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The Causal Relationship Between Temperature Change and Food Indices in The World

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R E S E A R C H A R T I C L E

A B S T R A C T

The effects of temperature change on different sectors have been one of the most essential problems in the last decades. Agricultural sector is definitely the most fragile sector of all, not only production of food causes temperature change but also temperature change led to the instability of production and prices. The objective of this study was to analyse the relationship between temperature change and production or price indices in the world for the period of 1990-2016. The time series of temperature change, Food Price Index and Gross Production Index for foods were obtained from the database of the Food and Agriculture Organization of the United Nations. Johansen cointegration and Granger causality analysis were used to evaluate relations between the indicators in the short and long runs. The results of the study indicated that temperature change, Food Price Index and Gross Production Index for foods were cointegrated and so they move together in the long run. On the other hand, Granger causality analysis highlighted that there is unidirectional causality runs from temperature change to both Food Price Index and Gross Production Index for foods and at the same time from Gross Production Index for foods to Food Price Index. This research concluded that temperature has an essential effect both on agricultural production and prices, whereas food prices are sensitive to production. Therefore, the environmentally friendly technologies should be developed and applied in agricultural sector. However, the food prices could be regulated via production controls which take temperature change into consideration.

1. Introduction

The latest global temperature change data of National Aeronautics and Space Administration (NASA) indicated that 2018 was the fourth warmest year. FAO confirmed this information such as the average global temperature change over land in 2018 was 1.19° C and the fourth warmest record of air temperature associated with climate change threaten plant growth and yield, putting millions of farmers and communities at risk throughout the world. Together with changes in precipitation and increases in extreme events such as flooding and droughts, temperature

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change threatens countries' food security and their ability to eradicate poverty and achieve sustainable development [1]. Therefore, the agenda of this century has considerably focused on the climate change and its effects on different sectors. Temperature change is one of the most susceptible indicators of climate change and agricultural sector is one of the most fragile sectors against temperature and climate changes. For this reason, the studies on the effects of climate change on agricultural sector are very essential to analyse the sustainability of agricultural sector.

The economic effects of climate change on agricultural production in developing countries has been reviewed by numerous studies [2-12] and it was introduced that climate change has considerable effect on agricultural crops in developing countries. In order to analyse the relation between climate change and yield, regression models [13-15] and time series techniques [16-18] have been used. The literature was substantially focused on crop production, but the agricultural sector required to be analysed in whole. Therefore, the objective of this study was to examine the relationship between the food indices, FPI and GPI with temperature change in the world for the period of 1990-2016.

The remainder of the paper was structured as follows. In the second section, the data and methodology of the research were introduced. In the third section, the model results and were presented and discussed. In the fourth section, conclusion and recommendations were introduced.

2. Material and Methods

2.1. Material

In this study, the time series of Food Price Index (FPI) Gross Production Index (GPI) for agriculture and temperature change were examined for the period of 1990-2016 and the data was obtained from the Food and Agricultural Organization [19-21].

The FPI is a measure of the monthly change in the international prices of a basket for food commodities. FPI was introduced in 1996 to monitor developments in the global agricultural commodity markets. FPI consists of 5 sub-commodity group price indices such as cereals, dairy, meat, vegetable oils and sugar and their weights are 0.272, 0.173, 0.348, 0.135 and 0.072, respectively [19]. In this study, annual deflated index series was used.

The GPI is an index of agricultural production and show the relative level of the aggregate volume of agricultural production for each year in comparison with the base period. The GPI index was based on the sum of price-weighted quantities of different agricultural commodities. The unit of GPI was valued in US Dollar [20].

Temperature change contains data on observed mean surface temperature changes by country over the period of 1961-2017. The data provide information on monthly, seasonal and annual average temperature anomalies. This study examined the temperature change for the period of 1990-2016 and the unit of temperature change is ºC [21].

