Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Aralık/December 2023, 20(4)
Başvuru/Received: 23/08/22
Kabul/Accepted: 02/08/23
DOI: 10.33462/jotaf.1166050

http://dergipark.gov.tr/jotaf
http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Agricultural Production Connectedness and Networks in Türkiye

Türkiye'de Tarımsal Üretim Bağlantılılığı ve Ağları

Türker Açıkgöz[1*]

Abstract

The world's population has been growing rapidly and since the 2006–2008 global food crisis, it has been questioned many times that how the world's growing population will be fed properly. According to reputable international institutions, the world may be insufficient to supply enough food in the near future, and this fact may cause many economic, social, and government problems. In Türkiye, these problems will be realized more harshly than in peer countries for some reasons. Türkiye has one of the highest population growth rates in the world, while it hosts the highest number of refugees in the world. In addition, Türkiye's agriculture sector has been experiencing a harsh downfall recently and the country has been dependent on importing food and agricultural commodities. Therefore, in this paper, I investigate the connectedness and networks of agricultural production in Türkiye by using the connectedness approach of Diebold and Yilmaz (2012, 2014), which is based on the forecast error variance decomposition methodology of generalized vector autoregressive models. I use Türkiye's most produced agricultural commodity data, which are barley, wheat, rye, paddy, lentil, chickpea, and oat. The material consists of annual production data from 1938 to 2019. According to the analysis results, Türkiye's agricultural production has been highly connected. Our findings show that production shocks arising from wheat and barley have spilled over to other commodities. Agricultural production networks and pairwise spillovers also exhibit a similar result that most of the commodities are highly interconnected to wheat and barley production. Besides, pairwise connectedness results show that there are some strong and weak connectivity relations, and these can be used for the decision-making process, risk aversion, and risk-seeking purposes. Our findings have important implications for policymaking for institutions, diversification, and risk management for producers, suppliers, and traders.

Keywords: Agricultural production, Agricultural policymaking, Network analysis, Risk management, Spillover effects

[1]***Sorumlu Yazar/Corresponding Author:** Türker Açıkgöz, Baskent University, Baglica Campus, Faculty of Economics and Administrative Sciences, Department of Management, Etimesgut/Ankara/Turkey. E-mail: turker.acikgoz1@gmail.com OrcID: 0000-0002-5613-1929
Atıf/Citation: Açıkgöz, T. (2023). Agricultural production connectedness and networks in Türkiye. *Journal of Tekirdağ Agricultural Faculty*, 20(4): 799-810.

Öz

Dünya nüfusu hızla artmakta ve 2006-2008 küresel gıda krizinden bu yana dünya nüfusunun nasıl doyurulacağı sorusu defalarca kez sorulmaktadır. Saygın uluslararası kuruluşlara göre, dünya yakın bir gelecekte yeterli gıdayı tedarik etmekte yetersiz kalabilir ve bu durum birçok ekonomik, sosyal ve devlet sorununa neden olabilir. Türkiye'de bu sorunların bazı nedenden dolayı benzer ülkelere göre daha sert bir şekilde gerçekleşeceğine inanılmaktadır. Türkiye, dünyadaki en yüksek nüfus artış oranlarından birine sahipken, dünyanın en fazla mülteciye ev sahipliği yapan ülkesidir. Buna ek olarak, Türkiye'nin tarım sektörü son yıllarda sert bir düşüş yaşamakta ve ülke gıda ve tarımsal emtia ithalatına bağımlı hale gelmektedir. Bu bağlamda, bu çalışmada, Vektör Otoregresif Modellerinin tahmin hata varyans ayrıştırma metodolojisine dayanan Diebold ve Yılmaz'ın (2012, 2014) bağlantılılık yaklaşımı kullanılarak Türkiye'deki tarımsal üretimin bağlantılılık ve ağları araştırılmaktadır. Çalışmada Türkiye’de en çok üretilen yedi tarımsal emtianın verisi kullanılmıştır. Bu ürünler; arpa, buğday, çavdar, pirinç, mercimek, nohut ve yulaf şeklindedir. Araştırmada kullanılan veri seti 1938 yılından 2019 yılına kadarki süreyi kapsayan tarımsal üretim verisidir. Analiz sonuçlarına göre, Türkiye'nin tarımsal üretimi yüksek oranda bağlantılıdır. Araştırmanın bulguları, buğday ve arpa kaynaklı üretim şoklarının diğer tarım ürünlerine de önemli ölçüde sıçradığını göstermektedir. Tarımsal üretim ağları ve ikili yayılmalar, emtiaların çoğunun buğday ve arpa üretimiyle yüksek oranda bağlantılı olduğu konusunda da benzer bir sonuç sergiler. Ayrıca, ikili bağlantılılık sonuçları, bazı güçlü ve zayıf bağlantı ilişkilerinin olduğunu ve bunların karar verme süreci, riskten kaçınma ve risk arama için kullanılabileceğini göstermektedir. Bulgularımızın kurumlar için politika oluşturma, çeşitlendirme ve üreticiler, tedarikçiler ve tüccarlar için risk yönetimi için önemli etkileri vardır.

Anahtar Kelimeler: Tarımsal üretim, Tarımsal politika, Ağ analizi, Risk yönetimi, Yayılma etkileri

1. Introduction

Since the recent global food crisis (from 2006 to mid-2008), the question of "how the world's growing population will be fed" has started to gain popularity and become one of the main questions by many national and international institutions (FAO, 2009; Tian et al., 2021). According to the projections of the United Nations, the world population will reach 9.3 billion by 2050. In this situation, the world has to increase its current global crop production by %70-%100 and this estimation has been made by taking consumption and income growth trends into account (Bruinsma, 2009; Van Wart et al., 2013). Although past and current production of agricultural commodities has been sufficient to support the growing population (Pingali, 2012; Rosa et al., 2018), the world is moving toward the point where this situation may change (Negiş et al., 2017). Thus, policymakers and institutions of national economies should take action and set measures proactively and manage the oncoming risks due to agricultural production and access to food.

