Forecasting Agricultural Production: A Chaotic Dynamic Approach[1]

Bünyamin Demir
Department of Mathematics, Anadolu University, Eskisehir, Turkey.
bdemir@anadolu.edu.tr

Nesrin Alptekin
Department of Management, Anadolu University, Eskisehir, Turkey.
nesrinesen@anadolu.edu.tr

Yılmaz Kılıçaslan[2]
Department of Economics, Anadolu University, Eskisehir, Turkey.
ykilicaslan@anadolu.edu.tr

Mehmet Ergen
Department of Mathematics, Anadolu University, Eskisehir, Turkey.
mergen@anadolu.edu.tr

Nilgün Çağlarırmak Uslu
Department of Economics, Anadolu University, Eskisehir, Turkey.
ncaglarirmak@anadolu.edu.tr

Abstract

The aim of this study is to examine the existence of chaotic structure in agricultural production in Turkey by using "Chaotic Dynamic Analysis (CDA)" and to provide accurate forecast of agricultural production. The data of wheat, barley and rice production in Turkey was obtained from Turkish Statistical Institute (TURKSTAT) and covers the period of 1991 to 2009. Our analysis shows that the supply of the selected agricultural products has chaotic structure. Our dynamic system constructed predicted the supply of year 2010 with % 0.5 error for wheat, %5 error for barley, and %2.5 error ratio for rice. This study is the first attempt using CDA to forecast future agricultural product supply in Turkey. The findings of this study will help to produce effective policies to prevent supply disequilibrium, and excess price fluctuations.

Keywords: Chaotic dynamic analysis, lyapunov exponent, deterministic nonlinear prediction, agriculture, Turkey.

JEL Codes: C60, C61, Q11

---

[1] This work was supported by TUBITAK (The Scientific and Technological Research Council of Turkey) as a part of 109K129 research project.
[2] **Correspondence:** Department of Economics, Faculty of Economics, Anadolu University, 26470, Eskisehir, Turkey. Phone: +90 222 3350580 ex: 2648, Fax: +90 222 3201304, e-mail: ykilicaslan@anadolu.edu.tr

1. Introduction

Changes in the Earth's ecological system due to climate change and the increase in the demand for agricultural products in recent years have triggered disequilibrium tendencies in the markets for agricultural products. This development has made agricultural production and productivity in agricultural sector more important than ever.

The aim of this study is to examine the existence of chaotic structure in agricultural production in Turkey by using "Chaotic Dynamic Analysis (CDA)" and to provide accurate forecast of agricultural production. The main reason for choosing this method is the assumption that crop production has a chaotic structure. The systems that have chaotic structure can't be solved by using deterministic linear models. But, estimation of the supply of agricultural products in the next period can be accurately estimated by models that are suitable to the products' production structure. That will help to produce effective policies to prevent supply disequilibrium, and excess price fluctuations.

The data of wheat, barley and rice production in Turkey was obtained from Turkish Statistical Institute (TURKSTAT) and cavers the period of 1991 to 2009. Our analysis shows that the supply of the selected agricultural products has chaotic structure. Our dynamic system constructed predicted the supply of year 2010 with %0.5 error for wheat, %5 error for barley, and %2.5 error ratio for rice. This study is the first attempt using CDA to forecast future agricultural product supply in Turkey. The findings of this study will help to produce effective policies to prevent supply disequilibrium, and excess price fluctuations.

The rest paper is organised as follows: The next section discuses chaos theory and its application in both economics and agriculture. Construction of the dynamic system and testing the chaotic structure of the series of the selected agricultural products is presented in section 3. One year supply predictions of wheat, barley and rice are given in section 4.

Prediction of the supply of the selected products in 2010 is provided in section 5. Finally, section 6 concludes.

2. Plant Production and Chaos: Theory and Literature

Chaos theory attempts to reveal the possible irregularities in the order. Chaos in a system may be due to a specific parameter of the system or the structure of the system. The most important indicator used in determining the chaotic structure of system which is extremely sensitive to initial conditions is said to be “Lyapunov exponent”. The indicator of chaotic behaviour in a system is the existence of positive Lyapunov exponential. Although in it is hard to make long-term predications for chaotic dynamic system, it is possible to make short term forecasts according to the degree of Lyapunov exponent which indicates the degree of chaotic structure.

2.1. Chaos and Chaos Theory

The most general definition of chaos referred to as ‘non–scheme and unpredictable situation’ is defined as ‘irregularity pattern’ in science. Perhaps, the most satisfactory definition of chaos concept is the one given by physicist Jensen: “Chaos is irregular and unpredictable behaviour of complex linear dynamic systems” (Gleick, 2000:16). Chaos represents a stochastic behaviour that is generated by deterministic system (Tsonis, 1992 and Medio, 1992). Chaotic series may be expressed as non–linear, dynamic and deterministic series (Brock, 1986). A chaotic system is the system highly sensitive to initial conditions. A very small change in initial conditions may cause system to create very large fluctuations in long term. The dynamics seems to be random in chaotic system may be the outcome of a deterministic system (Wei and Leuthold, 1998). Chaos is a phenomenon that can be controlled if it’s determined.

Chaos theory may be applied many branches of science, although it’s emerged in the field of science such as mathematics, physics. The idea that dynamic systems may show chaotic behaviour was first seen in the works of J.H.Poincare's as "three body problem". In the beginning of the 20th century Poincare showed that how much dynamic system depend on initial conditions by modelling the solar system in his study (Karaçay 2004). However the recognition of this phenomenon by different disciplines had been in the second half of 20th century. Lorenz in his model of weather pattern with 12 variables, for example, identified that a very small change in initial conditions could lead to unforeseen different situations as time progresses (Lorenz, 1963).

Chaotic dynamical systems usually have attractors that have called "strong attractors". Fractal dimension (*Minkowski dimension*) and correlation dimension of these attractors provide information about the magnitude of the chaotic structure. Intuitively the size of a set should be a natural number. Particularly the topological dimension, there are dimensions that the size of a set can be only natural numbers. However there are sets that characterize the size of these sets with the natural numbers doesn't seem to be realistic. For this reason, all non – negative real numbers may be the size needed. Trailers of fractals and chaotic dynamical systems are often the sets of this type.

