explanation of the results obtained from the Johansen cointegration test. Its ability to correct the interactions between the endogeneity and error terms may prevent biased results from being obtained. The process takes into account the possible interactions between the constant term, the error term and the differences in the independent variables (Gülmez and Yardımcıoğlu 2012). Under the assumption that the distribution is nominal, analyses related to the FMOLS equation can be performed with the help of Eqs. 4, 5 and 6:

$$\Lambda^*_{NT} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}\left(\mathrm{P}_t - \overline{\mathrm{P}_i}\right)^2\right]^{-1}\left[\sum_{t=1}^{T}\left(\mathrm{P}_t - \overline{\mathrm{P}_i}\right)\Lambda^*_t - T\hat{\tau}_i\right] \tag{4}$$

$$\Lambda^*_{NT} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}\left(\mathcal{E}_t - \overline{\mathcal{E}_i}\right)^2\right]^{-1}\left[\sum_{t=1}^{T}\left(\mathcal{E}_t - \overline{\mathcal{E}_i}\right)\Lambda^*_t - T\hat{\tau}_i\right] \tag{5}$$

$$\Lambda^*_{NT} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}\left(\mathrm{T}_t - \overline{\mathrm{T}_i}\right)^2\right]^{-1}\left[\sum_{t=1}^{T}\left(\mathrm{T}_t - \overline{\mathrm{T}_i}\right)\Lambda^*_t - T\hat{\tau}_i\right] \tag{6}$$

Canonical Cointegrating Regression (CCR)

The other analysis method used in the study to determine the long-run coefficients is the CCR. To eliminate the inconsistencies in classical OLS, it uses the transformed form of the variables with the long-run covariance matrix. This process asymptotically eliminates endogeneity in long-term interactions (Mehmood et al. 2014). In principle, it is completely similar to FMOLS. This confirms the results obtained from FMOLS. The small difference between the two analyses is that it transforms the data from I(0) to I(1) to minimize the relationship between the cointegration equation and stochastic shocks (Park 1992).

Table 2 Descriptive Statistics

	Λ	P	$\mathcal{E}$	T
Mean	1.449182	66,956,513	26,820,460	33,149,012
Median	1.393500	66,726,602	27,708,936	32,905,540
Maximum	2.459000	72,934,511	32,033,260	39,791,882
Minimum	0.530000	59,901,067	20,262,153	24,928,752
Std. Dev.	0.454929	3,045,106	4,059,054	4,786,287
Skewness	0.224813	–0.124464	–0.365789	–0.180676
Kurtosis	2.732873	3.192835	1.713956	2.053462
Jarque-Bera[a]	0.250726	0.090888	2.006689	0.940967
Probability[a]	0.882176	0.955573	0.366651	0.624700

[a]Probability value represents jarque bera value

Table 3 Unit Root Test

Variables	ADF			
	Intercept		Trend and Intercept	
	Level	Δ	Level	Δ
Λ	–2.8637	–6.5264*	–3.8065*	–6.3636*
P	–4.8854*	–1.4061	–1.406	–1.2768
$\mathcal{E}$	–2.7411***	0.6383	–2.5704	–2.5704
T	–1.6506	–3.4951***	–3.7137*	–4.1267**

*, **, *** sırasıyla %1, %5 ve %10 düzeyinde istatistiksel olarak önemlidir

Empirical Results

The descriptive statistics for the variables analyzed in the study are given in Table 2.

According to Table 2, the average annual temperature change is 1.44 °C, the maximum temperature is 2.45 °C, and the minimum temperature is 0.53 °C. The average total fruit production of the EU-27 was 66,956,513 t, with a maximum of 72,934,511 t and a minimum of 59,901,067 t. Total fruit exports averaged 36,820,460 t, with a maximum of 32,033,260 t and a minimum of 20,262,153 t. The average total fruit imports were 33,149,012 t, with a maximum of 39,791,882 t and a minimum of 24,928,752 t.

The unit root test results for the variables analyzed are given in Table 3.

When the unit root test results are analyzed, the annual temperature change is stationary at the I(1) level according to the intercept and stationary at both the I(0) and I(1) levels according to the trend and intercept. Total fruit production is stationary at the I(0) level according to the intercept, and total fruit exports are stationary at the I(0) level according to the intercept. Total fruit imports are stationary at the I(1) level according to the intercept and stationary at both the I(0) and I(1) levels according to the trend and intercept.