The agricultural production has an important place in national economies because of its highly integrated structure with social conflicts and macroeconomic problems (Bozkurt and Kaya, 2021). On the macroeconomic side, its importance is irrefutable for economic growth (Singariya and Naval, 2016; Mohammed, 2020), the labor market (Mellor, 1995; Cristea and Noja, 2019), and sustainable development (Johnston, 1970; Asim and Akbar, 2019), and its interrelation with the real side of the economy (Mohammad, 2020), both industrial and services, makes it one of the most important sectors in nations' economies. For socioeconomics, agricultural production has an important sociological role in societies as it bears and rivets negative impacts of income inequality and poverty (Machethe, 2004; Dhahri and Omri, 2020), and thus, it may cause social conflicts (Crost et al., 2018). Therefore, determining policies on agricultural production can be counted as one of the most crucial ones for policymakers and economic institutions in a nation for the sake of macroeconomic stability, future growth, sustainable development, and social welfare.

In the Republic of Türkiye, I believe that this problem will be realized more harshly than peer nations. There are many indicators that confirm this hypothesis. First, Türkiye's population grows rapidly. According to World Bank (2022) statistics, Türkiye has the second-highest population growth rate (last 10 years average is %1.5) in the European region after Luxembourg. Second, in addition to its swiftly increasing population, Türkiye is the number one country that hosts the highest number of refugees in the world with approximately 3.7 million refugees (UNHCR, 2022). With a high growth rate of population and being a center for immigration, Türkiye has to feed its rapidly growing population and may face many problems for this purpose.

Table 1. Türkiye's Export-Import Data of Agriculture, Forestry and Fishing (Thousands of US$)

Year	Export	Import	Net Export (Export-Import)
2021	7,160,039	12,082,065	-4,922,027
2020	5,956,937	9,834,246	-3,877,309
2019	5,588,545	9,835,392	-4,246,847
2018	5,846,649	9,498,144	-3,651,495
2017	5,579,339	9,374,405	-3,795,066
2016	5,686,894	7,345,239	-1,658,344
2015	5,293,786	7,501,500	-2,207,713
2014	5,712,144	8,948,939	-3,236,795
2013	5,339,324	7,792,640	-2,453,317
Mean	**5,795,962**	**9,134,730**	**-3,338,768**
Standard Deviation	**522,681**	**1,396,901**	**990,223**

Third, Türkiye's agriculture sector has been decaying for a long time. *Table 1* reports export and import statistics of Türkiye's agriculture, forestry, and fishing industries (TURKSTAT, 2022). There is a huge gap between import and export values. According to *table 1*, Türkiye's food demand has been dependent on and fulfilled by imports from other countries more and more every year. This picture has been realized because the demand for food has been increasing owing to the rapidly increasing population and immigration. But the supply side is in an insufficient position and cannot catch the trend. Considering global trends in increasing food prices and global population, exchange rates in Türkiye, and energy prices, this import-based agriculture policy is unsustainable. Thus, meeting the food demand by importing can cause many problems in the future. In the near future, the dependance on imports for food can reach to a point of no return. Therefore, it is not a sustainable solution to the problem.

Based on the discussion above, I believe that Türkiye will experience a food crisis in the future more severely than many other countries. For this reason, there is a need for research that will be a roadmap for regulating agricultural policy. Our study is important in policymaking.

Speaking of agricultural production, cereals and pulses are among the most important products because they are cheap, have high efficiency in terms of production, and are nutritious since they contain a high level of carbohydrates, protein, and vitamins. They also constitute most of Türkiye's agricultural production (Balkan et al., 2011). Therefore, this study mainly focuses on cereals and pulses, which are mentioned when talking about agricultural production.

This study examines the issue of agricultural production, which can become an important problem in the future. This study analyzes production connectedness and networks between barley, wheat, rye, paddy, lentils, chickpeas and oats, which are the seven most important agricultural products of Türkiye. For this purpose, I use the connectedness analysis of Diebold and Yilmaz (2012; 2014), which investigates connectedness between variables in the time domain. Connectedness and network analysis have gained popularity recently in finance and economics literature. The main purpose of connectedness analysis is to examine how different markets, economies, assets, or macroeconomic and financial variables are connected. Although the connectedness approach has been tested for macroeconomic and financial variables, its use in the agriculture area is quite limited. For instance, Diebold and Yilmaz (2009), Barunik et al., (2016), Zhang (2017), Su (2020) and Polat (2020) have tested equity markets around the world and concluded that connectedness effects exist and spillover effects of shocks are very high. Similar results are obtained by Alter and Beyer (2014), Reboredo et al. (2020), Shahzad et al. (2019) on debt markets, Antonakasis and Kizys (2015), Balli et al. (2019) on commodity markets, and Ferrer et al. (2018), Lovcha and Perez-Labardo (2020) and Toyoshima and Hamori (2018) on oil and energy markets. All these studies confirmed that economic and financial variables are highly connected, and spillover effects of volatility shocks spread rapidly in the system. However, its usage for agricultural economics and agricultural sciences has not yet been popularized. Thus, in the literature review conducted up to this date, I have not found sufficient studies in the agricultural economics literature that investigate connectedness and spillover effects. There is a huge gap on the connectedness and network studies in the literature on agricultural economics. In a way, this study has great value in showing that connectedness and network analysis can be used in the field of agricultural science to analyze interactions between variables, commodities, and countries as well as policy-making on economic and agricultural production.