A reconstruction of a dynamic system from a time series obtained from a specific system is based on a theorem of Taken (1981). According to this theorem, there are similarities between the original dynamic system and the dynamic system generated with the help of time series. It's quite possible to have information about the structure of the original dynamic system by the help of the dynamic system generated. For example, it's possible to determine whether the system has a chaotic structure by calculating the Lyapunov exponents of system generated by using the time series (Wolf et all.,1985; Eckmann and Ruelle,1985; Eckmann et all. 1986; Bryant and Brown 1990; Brown, 1993). Fractal dimension or correlation dimension of created dynamic system's attractor may also provide information about the chaotic structure of original dynamic system (DeGrauwe et all., 1993 and Çetin 1994).

Although long time series are preferred in investigating the chaotic structures of the systems, it's possible to examine the chaos by using short time series (Rosenstein et all 1993; Demir, 1999; Sakai et all, 2008). If the generated system is chaotic, then it's possible to make short-term predictions (Sakai et all, 2008; Casidagli, 1989).

2.2. Chaotic Approach to Economic Modelling

The first step in chaotic dynamic approach is to determine the classic 'white noise' or 'chaotic noise'. Brock, Dechert and Scheinkman (1987) (CBT) test is a test developed to check if there is any random or unknown structure in a given time series. This test is very important in determination of whether the series repeats itself in a systematic way or has any random values or not. The problem emerging frequently in economic modelling is the use of deterministic equilibrium models observed mostly in irregular movements of time series and random looking fluctuations. Superiority of non linear chaotic models is that they enable to drive this kind of irregular moments without stochastic variables (Bacsi, 1997).

Establishment of models that have chaotic dynamics is very simple in economics. Collett and Eckmann (1980) showed that any shifting relation in x(t+1) curve as a function of x(t) is hill shaped. Moreover, this kind of behaviour can be constructed with the help of appropriate parameters. The most fundamental problem of the existence of chaos in an economic time series is to model the noise, trend and general structural changes of the time series.

While changes in the structure of series may be modelled by ARCH (autoregressive conditional heteroscedasticity) or GARCH (generalised autoregressive conditional heteroscedasticity) that allows changing mean and variance, modelling the noise and the trend in series is much more difficult. These problems are usually due to lack of sufficient number of observations.

Hinich, BDS, White and Kaplan tests are the tests used in investigating the existence of non-linear structure and chaos in economic variables. Grassberger-Procaccia (GP) Correlation Dimension test which based on restructuring of phase space is used in investigation of the chaos existence in time series.

The most prominent feature of chaotic systems is being highly sensitive to initial conditions. The most important method used in determining the sensitive dependence on initial conditions of the system, or the existence of chaotic structure, is the method of Lyapunov exponent (Barnett and Serletis, 2000). Lyapunov exponent measures the mean level of convergence or divergence from difference between paths due to infinitely small differences in initial conditions of series (Barnett and Serletis, 2000). A positive Lyapunov exponent indicates the existence of chaotic behaviour in the series. Therefore, Nychka et all. (1992) has proposed a regression method, NEGM for testing positive dominant Lyapunov exponent. Lyapunov exponent approach used to analyze chaotic structure in series, is an approach that requires both long time series and more sensitive to dynamic noise (Barnett and Serletis, 2000).

The applications of chaotic approach in economic modelling are observed to be concentrated more in financial markets. There are two reasons for this: First chaotic dynamic analysis methods require long time series. The data on financial markets are quite suitable because one may find hourly, daily and weekly data for financial markets. Secondly, prediction of future price and / or return realizations of estates is very important in these markets.

One of the first studies investigating the existence of chaotic structure of securities is Frank and Stengos (1989)’s study using methods that analyze GP correlation dimension and

Kolmogorov entropy for daily, weekly and two weekly returns for the period 1974 – 1986 of silver and gold market. The study has determined that gold and silver yield series show chaotic behaviour and reached the result that price changes in securities can be estimated for short term. Hsieh (1989) in his study describing the non linear dependence of five different exchange rate series has found that the GARCH model explains a large part of the non linear dependence of series. Lee, Sewell and Stansell (1992) have found that existence of non – linear structures of weekly changes of stock exchange market indices of four emerging Asian (Hong Kong, Korea, Singapore and Taiwan), Japan and America markets. Abhyankar ve Copeland (1997), in their work exploring whether there is a low dimensional chaotic processes in these markets and testing non – linear dependence in securities markets, showed the presence of non – linear structures, but have found that these series have not a low – dimensional chaos.

Harrison et. all. (1999) in their study on Standard and Poors composite index series between the years 1928 and 1987 consisting of 16127 observations investigated the existence of chaotic structure in the series. In this study, they found a strong degree of chaos in S&P 500 series by using the GP correlation dimension test. Furthermore, the accuracy of the results was directly proportional to the length of the series and 5000 observation was adequate in determining the deterministic dynamics. In 1960 – 1992, Serleris (1995) examined the chaotic dynamics of monthly money supply series by different methods and concluded that money supply series were chaotic in the period examined. In another study investigating the chaotic structure in the series of black market exchange rates of seven Eastern European countries by using the BDS test, Negm test and Lyapunov exponent approaches, Serletis and Gogas (1997) have identified the existence of chaotic structure in the series of Russian Ruble and East Germany Mark.

Panas (2001) tested if there is long term memory and chaotic structure by price series of six selected metal product in London metal market. In this study correlation dimension for the returns of metal products, entropy and Lyapunov exponent are used for determining the chaotic behaviour. The findings showed that metal price series show time dependent varying volatility and large skewness and kurtosis. That means that the series are not normally distributed. This result suggests that there are non – linear dynamics in these series.

2.3. Chaotic Approach to Modelling Supply and Demand of Agricultural Products

The first dynamic system developed to explain the cycles in agricultural production and thereby product price cycles was perhaps suggested by Cobweb. The Cobweb model replaced as Cobweb theorem in the literature of the agricultural economics. This model argues that the imbalances between supply and demand of agricultural products, so price fluctuations, is the result of supply decision of next semester based on the current market data in this period. These imbalances in the market of agricultural products that have different elasticity of supply and demand are an inevitable phenomenon.