The results of the cointegration analysis for the factors affecting the annual temperature level in the EU-27 countries are given in Table 4.

Table 4 shows that there is a long-run cointegration relationship between the annual temperature change and the variables assumed to affect it. According to the trace statistics, there are four cointegration vectors, and according to the maximum eigenvalue statistic, there are two cointegration vectors. It is not possible to determine the direction and severity of this relationship through cointegration analysis. FMOLS and CCR tests were conducted to determine the direction and severity of the long-term relationships. The FMOLS and CCR test results are given in Table 5.

Table 5 shows that total fruit production and total fruit imports, which are among the factors affecting the annual temperature change in EU-27 countries in the long run, are statistically significant at the 1% level according to both the FMOLS test results and CCR test results. According to the FMOLS test results, when total fruit production increases by 1%, the annual temperature change increases by 1.76%.

Table 4 Cointegration Analysis Results for the Factors Affecting Λ Levels between 2000 and 2021 in the EU-27

	Trace			Maximum Eigenvalue			
	Eigenvalue	Trace Statistic	0.05 Critical Value		Eigenvalue	Max-Eigen Statistic	0.05 Critical Value
r = 0*	0.802663	62.95683	47.85613	r = 0*	0.802663	32.45683	27.58434
r = 1*	0.526165	30.50000	29.79707	r = 1	0.526165	14.93791	21.13162
r = 2*	0.400951	15.56209	15.49471	r = 2	0.400951	10.24825	14.26460
r = 3*	0.233325	5.313842	3.841465	r = 3*	0.233325	5.313842	3.841465

*, **, *** sırasıyla %1, %5 ve %10 düzeyinde istatistiksel olarak önemlidir

Table 5 Long-term effects of factors affecting the level of Λ between 2000 and 2021 in the EU-27

Dependent Variable: Λ	FMOLS		CCR (Canonical Cointegrating Regression)	
	Coff.	t-stat	Coff.	t-stat
P	1.760391	4.250973*	2.001532	4.106693*
$\mathcal{E}$	–0.344036	–0.843581	–0.394075	–1.110189
T	1.399027	3.313565*	1.744791	4.885035*
Constant	–49.69129	–6.193745	–59.16383	–6.417242
Diagnostic Tests				
R-squared	0.27		0.29	
Jarqua-bera	5.80		5.33	

*,**,*** sırasıyla %1,%5 ve %10 düzeyinde istatistiksel olarak önemlidir

When total fruit imports increase by 1%, the average annual temperature increases by 1.39%. The CCR test results also coincide with the FMOLS test results. A 1% increase in total fruit production increases the average annual temperature by 2.00%. A 1% increase in total fruit imports increases the average annual temperature by 1.74%. When the model is analyzed as a whole, the distribution is normal, and the R^2 value is sufficient. Fruit growing activities and foreign trade are among the factors affecting climatic events.

Another analysis used in the research is impulse-response analysis. Impulse-response analyses allow us to see the long-run effects of a one-unit variance shock arising from independent variables on the dependent variable. The results of the impulse-response analyses for the variables used in this study are given in Fig. 3.

In the EU-27 countries, one unit shock originating from total fruit production (green graph) reached the highest level in the second period of annual temperature change and stabilized in the third and fourth periods. A one-unit shock from total fruit exports (red graph) and total fruit imports (blue graph) on the annual temperature change is greatest in the second period and decreases in the third and fourth periods. While the effect of all three variables on the annual temperature change is clear, the largest response is given to total fruit production.