2. Materials and Methods

2.1. Dataset

Since this study investigates agricultural production, I use production amount data for seven agricultural commodities which are barley, wheat, rye, paddy, lentils, chickpeas, and oats. The dataset was obtained from the Turkish Grain Board (TGB, 2022) website and is publicly available. For the sake of stationary and robust econometric modeling, I use logarithmic returns of the raw data in connectedness analysis. The calculation of return series is given in Equation 1.

$$r_{i,t} = \ln\left(\frac{d_{i,t}}{d_{i,t-1}}\right) \qquad \text{(Eq. 1)}$$

In equation 1, parameters are given as follows: $d_{i,t}$: production amount of i^{th} commodity and $r_{i,t}$: logarithmic returns of production series of i^{th} commodity.

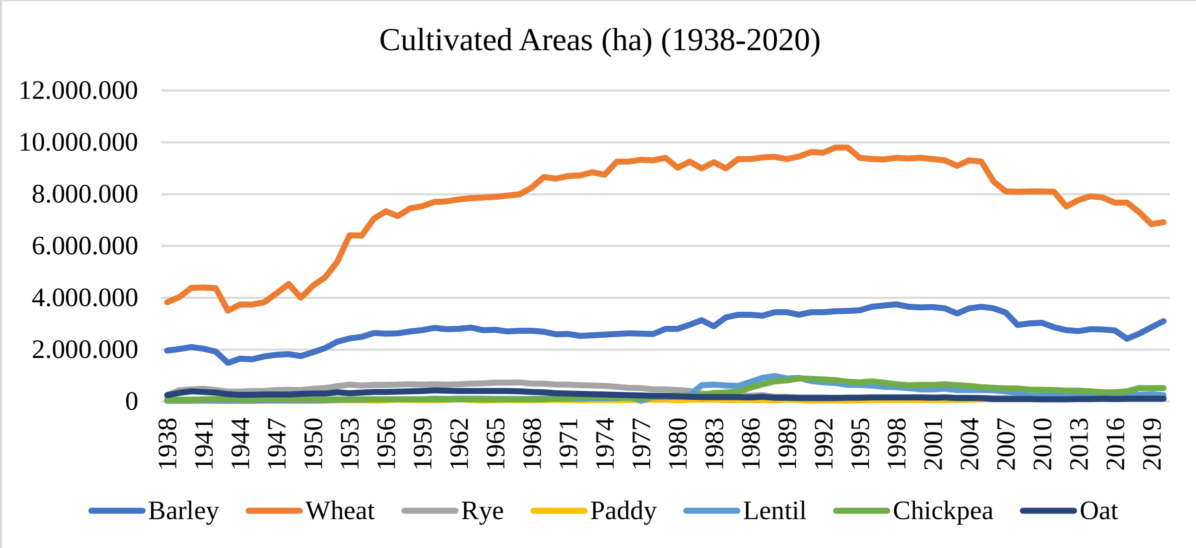

Figure 1. Cultivated areas in Türkiye

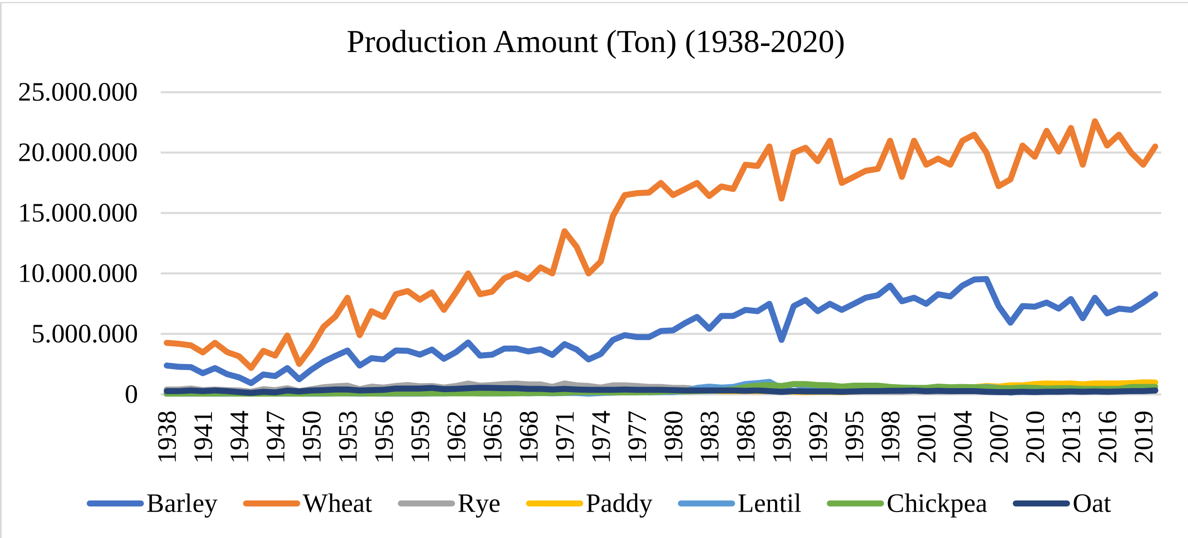

Figure 2. The production number of agricultural commodities

Figures 1 and *2* exhibit cultivated areas (ha) and production amounts (ton) of agricultural commodities. According to *figure 1*, wheat and barley have been dwelling in almost all areas for cultivation. Barley has performed very slow upward trend from 1943 to 2008. Speaking of wheat, it is one of the most important commodities of Türkiye's agricultural policies. Most of the cultivated land has been assigned to the wheat production. Besides, Türkiye's policy on wheat production has been consistent. Türkiye's cultivated land policy has been mostly stable in the sample period for the rest. I may comment that other commodities have not been getting attention from policymakers as their cultivated areas are too low compared to others. *Figure 2* displays characteristics similar to *figure 1*, but with some strict differences. The production amount is more volatile than cultivated areas. Although the behavior of cultivated areas is smoother, the production amount exhibits an exponential increasing and oscillates around the trend. Production amounts increased sharply while cultivated areas shrunk. This may be due to the fact that agricultural technologies have been increasing since the last century, and Türkiye has successfully benefited from it. Therefore, Türkiye's productivity per hectare has been increasing higher than the increase in cultivated areas. Besides, the fact that the production amount has been increasing exponentially while cultivated areas go up smoother supports this view.

Table 2. Descriptive statistics and correlation matrix

Panel A. Descriptive Statistics							
	Barley	**Wheat**	**Rye**	**Paddy**	**Lentil**	**Chickpea**	**Oat**
Mean	0.015	0.019	-0.004	0.037	0.033	0.030	0.002
Median	0.034	0.025	0.000	0.039	0.047	0.009	0.005
Std. Dev.	0.203	0.184	0.212	0.215	0.295	0.153	0.167
Kurtosis	1.082	2.367	1.365	3.305	6.682	1.045	3.905
Skewness	-0.177	-0.356	0.141	-0.606	-1.184	0.262	0.820
Range	1.124	1.162	1.299	1.507	2.240	0.837	1.063
Min.	-0.553	-0.660	-0.627	-0.764	-1.406	-0.383	-0.424
Max.	0.571	0.502	0.671	0.743	0.834	0.454	0.639
Total	1.246	1.567	-0.320	3.052	2.700	2.441	0.135
# of obs.	82	82	82	82	82	82	82
Panel B. Correlation Matrix							
	Barley	Wheat	Rye	Paddy	Lentil	Chickpea	Oat
Barley	1						
Wheat	0.924	1					
Rye	0.842	0.875	1				
Paddy	0.006	0.033	0.009	1			
Lentil	0.565	0.432	0.365	-0.060	1		
Chickpea	0.528	0.480	0.450	-0.021	0.297	1	
Oat	0.771	0.778	0.781	0.099	0.337	0.601	1