Chavasand and Holt (1993) in his study examining the deterministic chaotic structure of pork production found evidence the existence of chaotic structure by using GP correlation. Similarly, Chiarella (1988) found chaotic behaviour in the parameters of Cobweb model that used to determine the price dynamics in fully competitive markets. Cromwell and Labys (1993) examined the movements of monthly cocoa, coffee, rice, sugar, tea and wheat prices between the years of 1960 – 1992 and found nonlinear dependence in the cocoa, tea and sugar prices by using that Garch (1,1). Moreover with the help of the Lyapunov exponent, they show that wheat price has a chaotic structure. Burton (1993) showed the existence of chaos in the model of agricultural products with the help of the logistic map.

While there is quite enough study modelling the chaotic structure in price or returns of goods or asset, there are quite few studies investigating the chaotic structure in crop production series. Perhaps the first study investigating the chaotic structure of variables in agriculture, crop production or ecological system is May's (1976) discrete logistic model showing the chaotic structure of the ecological system. However, the one – dimensional discrete models derived from ecological data to determine the chaotic behaviour wasn't very successful (Sakai, 2001:59). In determining the chaos in ecological systems the responce surface methodology (RMS) developed by Turchin and Taylor has been emerged as a new alternative. Indeed, Sakai (2001:67) determined low dimensional deterministic chaotic structure in a corn production series by using RMA. Similarly, Tilman and Wedin (1993) identified the chaotic surge in grass production. Sakai et. all. (2008), examined the chaotic dynamics in the ecological time series with a very few data and found that the system has a chaotic structure. In the same study, they found that tangerine production exhibit chaotic behaviour.

3. Chaotic Dynamic Analysis of Selected Agricultural Products and Supply Predictions

In this part of the study, the dynamics of the production barley, wheat and rice produced in Turkey are examined and production quantities of these products are predicted in the near future. Lyapunov exponents are calculated for examination of the dynamics of production of the related products by following Sakai et al. (2008) and the supply of the next year was predicted.

The data on the production volumes of the provinces are obtained from the Statistical Institute of Turkey between the years 1991-2009.

Barley, wheat and rice production data are examined separately. If i and t denotes province/region and year respectively, then the series for each product may be written as follows:

$$x(i,t)$$

Time series for these products are constructed as follows:

for wheat and barley;

x(Adana,1991), x(Adana,1992),…, x(Adana,2008), x(Adana,2009)

x(Adıyaman,1991), x(Adıyaman,1992),…, x(Adıyaman,2008), x(Adıyaman,2009)

.

.

.

x(Zonguldak,1991), x(Zonguldak,1992),…, x(Zonguldak,2008), x(Zonguldak,2009)

and for rice,

x(1. region,1991), x(1. region,1992),…, x(1. region,2008), x(1. region,2009)

x(2. region,1991), x(2. region,1992),…, x(2. region,2008), x(2. region,2009)

.

.

.

x(6. region,1991), x(6. region,1992),…, x(6. region,2008), x(6. region,2009).

The points of three-dimensional space (R^3) are obtained from provincial time series of each product over the years, $t = 1993, 1994, ..., 2009$

$$X(i,t) = \left(x(i,t), x(i,t-1), x(i,t-2)\right)$$

In other words, the time series are embedded to R^3. A dynamic is defined in R^3 by setting the next period value of any $X(i,t)$ to the point $X(i,t+1)$. To determine whether the system has a chaotic structure, after selecting a point $X(i,t)$, the near points were determined. The same calculations were repeated by changing the near points from 4 to 12. The *k* points those near to the point $X(i,t)$ are shown as $Y(i,t,p),\ p = 1,2,...,k$. In this case, if the distance between $Y(i,t,p)$ and $X(i,t)$ is $D(i,t,p)$, then the point $V(i,t)$ representing points sufficiently near to the $X(i,t)$ may be formulated as follows:

$$V(i,t)=\sum_{p=1}^{k}\frac{Y(i,t,p)(D(i,t,p))}{\sum_{q=1}^{k}D(i,t,q)}$$

The value of $V(i,t)$ in the next period is defined as follow:

$$U(i,t)=\sum_{p=1}^{k}\frac{Y(i,t+1,p)(D(i,t,p))}{\sum_{q=1}^{k}D(i,t,q)}$$

To determine the Jacobian matrix around $V(i,t)$, again k points near to the point $V(i,t)$ are determined in R^3. These points are defined as $R(i,t,p), p=1,2,...,k$. Let the difference between $R(i,t,p), p=1,2,...,k$ and $V(i,t)$ is

$$y(i,t,p)=R(i,t,p)-V(i,t)$$

and the difference vector between value of $R(i,t,p)$ and $U(i,t)$ is

$$z(i,t,p)=R(i,t+1,p)-U(i,t).$$

If the Jacobian matrix around $V(i,t)$ is $G(i,t)$, then it should be

$$z(i,t,p)\approx G(i,t)y(i,t,p) \qquad p=1,2,...,k.$$

For $z(i,t,p)=(z_{1,p},z_{2,p},z_{3,p})$ and $y(i,t,p)=(y_{1,p},y_{2,p},y_{3,p})$, $G(i,t)$ matrix can be calculated as follow:

$$G(i,t).\begin{bmatrix}\sum_{p=1}^{k}y_{1,p}^{2} & \sum_{p=1}^{k}y_{2,p}y_{1,p} & \sum_{p=1}^{k}y_{3,p}y_{1,p}\\ \sum_{p=1}^{k}y_{1,p}y_{2,p} & \sum_{p=1}^{k}y_{2,p}^{2} & \sum_{p=1}^{k}y_{3,p}y_{2,p}\\ \sum_{p=1}^{k}y_{1,p}y_{3,p} & \sum_{p=1}^{k}y_{2,p}y_{3,p} & \sum_{p=1}^{k}y_{3,p}^{2}\end{bmatrix}=\begin{bmatrix}\sum_{p=1}^{k}z_{1,p}y_{1,p}^{2} & \sum_{p=1}^{k}z_{1,p}y_{1,p} & \sum_{p=1}^{k}y_{3,p}y_{1,p}\\ \sum_{p=1}^{k}y_{1,p}y_{2,p} & \sum_{p=1}^{k}y_{2,p}y_{1,p} & \sum_{p=1}^{k}y_{3,p}y_{2,p}\\ \sum_{p=1}^{k}y_{1,p}y_{3,p} & \sum_{p=1}^{k}y_{2,p}y_{3,p} & \sum_{p=1}^{k}y_{2,p}y_{1,p}\end{bmatrix}$$

3.1. Determining Lyapunov exponents

For obtaining time series predictions of supply of barley, wheat and rice, Oseledec eigenvalues of the matrix is calculated by taking time shift for one year as follow:

$$O(i,t)=[G(i,t)G(i,t)^{T}]^{\frac{1}{2}}.$$

The eigenvalues at the point $V(i,t)$ are the local Lyapunov exponents and existence of positive eigenvalues (positive Lyapunov exponents) is the indicator of being chaotic.