Conclusion and Recommaditation

Global climate change is one of the most important issues of the third millennium. Almost all sectors contribute negatively to the global climate change process in terms of their results. Regardless of the sector, these results are anthropogenic. One of the sectors that directly labels the climate change process is the agricultural sector. The agricultural sector consists of crop production and animal production. Within crop production, the fruit growing sector is important both in terms of economy and food security. In parallel with the ever-increasing world population, the need for food is increasing daily (Avan and Kotan 2021). Greenhouse gases such as CO2, CH4 and N2O, which occur as a result of agricultural activities (energy consumption, plant and animal production, fertilization, pesticide use, etc.), are considered among the causes of climate change (Akalın 2014). The impact of fruit production on climate change in EU-27 countries is the focus of this study. In this research, which analyses the fruit growing sector in terms of production, imports and exports, important results were obtained. The annual average temperature increase is continuously increasing at the EU-27 level. Here, total fruit production and fruit imports were found to be statistically significant. Fruit production is an intensive process consisting of intensive input use, pesticide use and human-induced processes. According to the Climate Transparency Report (2022), the methane emission rate of EU-27 countries between 2015 and 2019 was 8.2%. A significant portion of

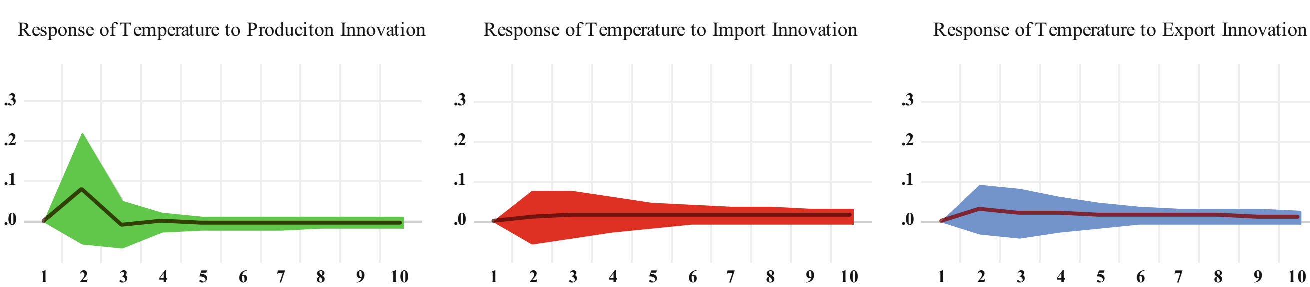

Fig. 3 Impulse-response analysis results

the emissions from the agricultural sector are methane (approximately 46%). When CO2 is considered a CO2 equivalent, it also constitutes a significant part of CO2 emissions. It is considered important to implement international environmentalist practices in fruit care, harvesting, pest and harvesting processes. The use of slow-release fertilizers in fertilizer (Sitaula et al. 1995; Cole et al. 1997; Lal and Singh 2000; Tolay et al. 2010; Zhai et al. 2011; Şahin and Onurbaş 2016; Yerli et al. 2019), the use of biopesticides in pesticide use (Nations and Hallberg 1992; Yeo et al. 2003; Holland and Sinclair 2003; Bloomfield et al. 2006; Navarro et al. 2007; Ayyıldız 2022), agroecological practices, recycling of plant wastes, and minimizing tillage (Raich and Potter 1995; West and Marland 2002; de-Oliveira Silva et al. 2019). In this way, CO2 emissions from production processes can be controlled. Fruit exports and imports are related to transport processes. In the trade that continues from one country to another country during the export and import of fruit in the international arena, emissions can be emitted from heavy tonnage vehicles, as well as through evaporation from fruit surfaces during transportation. The storage conditions of fruits in foreign trade are important. Practices to control evaporation can affect this process. Waxing, packaging, and closed transport methods can be preferred. On the other hand, mobility increases with increasing import and export levels. With the increase in foreign trade, there is an increase in the number of transport vehicles. The transport sector, which is the sector that consumes the most fossil fuels in the world, emits 37% of carbon dioxide (CO2) emissions alone among all sectors. This ratio is estimated to increase to 50% in 2030 and 80% in 2050 (Teter 2022). Considering the maximum amount of transport permitted by law, the number of vehicles engaged in international transport is increasing along with foreign trade. Practices that reduce the total number of vehicles during transport activities can be implemented within the framework of laws. In addition, the use of alternative energy sources to fossil fuels in transport can be encouraged. For a more comprehensive framework policy, it is critical to introduce and enforce rigid rules for the adoption of cleaner production processes in both the manufacturing and transport sectors, taking into account all possible risks, in line with the EU green deal objectives.

Data availability statement Data will be made available upon reasonable request.

Conflict of interest H.G. Doğan and E. Kaplan declare that they have no competing interests.

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