Table 2 presents descriptive statistics and the Pearson correlation matrix of the log return series to draw a general picture of the dataset. Panel A in *Table 2* reports that most of the variables have positive means and high standard deviations. For all commodities, maximum and minimum values are relatively high. Passing through panel B, the results suggest a high correlation between wheat-barley (92.4%), wheat-rye (87.5%), and barley-rye (84.2%). There are positive correlations between almost all variables except paddy-lentil and paddy-chickpea. Lastly, correlation results indicate that paddy moves independently and that there is almost no significant correlation with any other commodities.

2.2. Econometric Models

Introduced by Diebold and Yilmaz (2014), connectedness analysis is a variance decomposition method based on a covariance-stationary vector autoregressive model. Using this methodology, I decompose forecast error variance shares of shocks for all variables in the VAR system. Afterwards, in line with the results of the connectedness methodology, I perform network analysis, which uses variance decompositions for interactions. This part of the study first introduces the time domain connectedness methodology of Diebold and Yilmaz (2012) and then discusses the network topology of the variance decomposition.

2.2.1. DY Method

The DY method is based on a covariance stationary N variable generalized vector autoregressive (VAR) process with (p) order as in equation 2:

$$y_t = \sum_{i=1}^{p} \Phi_i y_{t-i} + \varepsilon_t \,;\, \varepsilon_t \sim (0, \Sigma) \qquad \text{(Eq.2)}$$

As the VAR (p) model has constant covariance, it has the following moving average MA (∞) representation in equation 3:

$$y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \qquad \text{(Eq.3)}$$

In equation 3, A_i represents a square coefficient matrix with N dimension and it has a recursive process such that $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \ldots + \Phi_p A_{i-p}$. Furthermore, A_0 matrix is compatible with the identity matrix of N dimension and has a value of zero where $i=0$. Following Diebold and Yilmaz (2012) using a generalized impulse response function, it is possible to assess the shares of each variable j in the H-step ahead forecast error variance decomposition of variable i

for each H step ahead where $H=1,2,3,\ldots$ can be calculated as follows in equation 4:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1}\sum_{h=0}^{H-1}(e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1}(e_i' A_h \Sigma A_h' e_i)^2} \qquad \text{(Eq.4)}$$

where Σ symbolizes the variance-covariance matrix of the error vector, σ_{ii} stands for the standard deviation of the i^{th} error term, and e_i stands for the selection vector that i^{th} component takes 1 and others take zero. Since the shocks to each variable are not orthogonalized, the sum of each row does not equal one. Therefore, each element of the variance decomposition matrix can be normalized as follows in equation 5:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N}\theta_{ij}^{g}(H)} \qquad \text{(Eq.5)}$$

By utilizing normalized forecast error variance decompositions (spillovers), various connectedness measures are possible. For instance, total connectedness in the system (C(H)) can be calculated as shown in equation 6. The total connectedness index shows the extent to which shocks occur in a variable spillover through the system.