The chaotic structure of barley, wheat and rice production in Turkey is determined by considering Lyapunov exponents. Three-dimensional dynamical systems separately for each product are built from the data between 1991 and 2008. Thus, the system will have 3 different Lyapunov exponents. It is sufficient for the chaos that the system has one Lyapunov exponent

For creating Jacobian matrix, different near points from 3 to 12 are used. In each case, it is found that one of the Lyapunov exponents of cities or regions is always positive, one is around zero and the other is negative.

Lyapunov exponents have a variable structure in provincial or regional data although average is between 1 and 2. Lyapunov exponents obtained for Turkey are given in Table 1. Table 1 shows that Lyapunov exponents for each product is all positive so barley. This finding implies that wheat, barley, and rice production in Turkey have a chaotic structure.

Table 1. Lyapunov exponents for Turkey

	Barley	Wheat	Rice
1993	1,37	1,39	1,01
1994	1,36	1,43	1,01
1995	1,30	1,44	0,97
1996	1,42	1,31	0,96
1997	1,46	1,58	1,30
1998	1,48	1,38	0,84
1999	1,25	1,47	1,11
2000	1,36	1,37	0,83
2001	1,20	1,24	0,58
2002	1,19	1,15	0,67
2003	1,30	1,38	1,20
2004	1,32	1,27	1,15
2005	1,29	1,24	1,42
2006	1,43	1,46	1,04
2007	1,39	1,38	0,92
2008	1,17	1,10	0,73

Source: It is calculated by the authors using the data TUİK (2010).

4. One-Year Supply Predictions of Selected Products

The next year predicted value of production of barley, wheat and rice is as follows: Let denote the next year predicted point $\hat{X}(i,t+1)$ that is obtained from the point $X(i,t)=\left(x(i,t),x(i,t-1),x(i,t-2)\right)$. The following equation is used for the predicted point:

$$\hat{X}(i,t+1)=U(i,t)+G(i,t)(X(i,t)-V(i,t)).$$

Thus, the predicted supply of the product is equal to the first component of predicted production. Turkey's total production estimate is obtained by collecting of these values.

Annual supply predictions of barley, wheat and rice are obtained for near points 4, 5 and 6. Reasonable results were obtained from close point 5.

4.1. Barley Prediction for Near 5 Points:

Barley production prediction for five near point and the actual production values are given in Figure 1. The Figure 1 shows that predicted values from the year 1994 to 2004 are quite close to the values of the actual production.

Predicted values are obtained with a zero error between in 2001. However, the actual production is under predicted between 1994-2001 and over predicted between 2001-2004. The average prediction error for wheat is about 0.6%.

4.2. Barley Prediction for Near 6 Points:

Barley production prediction for near six point and the actual production values are shown in Figure 2. From the near 6-point predictions of barley production, it can be seen that the barley production has not been predicted exactly during the analysis period. It can be seen from the Figure 2, predicted values are very close to the actual ones in the years 2000, 2001, 2002 and 2006. The margin of error is 2% for the years 2000, 2001 and 2002, while the margin of error is 1% for the year 2006. The largest deviations of predicted from actual values realized in 2007 and 2008. Prediction error is 16% in 2007 and 23% in 2008. Percentage of prediction error of near six point prediction is about 2%.

4.3. Wheat Prediction for Near 5 Points:

Wheat production prediction for five near point and the actual production values are shown in Figure 3. The closest results to the actual production value are obtained in years 1997 and 2002. The prediction error in these years came out to be 1%. Wheat production has not been precisely predicted during the analysis period. Prediction error is the highest in years 2009 and 2007, respectively with 14% and 15%. Average error margin of predictions is obtained as 1% in the period under examination.

4.4. Wheat Prediction for Near 6 Points:

Wheat production prediction for six near point and the actual production values are shown in Figure 4. Actual production and predicted production amount in wheat are same in year 2002. The highest margin of error was in year 2006 with 16%. The error percentage of average of predicted values is 1% in the analysis period. The results on the wheat production, shows that the near 5 point estimations is better than the near 6 point predictions.

4.5. Predictions of Rice Production

Because rice is not produced in every provinces of Turkey, the rice production is predicted for 6 different region of Turkey. These regions are:

1. region: Edirne, İstanbul, Kırklareli, Tekirdağ
2. region: Balıkesir, Bursa, Çanakkale, İzmir
3. region: Ankara, Bolu, Çankırı, Eskişehir, Zonguldak, Kırıkkale, Karabük, Düzce
4. region: Amasya, Çorum, Kastamonu, Samsun, Sinop, Tokat
5. region: Adana, Antalya, Gaziantep, Hatay, Mersin, Kahramanmaraş, Osmaniye
6. region: Adıyaman, Artvin, Bingöl, Bitlis, Diyarbakır, Elazığ, Erzurum, Hakkâri, Malatya, Mardin, Siirt, Şanlıurfa, Batman, Şırnak, Iğdır.

4.6. Rice Prediction for Near 5 Points:

The near 5 point prediction results of rice production are given Figure 5. Actual and predicted rice production in 2001 is equal. The highest deviation of predicted value from actual value in rice production is realized in year 2005. The error is about 55% in this year.

4.7. Rice Prediction for Near 6 Points:

Figure 6 shows that the predicted rice production values are very close to the actual values from 1995 to 2003.The best results for near six point predictions are obtained in 1995 and 2001 with a prediction error of 1%.