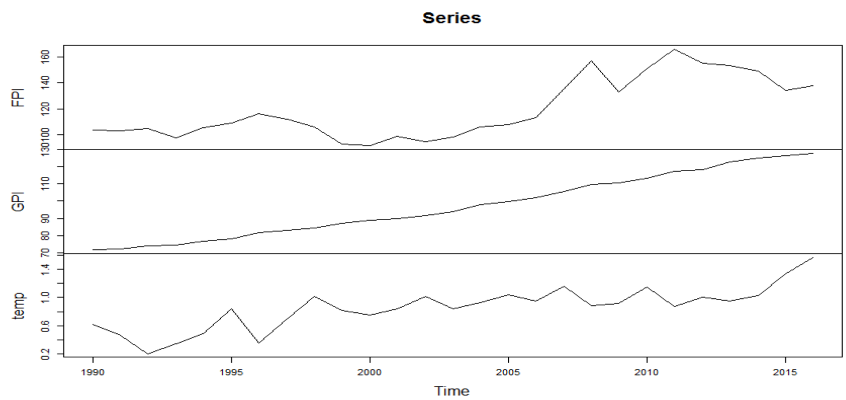

Figure 1. Time series graph of FPI, GPI and temperature change in the world for the period of 1990-2016

Figure 1 reported the time series of FPI, GPI and temperature change and highlighted that GPI has shown an increasing trend over the period of 1990-2016, whereas FPI and temperature change has shown fluctuations in time.

2.2. Method

This study examined the short and long runs relationships between 2 food indices of FAO; FPI and GPI with temperature change. The long run relationship was examined by Johansen cointegration test and short run relationship was introduced by Granger causality test. The EViews 8 and RStudio were used in order to analyse the series via cointegration and causality methods.

The Johansen cointegration test can be seen as a multivariate generalization of Augmented Dickey-Fuller (ADF) test (Equation 1). The generalization is the examination of linear combinations of variables for unit roots. Johansen suggests a method for both determining how many cointegrating vectors there are and estimating all the distinct relationships [22]. The Johansen test and estimation strategy – maximum likelihood – make it possible to estimate all cointegrating vectors when there are more than two variables. If there are n variables which all have unit roots, there are at most $n-1$ cointegrating vectors [23].

$$\Delta y_t = (a_1 - 1)y_{t-1} + \varepsilon_t \tag{1}$$

In Granger causality test, there are more than two time series and the relationship among the series is analysed through the direction of them. The causality among two series such as X_t and Y_t can be revealed in Equation 2 and 3. The coefficients of the variables will be statistically significant if the causality runs from X_t to Y_t [24].

$$Y_t = \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{j=1}^{m} \beta_j X_{t-j} + u_{1t} \tag{2}$$

$$X_t = \sum_{i=1}^{m} \lambda_i X_{t-i} + \sum_{j=1}^{m} \delta_j Y_{t-j} + u_{2t} \tag{3}$$

This study indicates that there is cointegration and causality among three indicators and therefore, there has been the short and long run relationships between FPI, GPI and temperature change.

3. Results and Discussion

Before application of any model, the unit root test should be taken into consideration. Autocorrelation (ACF) and partial autocorrelation (PACF) graphs of the series indicate that FPI, GPI and temperature change series are non-stationary at level (Figure 2). Therefore, Augmented Dickey-Fuller (ADF) was applied in order to decide whether the series have unit root or not.

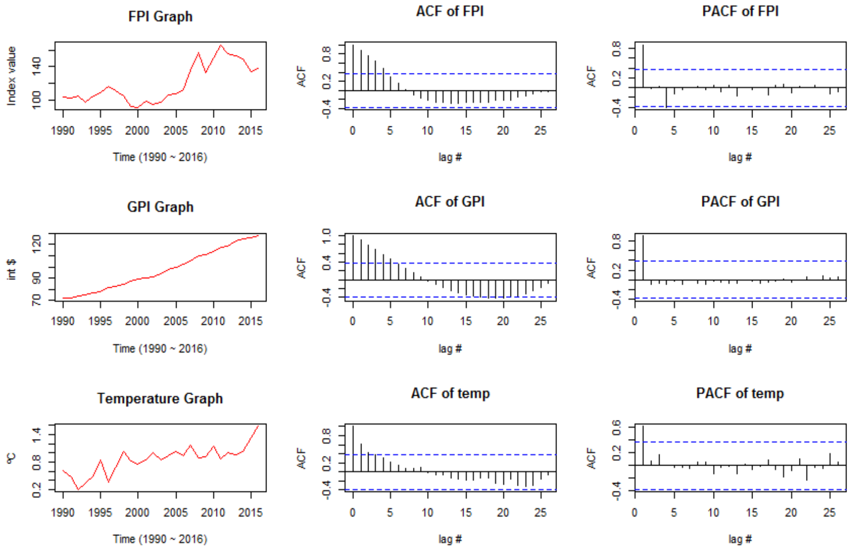

Figure 2. Time series graph and ACF-PACF plots of FPI, GPI and temperature changes in the world