$$C(H) = \frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H)} = \frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\theta}_{ij}^{g}(H)}{N} \qquad \text{(Eq.6)}$$

Volatility shocks from all other variables j to the variable i due to the shocks arising from all other j are named contributions from other spillovers. These directional "FROM" spillovers are calculated as follows in equation 7:

$$C_{i\leftarrow\blacksquare}(H) = \frac{\sum_{j=1,j\neq i}^{N}\tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N}\tilde{\theta}_{ij}^{g}(H)} * 100 = \frac{\sum_{j=1,j\neq i}^{N}\tilde{\theta}_{ij}^{g}(H)}{N} * 100 \qquad \text{(Eq.7)}$$

Similarly, shocks arising from variable i directed to all other variables j due to shocks to i are called contributions to others spillovers (directional "TO" spillovers). Directional "TO" spillovers are calculated as in equation 8.

$$C_{\blacksquare\leftarrow i}(H) = \frac{\sum_{j=1,j\neq i}^{N}\tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N}\tilde{\theta}_{ji}^{g}(H)} * 100 = \frac{\sum_{j=1,j\neq i}^{N}\tilde{\theta}_{ji}^{g}(H)}{N} * 100 \qquad \text{(Eq.8)}$$

Net spillovers can be estimated by equation 9. It estimates net directional spillovers by subtracting total shocks from all others j to i and shocks from variable i to all others j.

$$C_i(H) = C_{\blacksquare\leftarrow i}(H) - C_{i\leftarrow\blacksquare}(H) \qquad \text{(Eq.9)}$$

Lastly, net pairwise spillovers can be estimated by equation 10. Net pairwise spillovers are important to understand pairwise dynamics in a system. It measures net directional spillovers between i and j. In other words, it is the difference between how many shocks are transmitted from variable j to i and from variable i to j.

$$Cn_{ij}(H) = C_{i\leftarrow j}(H) - C_{j\leftarrow i}(H) \qquad \text{(Eq.10)}$$

2.2.2. Network Topology of Variance Decomposition.

The network topology of this study relies on variance decompositions and directional spillovers in the system. As Diebold and Yilmaz (2014) proved, variance decompositions can determine weighted and directed networks in a system of variables. By using the variance decomposition, it is possible to measure connectedness among variables and describe networks of various economic and financial relationships. In line with the abovementioned methodology of variance decomposition, I draw networks of Türkiye agricultural production. To effectively depict interactions in the network topology, it is preferable to examine ties bigger than a given threshold value (φ). The following equation (11) defines this function.

$$\tau_x \coloneqq (\max(\text{directional from spillovers})) * \varphi;\ 0 \leq \varphi < 1 \qquad \text{(Eq.11)}$$

In network analysis, node sizes and labels are attributed to the average production amount of each agricultural commodity, while tie thickness is attributed to directional spillovers from commodities i to j. Arrow and arrowhead sizes are determined by the strength of pairwise directional spillovers. Lastly, for node colors, I use net total directional spillovers. In this process, I select the color green for positive net total directional spillovers and the color red for negatives. Color tones approach dark green as net total directional spillovers for positive ones rise. Color tones approach deep red as they drop for negative ones. To scale color tones, I use the deepest green and red to paint the highest and lowest values, respectively.

3. Results and Discussion

This section first introduces connectedness analysis results and presents networks afterward. I use a generalized VAR (1) model with six years ahead variance decomposition H=6 since after H=6 analyzes results remain unchanged. For network analysis, I use two different threshold values such that $\varphi_1=0$, $\varphi_2=0.20$. φ_1 displays all ties in the networks but suffers from noise. By using φ_2, I apply a denoising process and eliminated weak ties. *Table 3* presents the connectedness results for production data.

Table 3. Connectedness Matrix of Agricultural Production

	Barley	Wheat	Rye	Paddy	Lentil	Chickpea	Oat	**FROM**
Barley	26.92	23.40	18.05	1.91	8.66	6.32	14.74	73.08
Wheat	22.69	28.37	20.25	2.56	4.96	4.86	16.31	71.61
Rye	19.86	22.44	29.81	1.46	4.44	4.60	17.39	70.21
Paddy	3.41	5.53	2.55	81.70	0.32	0.79	5.69	18.27
Lentil	16.54	8.50	5.62	4.17	57.16	3.55	4.46	42.84
Chickpea	13.07	9.85	8.62	1.06	4.00	45.96	17.44	54.04
Oat	17.17	17.81	17.42	2.42	3.91	9.74	31.53	68.46
TO	92.75	87.57	72.52	13.58	26.32	29.89	76.02	**TSI: 56.94%**
NET	19.67	15.96	2.31	-4.69	-16.52	-24.15	7.56	

Table 3 presents that the total spillover index is %56.94 for agricultural production. These results show that most of the volatility shocks of production amount arise from system-wide shocks. Directional "FROM" spillovers show that volatility shocks in the production of barley, wheat, rye, and oat are mostly due to production shocks arising from all other commodities. Directional "TO" spillovers also display similar results. Production shocks in these four commodities are highly transmitted to others. For the directional pairwise connectedness of commodities, my findings indicate that production shocks between barley, wheat, rye, and oat are transmitted to each other mutually. Therefore, these findings show that from a production amount perspective, these four commodities are highly connected. Lastly, on net spillovers, the findings show that barley and wheat have the highest positive net spillovers in the system. These commodities spread more shocks to others than they receive from others. On the other hand, chickpea and lentil have the highest negative net spillovers.