5. Supply Predictions of Selected Products in 2010

In this section of study, predicted values of production of barley, wheat, and rice in 2010 were obtained by using data of 1991 – 2009. The values of the actual production quantities are obtained from TURKSTAT's bulletin 'Crop Production (Final Results)' published on March 25 of 2011.

5.1. Barley Production Predictions

Actual barley production in 2010 and predicted barley production (near 4, 5 and 6 points) are shown in Figure 7. The amount of actual barley production in 2010 was 7.2 million tons. The amount of barley production was predicted as 8.9 million tons obtained with estimate of the near point 4. Near 5 and 6 point predictions were found to be 9 and 7.5 million tons , respectively. The best prediction for barley production is obtained with near 6 point estimate in 2010 with 5% error.

5.2. Wheat Production Predictions

Near 4, 5, 6 point predicted and actual wheat production in 2010 are given in Figure 8. The amount of actual wheat production in 2010 was 19.6 million tons. The amount of wheat production was predicted as 18.4 million tons obtained with estimate of the near point 4. Near 5 and 6 point estimates turned out to be even better. The predictions were 19.2 and 19.5 million tons. The best estimate for wheat production in 2010 was the 6 point prediction with 0.5% error.

5.3. Rice Production Predictions

Figure 9 shows actual and predicted rice production in 2010. The amount of actual rice production in 2010 was 860 thousand tons. The 4, 5, and 6 point prediction of rice production were found to be 985, 838 and 780 thousand tons. The best estimate for rice production in 2010 with 2.5% error was the 5 point estimate.

6. Conclusion

This study examines the existence of chaotic structure in the supply of wheat, barley and rice in Turkey by using "Chaotic Dynamic Analysis (CDA)" and provides an alternative model of forecast of agricultural production. The systems that have chaotic structure can't be solved by using deterministic linear models. Therefore this study proposes a new model of forecast by using chaotic approach.

The data of wheat, barley and rice production in Turkey was obtained from Turkish Statistical Institute (TURKSTAT) and cavers the period of 1991 to 2009. Our analysis shows that the supply of the selected agricultural products has chaotic structure. Our dynamic system constructed predicted the supply of year 2010 with %0.5 error for wheat, %5 error for barley, and %2.5 error ratio for rice. This study is the first attempt using CDA to forecast future agricultural product supply in Turkey. This study, by proposing a new model of predication of the future values of agricultural supply, will help to produce effective policies to prevent supply disequilibrium, and excess price fluctuations.

References

Abhyankar, A. and Copeland L.S. (1997) Uncovering nonlinear structure in real-time stock market indices: The S&P 500, The DAX, The NIKKEI 225 and The FTSE 100, *Journal of Business& Economic Statistics*, **15(1)**, 1-14.

Bacsi, Z. (1997) Modelling chaotic behaviour in agricultural prices using a discrete deterministic nonlinear price model, *Agricultural Systems*, **55(3)**, 445-459.

Barnett, W.A.. and Serletis, A. (2000) Martingales, nonlinearity and chaos, *Journal of Economic Dynamics and Control*, **24**, 703-724.

Brown, R. (1993) Calculating lyapunov exponents for short and/or noisy data sets*, Physical Review E*, **47(6)**, 3962-3969.

Brock, W. A.. (1986) Distinguishing random and deterministic systems: abridged version, *Journal of Economic Theory*, **40**, 168-195.

Brock, , W.A., Dechert, W. and Schienkman, J. A. (1987) Test for independence based on the correlation dimension, Working Paper, University of Wisconsin at Madison, University of Houston, University of Chicago.

Bryant, P. and Brown, R. (1990) Lyapunov Exponents from Observed Time Series, *Physical Review Letters*, **65 (13)**, 1523-1526.

Burton, M. (1993) Some illustrations of chaos in commodity models, *Journal of Agricultural Economics*, **44(1)**, 38-50.

Casidagli, M. (1989) Nonlinear prediction of chaotic time series, *Physica D*, **35**, 335-356.

Chavas, J. P. and Holt, M. T. (1993) Market instability and nonlinear dynamics, *American Journal of Agricultural Economics*, **75**, 113-120.

Chiarella, C. (1988) The cobweb model, its instability and the onset of chaos, *Economic Modelling*, **5(4)**, 376-384.

Collett, P. and Eckmann, J. P. (1980) *Iterated Maps on the Interval as Dynamical Systems*, Birkhauser, Basle.

Cromwell, J.B. and Labys, W.C. (1993) *Testing for Nonlinear Dynamics and Chaos in Agricultural Commodity Prices*, Institute for Labor Study, West Virginia University.

Çetin, N. (1994) EEG'de Kaotik Boyut, Yayınlanmamış Doktora Tezi, Anadolu Üniversitesi, Fen Bilimleri Enstitüsü, Eskişehir, (1994).

Demir, B.,Dinamik Sistemler ve Nöron Siklusları, Yayınlanmamış Doktora Tezi, Anadolu Üniversitesi, Fen Bilimleri Enstitüsü, Eskişehir,(1999).

Degrauwe, P., Dewachter, H. and Embrechts, M. (1993) *Exchange Rate Theory, Chaotic Models of Foreign Exchange Markets*, Blackwell Publishers, London.

Eckmann, J. P. and Ruelle, D. (1985) Ergodic theory of chaos and strange attractors, *Reviews of Modern Physics*, **57**, 617-656.

Eckmann, J. P., Kamphorst, S. O., Ruelle, D. and Ciliberto, S. (1986) Liapunov exponents from time series, *Physical Review A*, **34(6)**, 4971-4979.

Frank, M. and Stengos, T. (1989) Measuring the strangeness of gold and silver rates of return, *Review of Economic Studies*, **56**, 553-567.

Gleick, J. (çev. F. Üçcan) (2000) *Kaos*, TÜBİTAK Popüler Bilim Kitapları, TÜBİTAK, Ankara.

Harrison, R., Yu, D., Oxley, L., Lu, W. and Donald, G. (1999) Non-linear noise reduction and detecting chaos: some evidence from the S&P composite price index, *Mathematics and Computers in Simulation*, **48**, 497-502.

Hsieh, D. (1989)Testing for nonlinear dependence in daily foreign exchange rates, *Journal of Business*, **62 (3)**, 339-368.