ADF test results reported that we cannot reject the null hypothesis of unit root in the time series of FPI, GPI and temperature change and they are non-stationary (Table 1). However, all of the series are stationary in first-differences and the null of a unit root in the differenced of the series could be rejected. Therefore, the series are I (1).

Table 1. The results of unit root test

Variables	Level		First-difference	
	***t*-statistic**	**Prob.**	***t*-statistic**	**Prob.**
FPI	0.378	0.786	-5.079	0.000
GPI	-2.754	0.225	-5.808	0.000
Temperature Change	1.712	0.975	-5.295	0.000

As the series are stationary at first level, Johansen Cointegration Test could be applied in order to determine whether there is the long-run relation among the series. The results of the Johansen Cointegration Test with trace and Max-Eigen statistics indicated that FPI, GPI and temperature change are cointegrated (Table 2). Therefore, the null hypothesis of non-cointegration (r=0) was rejected at the level of 0.05 significance and there is long-run relationship among the series.

Table 2. Johansen cointegration test results

H_0	Eigenvalue	Trace Statistics	5% Critical Value	Prob.	Max-Eigen Statistics	5% Critical Value	Prob.
r = 0	0.708717	51.42855	42.91525	0.0057	27.13609	25.82321	0.0334
r ≤ 1	0.554618	24.29246	25.87211	0.0776	17.79413	19.38704	0.0839
r ≤ 2	0.255750	6.498332	12.51798	0.3998	6.498332	12.51798	0.3998

All of the indicators were examined as dependent variable in VAR model and Granger Causality test results were reported in Table 3. The results highlighted that in FPI dependent variable model, GPI and temperature change were not Granger cause of FPI. Therefore, the null hypothesis was rejected for both of the causality relation. On the other hand, GPI dependent variable model revealed that no causality between FPI and GPI whereas causality runs from temperature change to GPI. So, null hypothesis was rejected for the former, whereas it was failed to reject for the latter. Lastly, temperature dependent variable model indicated that causality runs both from FPI and GPI to temperature change. For this reason, the null hypothesis could not be rejected. To sum up, there is bidirectional causality between GPI and temperature change and unidirectional causality from FPI to temperature change. The bidirectional causality between GPI and temperature change indicated that not only temperature change affects the agricultural production, but the quantity and quality of production also led to temperature change. [14] and [18] also introduced that temperature change with other climate variables had significant effects on yields whereas [13] revealed that climate had modest effects on yields. On the other hand, although no causality between production and price was revealed, causality from FPI to temperature change indicated that volatility in food prices was caused by excess demand and amount of production.

Table 3. Granger causality test results

Dependent variable: FPI			
Excluded	Chi-sq	df	Prob.
GPI	0.058766	1	0.8085
Temperature change	0.679720	1	0.4097
All	2.543821	2	0.2803
Dependent variable: GPI			
Excluded	Chi-sq	df	Prob.
FPI	0.279026	1	0.5973
Temperature change	5.078223	1	0.0242
All	5.405022	2	0.0670
Dependent variable: Temperature change			
Excluded	Chi-sq	df	Prob.
FPI	8.465829	1	0.0036
GPI	20.81146	1	0.0000
All	22.74389	2	0.0000

4. Conclusion

This paper mainly focused on the relationship between temperature change and food indices of FAO via time series analysis. The results of the study indicated that the indices of FPI and GPI are cointegrated with the temperature change. The bidirectional causality between GPI and temperature change indicated that temperature change and GPI affect each other. In other words, agricultural production has simultaneously affected and affects the temperature change. For this reason, the agricultural sector should be regulated via policies which take sustainable and environmental development into consideration. By the way, the food production and environment could be considerably well managed. In brief, this study revealed that temperature change is the key indicator of agricultural sector and the price and production balance could not be maintained unless the external factors has been taken into consideration.

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