Table 4. Net Pairwise Connectedness Matrix

	Barley	Wheat	Rye	Paddy	Lentil	Chickpea	Oat
Barley	0.00	0.71	-1.81	-1.50	-7.88	-6.75	-2.43
Wheat	-0.71	0.00	-2.19	-2.97	-3.54	-4.99	-1.50
Rye	1.81	2.19	0.00	-1.09	-1.18	-4.02	-0.03
Paddy	1.50	2.97	1.09	0.00	-3.85	-0.27	3.27
Lentil	7.88	3.54	1.18	3.85	0.00	-0.45	0.55
Chickpea	6.75	4.99	4.02	0.27	0.45	0.00	7.70
Oat	2.43	1.50	0.03	-3.27	-0.55	-7.70	0.00

Table 4 exhibits the net pairwise connectedness results for agricultural commodities. Notice that *table 4* is a skew-symmetric matrix where the transpose of the [Cn_{ij}] component equals minus [Cn_{ji}] and the summation of all component in the matrix equals zero. The net pairwise connectedness matrix measures the pairwise direction of net volatility shocks. Among all commodities, the direction of production shocks is from wheat to others. Production shocks arising from wheat that spills over to others are much higher than the shocks transmitted from others to wheat production. Besides wheat, barley is also an important commodity whose net pairwise volatility shocks are transmitted to others, but wheat. Lastly, in *table 4*, the most important net pairwise connectedness of agricultural production in the system occurs from lentil → barley, chickpea → oat, and chickpea → barley, respectively.

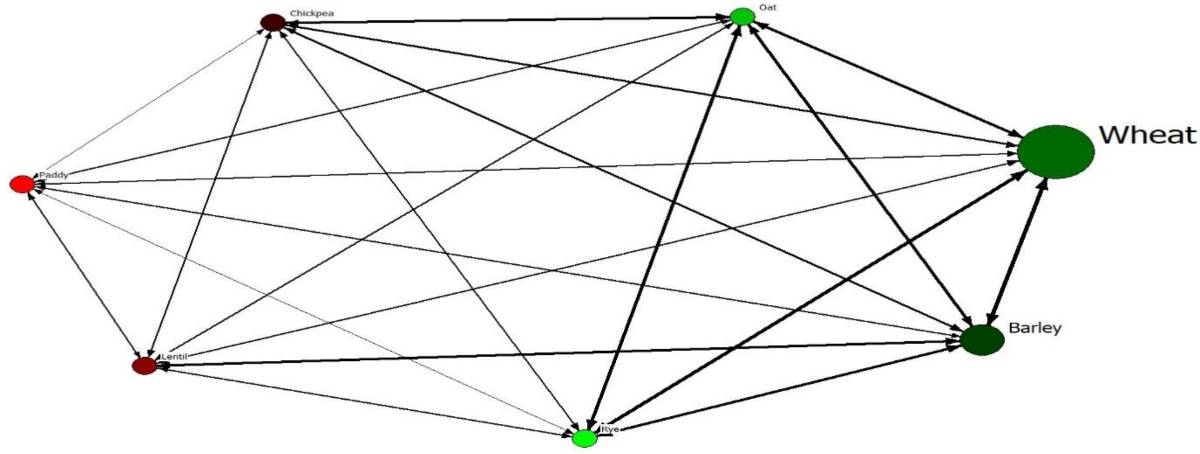

Figure 3.A. Networks of Production Amounts (φ_0=0, τ_x=0)

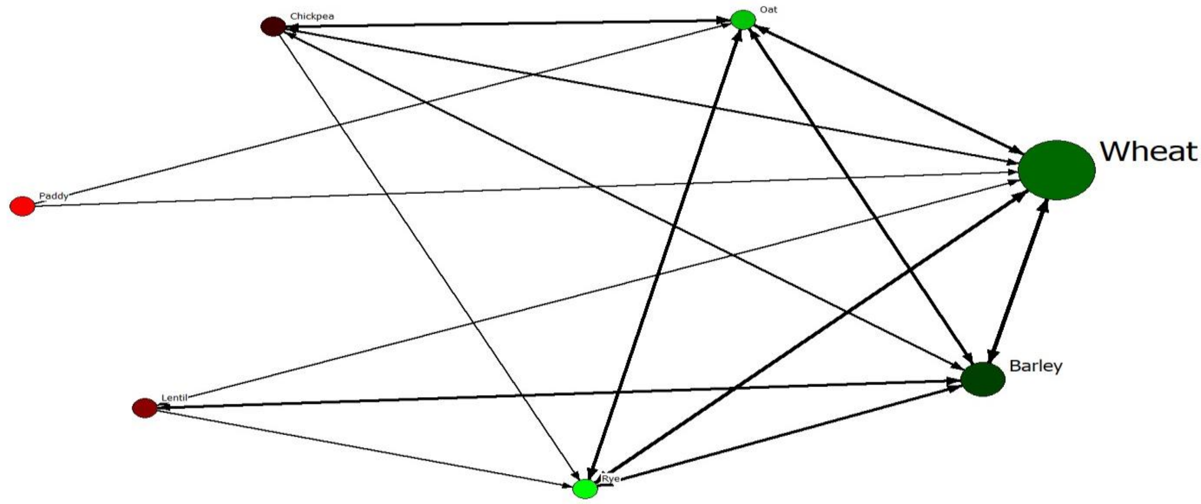

Figure 3.B. Networks of Production Amounts (φ_1=0.20, τ_x=4.68)

From now on, I exhibit network analysis based on variance decompositions. *Figure 3* displays networks for production amounts of seven agricultural commodities. As described in *figure 3*, the agricultural production of four commodities; wheat, barley, rye, and oat, are highly interconnected to each other. Between production amounts of agricultural commodities, many strong ties exist such as wheat-oat, wheat-rye, wheat-barley, barley-oat, barley-rye, and rye-oat. Besides these seven pairwise ties, there are also some one-sided bounds and dependence such as from paddy to oat, paddy to wheat, lentil to barley, chickpea to rye, and chickpea to wheat. Once again, the findings on production networks indicate that the most important actors in the system are wheat and barley. The results show that the most dominant actors in the network, according to the number of ties and strength of links, are barley and wheat.