Karaçay, T. (2004) Determinizm ve Kaos, II.Mantık, Matematik ve Felsefe Sempozyumu, Tema: Kaos. Assos, (2004).

Lee, I. S., Sewell, S.P. and S.R. Stansell (1993) Nonlinearities in emerging foreign capital markets, *Journal of Business Finance & Accounting*, **20**, 237-248.

Lorenz, E. (1963) Deterministic nonperiodic flow, *Journal of Atmospheric Sciences*, **20**, 130-140.

May, R. (1976) Simple mathematical models with very complicated dynamics, *Nature*, **261**, 459-467.

Medio, A. (1992) *Chaotic Dynamics: Theory and Applications to Economics*, Cambridge University Press.

Nychka, D., Ellner, S., Gallant, R. and McCa!rey, D. (1992) Finding chaos in noisy systems, *Journal of the Royal Statistical Society B*, **54**, 399-426.

Panas, E. (2001) Long memory and chaotic models of prices on the London Metal Exchange, *Resources Policy*, **27**, 235–246,(2001).

Sakai, K. (2001) *Nonlinear Dynamics and Chaos in Agricultural Systems*, Elsevier, The Netherlands.

Sakai, K., Noguchi, Y. and Asada, S. (2008) Detecting chaos in a citrus orchard: reconstruction of nonlinear dynamics from very short ecological time series, *Chaos, Solutions and Fractals,* **38**, 1274-1282.

Tilman, D. and Vedin, D. (1993) Oscillation and in the dynamics of a perennial grass, *Nature*, **353**, 653-655.

Tsonis, A. A. (1992) *Chaos: From Theory to Applications*, Plenum Press, New York and London.

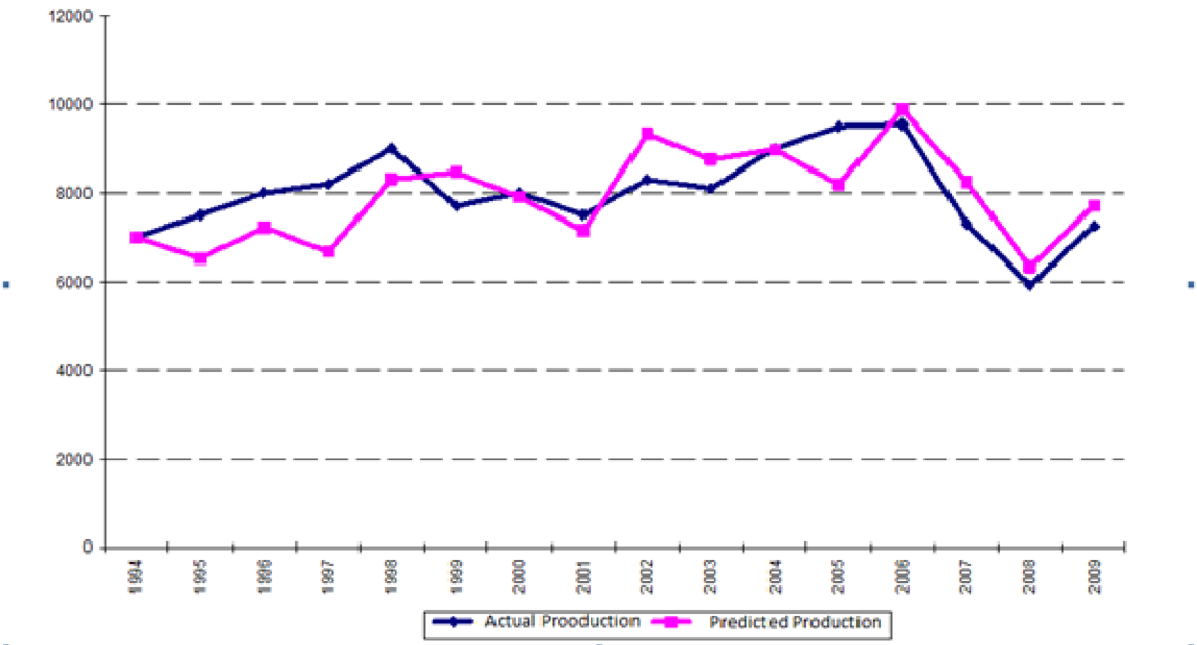
TUİK (2010) Tahıllar ve Diğer Bitkisel Ürünler, Tarım İstatistikleri, Türkiye İstatistik Kurumu, Ankara.

Turchin, P. and Taylor, A.D. (1992) Complex dynamics in ecological time series, *Ecology*, **73(1)**, 289-305,(1992).

Wei, A. and Leuthold, R. M. (1998) Long agricultural futures prices: ARCH, Long Memory Chaos Processes?, OFOR Paper Number 98-03.