4. Conclusion

The principal purpose of this article is to analyze the connectedness and networks of agricultural production in Türkiye. According to the worlds acknowledged economic and agricultural institutions, global agricultural production cannot meet the rapidly growing population of the world. Therefore, the scarcity of food will be a non-negligible issue in the near future and some actions must be taken proactively. Having the second-highest population growth rate in Europe and being the world's immigration center, Türkiye has a special role and the effect of this dilemma on Türkiye should be carefully watched.

This paper aims to guide policymakers of agriculture and stakeholders of agricultural production such as producers, suppliers, traders, etc. about how the production of agricultural commodities is interconnected to each other. The findings of this study indicate a convergence situation in producing agricultural commodities. I found that the production shocks of agricultural commodities have highly spilled over among each other. This convergence situation demonstrates that agricultural commodity production highly interacts with each other. Therefore, when developing policies related to a specific product, the impacts on the production of other products should also be considered. This is because research findings on production networks have shown the existence of highly interconnected networks.

The findings also report that wheat and barley production in Türkiye has been highly integrated, and these two commodities are the most important actors in the agricultural production network of Türkiye. Production shocks arising from wheat and barley have been highly transmitted to others. Thus, the production of these two commodities should be carefully monitored. The policies implemented for these commodities, such as production planning, incentives, and export/import regulations, will have a significant impact on the production of other products. Policy makers should consider the potential effects of the policies applied to these two commodities, especially on oat, rye, and chickpea, and plan accordingly.

The results on pairwise connectedness demonstrate that diversification opportunities and risk management tools exist. For instance, a producer can cultivate a type of commodity that has low connectedness (e.g. paddy or lentil) with others in absolute terms or cultivate two commodities rather than one commodity that almost has no pairwise shock transmissions. Thus, with this perspective, diversification and managing operational risks are possible. Besides, if there is an expectation (market or individual) that the production of a specific commodity will rise in the next period, a risk-seeking producer may take a counter position by connectedness and network analysis results and maximize his/her profit. For example, if there were an expectation that barley production would rise in the next period, one could cultivate lentils and chickpeas to benefit from the decreasing supply of these commodities. Although many other producers would cultivate barley and the supply of other commodities in the market will fall, the ones with the highest net negative pairwise connectedness with barley will be affected more than others. Different scenarios can be constituted for other commodities as well. The recommendations above are also true for parties other than producers, such as governments who would like to direct the production of specific commodities and set agricultural policies, profit-seeking suppliers, traders, business parties both national and cross-border, and so on.

The main limitation of this study is that I only constructed a static analysis that has no time-varying features of agricultural production. But as the theory of economics tells us, relationships and interactions in economic variables are time-varying and change over time. Also, some important global events and crises (such as wars, global financial crises, and global food crises) have important impacts on economic variables. By using a static analysis, I ignore these effects. For further studies, this issue can be overcome with a model capable of predicting time-varying parameters. This can be accomplished using higher frequency time series data (such as monthly or quarterly data). As a result, the evolving structure of network relationships can be examined, enabling a more in-depth analysis.

Another important limitation of this study is that I built an endogenous model and did not consider any exogenous effects. In further studies, considering the influences of other variables such as production in other countries, the real side of the economy, socioeconomic indicators, and so forth, on agricultural production will contribute to the literature on economics. A panel VAR model based on different countries' agricultural productions can be used to examine the impact of inter-country interactions agricultural production. Alternatively, the effect of various variables that are assumed to influence the agricultural production, such as industrial output, inflation, and energy prices, can be studied. Thus, the impact of different economic dimensions on agricultural production in Turkey can be investigated, leading to a better understanding of the subject.

References

Alter, A. and Beyer, A. (2014): The dynamics of spillover effects during the European sovereign debt turmoil. *Journal of Banking & Finance*, 42: 134-153.

Antonakakis, N. and Kizys, R. (2015). Dynamic spillovers between commodity and currency markets. *International Review of Financial Analysis*, 41: 303-319.

Asim, H. and Akbar, M. (2019): Sectoral growth linkages of agricultural sector: Implications for food security in Pakistan. *Agricultural Economics – Czech*, 65: 278–288.

Balkan, A., Özdüven, M., Nizam, İ., Teykin, E. and Tuna., M. (2011). The effect of grazing applied in the different phenological stages on yield and yield components of bread wheat and triticale. *Journal of Tekirdag Agricultural Faculty*, 8(1): 93-100.

Balli, F., Naeem, M. A., Shahzad, S. J. H. and de Bruin, A. (2019): Spillover network of commodity uncertainties. *Energy Economics*, 81: 914-927.

Barunik, J., Kočenda, E. and Vácha L. (2016): Asymmetric connectedness on the US stock market: Bad and good volatility spillovers. *Journal of Financial Markets*, 27: 55-78.

Bozkurt, İ. and Kaya, M. V. (2021): Agricultural production index: International comparison. *Agricultural Economics – Czech*, 67(6): 236-245.

Bruinsma, J. (2009). The Resource Outlook to 2050: by How Much Do Land, Water, and Crop Yields Need to Increase by 2050?, Rome, Italy: Food and Agriculture Organization of the United Nations. Available at: https://www.cabdirect.org/cabdirect/abstract/20093293510 (Accessed April 2, 2022).

Cristea, M. and Noja, G. G. (2019): European agriculture under immigration effects: New empirical evidence. *Agricultural Economics – Czech*, 65: 112–122.

Crost, B., Duquennois, C., Felter, J. H. and Rees, D. I. (2018): Climate change, agricultural production and civil conflict: Evidence from the Philippines. *Journal of Environmental Economics and Management*, 88: 379–395.

Dhahri, S. and Omri, A. (2020): Foreign capital towards SDGs 1 & 2 – Ending poverty and hunger: The role of agricultural production. *Structural Change and Economic Dynamics*, 53: 208–221.

Diebold, F. X. and Yilmaz, K. (2009): Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, 119(534): 158-171.

Diebold, F. X. and Yilmaz, K. (2012): Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, 28(1): 57-66.

Diebold, F. X. and Yilmaz, K. (2014): On the network topology of variance decompositions: Measuring the connectedness of financial firms. *Journal of Econometrics*, 182(1): 119-134.

FAO (2009): Global Agriculture Towards (2050) How to Feed the World 2050, High-level Expert Forum. Available at: http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf (Accessed April 2, 2022).

Ferrer, R., Shahzad, S. J. H., López, R. and Jareño, F. (2018): Time and frequency dynamics of connectedness between renewable energy stocks and crude oil prices. *Energy Economics*, 76: 1-20.

Johnston, B. F. (1970): Agriculture and structural transformation in developing countries: A survey of research. *Journal of Economic Literature*, 8: 369–404.

Lovcha, Y. and Perez-Laborda, A. (2020): Dynamic frequency connectedness between oil and natural gas volatilities. *Economic Modelling*, 84: 181-189.

Machethe, C. L. (2004): Agriculture and poverty in South Africa: Can agriculture reduce poverty? *Conference on the Overcoming Underdevelopment in Pretoria, South Africa*, Oct 28–29, 1–14. Pretoria, South Africa.

Mellor, J. W. (1995): Agriculture on the Road to Industrialisation. London, UK, the Johns Hopkins University Press: 1–358.

Mohammed, R. (2020): The causality between agriculture and economic growth in the Arab world. *Eurasian Journal of Economics and Finance*, 8: 54–67.

Negiş, H. (2017). Effects of four different crops harvest processes on soils compaction. *Journal of Tekirdag Agricultural Faculty*, The Special Issue of 2nd International Balkan Agriculture Congress: 25-29.

Pingali, P. L. (2012): Green revolution: impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, 109(31): 12302-12308.

Polat, O. (2020): Frequency connectedness and network analysis in equity markets: evidence from G-7 countries. *Akdeniz Journal of FEAS*, 20(2): 221-226.

Reboredo, J. C., Ugolini, A. and Aiube, F. A. L. (2020): Network connectedness of green bonds and asset classes. *Energy Economics*, 86: 104629.

Rosa, L., Rulli, M. C., Davis, K. F., Chiarelli, D. D., Passera, C. and D'Odorico, P. (2018): Closing the yield gap while ensuring water sustainability. *Environmental Research Letters*, 13(10): 104002.

Shahzad, S. J. H., Bouri, E., Arreola-Hernandez, J., Roubaud, D. and Bekiros, S. (2019): Spillover across Eurozone credit market sectors and determinants. *Applied Economics*, 51(59): 6333-6349.

Singariya, M. R., Naval, S. C. (2016): An empirical study of intersectoral linkages and economic growth in India. *American Journal of Rural Development*, 4: 78–84.

Su, X. (2020): Dynamic behaviors and contributing factors of volatility spillovers across G7 stock markets. *The North American Journal of Economics and Finance*, 53: 101218.

TGB (2022): Grain purchases tables. Turkish Grain Board. Available at: https://www.tmo.gov.tr/info-center/38/tables (Accessed April 2, 2022).

Tian, X., Engel, B. A., Qian, H., Hua, E., Sun, S. and Wang Y. (2021): Will reaching the maximum achievable yield potential meet future global food demand?. *Journal of Cleaner Production*, 294: 126285.

Toyoshima, Y. and Hamori S. (2018): Measuring the time-frequency dynamics of return and volatility connectedness in global crude oil markets. *Energies*, 11(11): 2893.

TURKSTAT (2022): Foreign trade statistics of Turkey. Turkish Statistical Institute. Available at: https://data.tuik.gov.tr/Bulten/Index?p=Dis-Ticaret-Istatistikleri-Aralik-2021-45535 (Accessed April 2, 2022).

UNCHR (2022): Refugee data finder. The United Nations Refugee Agency. Available at: https://www.unhcr.org/refugee-statistics/#:~:text=Between%202018%20and%202020%2C%20an,a%20refugee%20life%20per%20year.&text=Some%20126%2C700%20refugees%20returned%20to,with%20or%20without%20UNHCR's%20assistance (Accessed April 2, 2022).

Van Wart, J., Kersebaum, K. C., Peng, S., Milner, M. and Cassman, K. G. (2013): Estimating crop yield potential at regional to national scales. *Field Crops Research*, 143: 34-43.

World Bank (2022): Population growth (annual %) data. The World Bank. Available at: https://data.worldbank.org/indicator/SP.POP.GROW (ccessed April 2, 2022).

Zhang, D. (2017): Oil shocks and stock markets revisited: Measuring connectedness from a global perspective. *Energy Economics*, 62: 323-333.