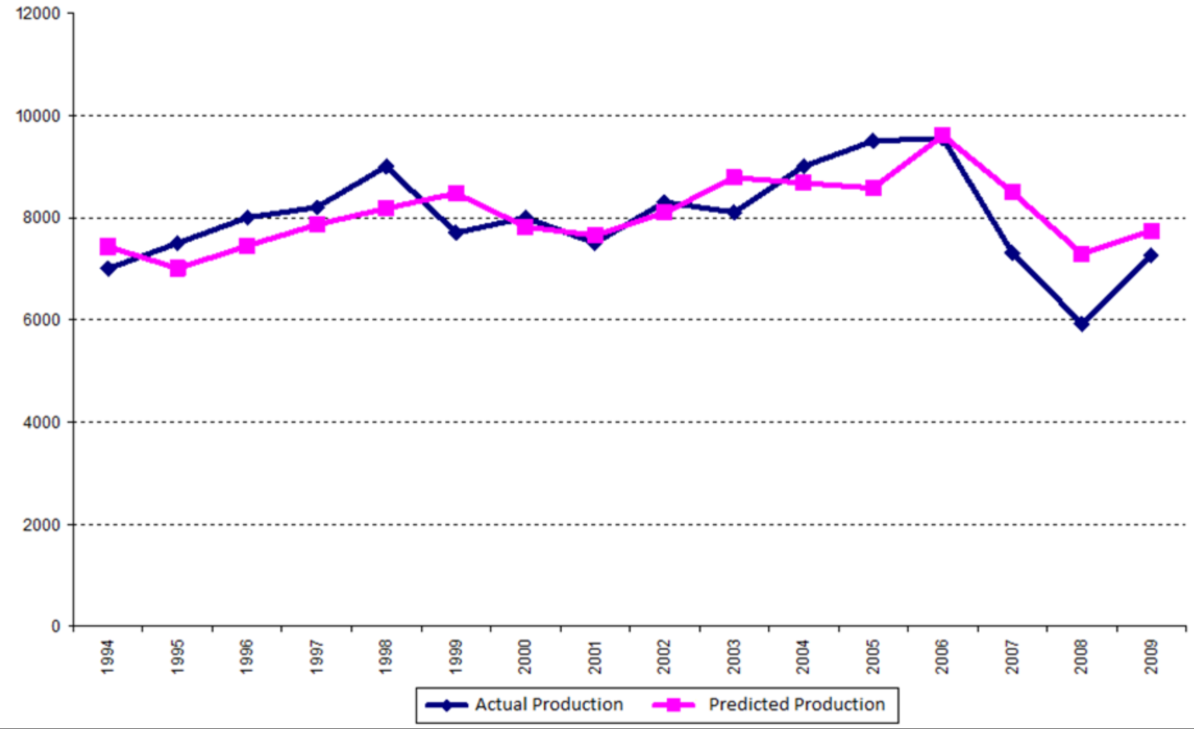
Wolf, A., Swift, J. B., Swinney, H. L. and Vastano, J. A. (1985) Determining lyapunov exponents from a time series, *Physica D*,**16**, 285-317.

Figure 1. Barley 5 Point Predictions



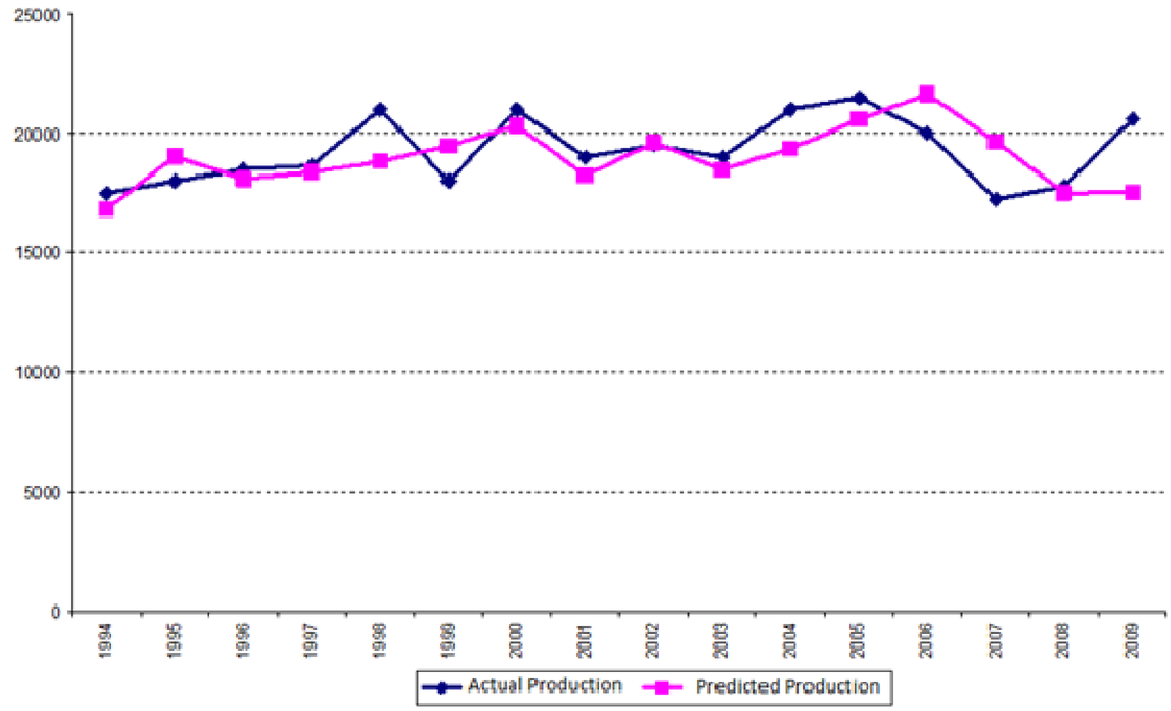
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 2. Barley 6 Point Predictions



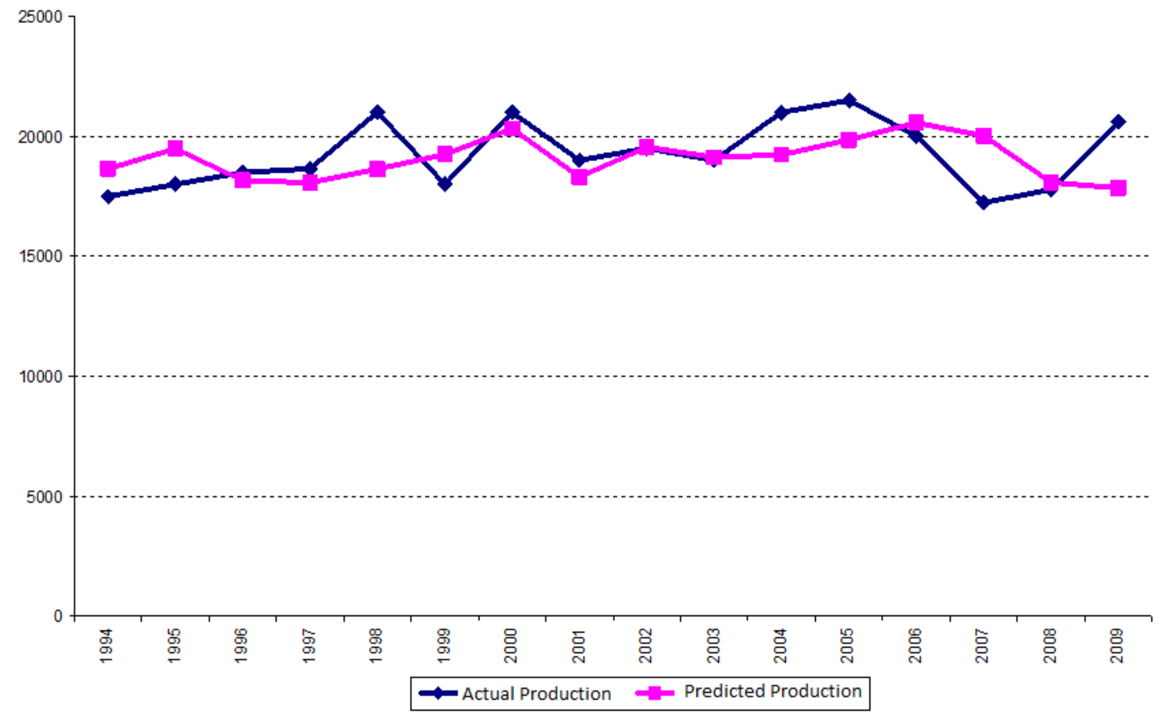
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 3. Wheat 5 Point Predictions



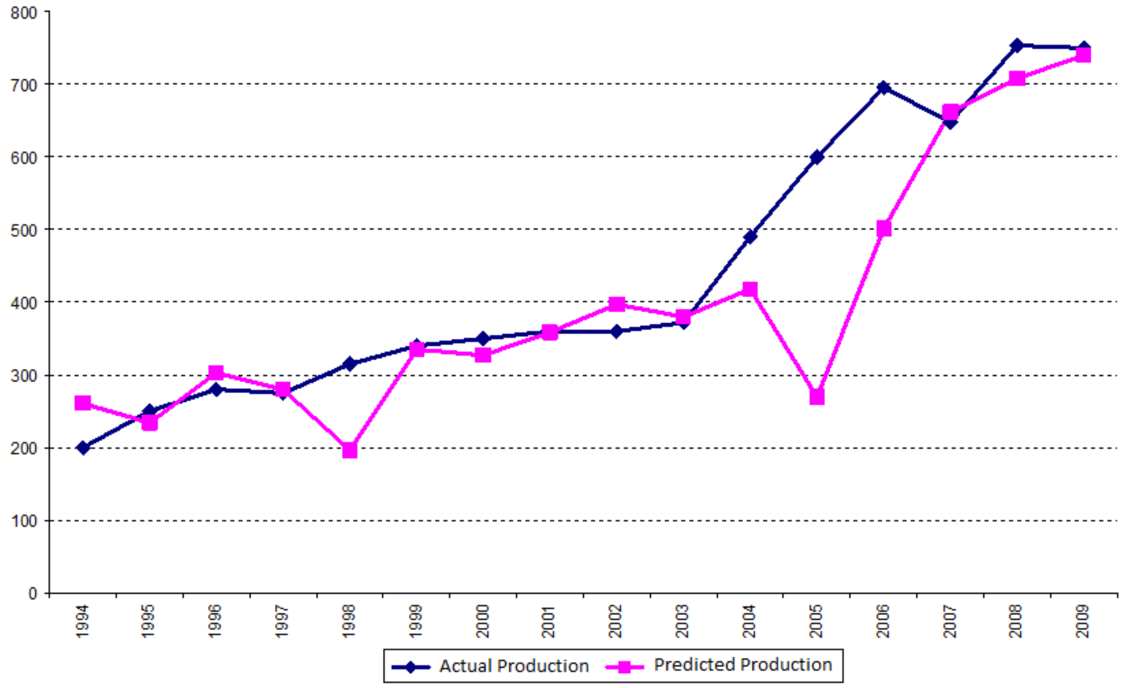
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 4. Wheat 6 Point Predictions



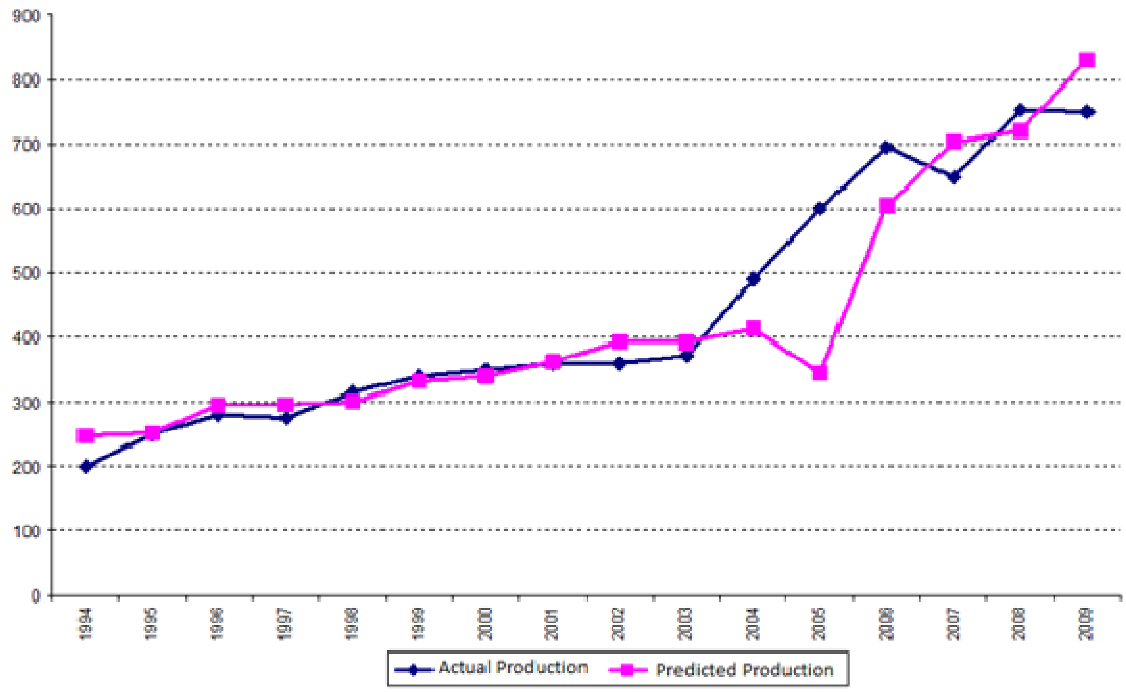
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 5. Rice 5 Point Predictions



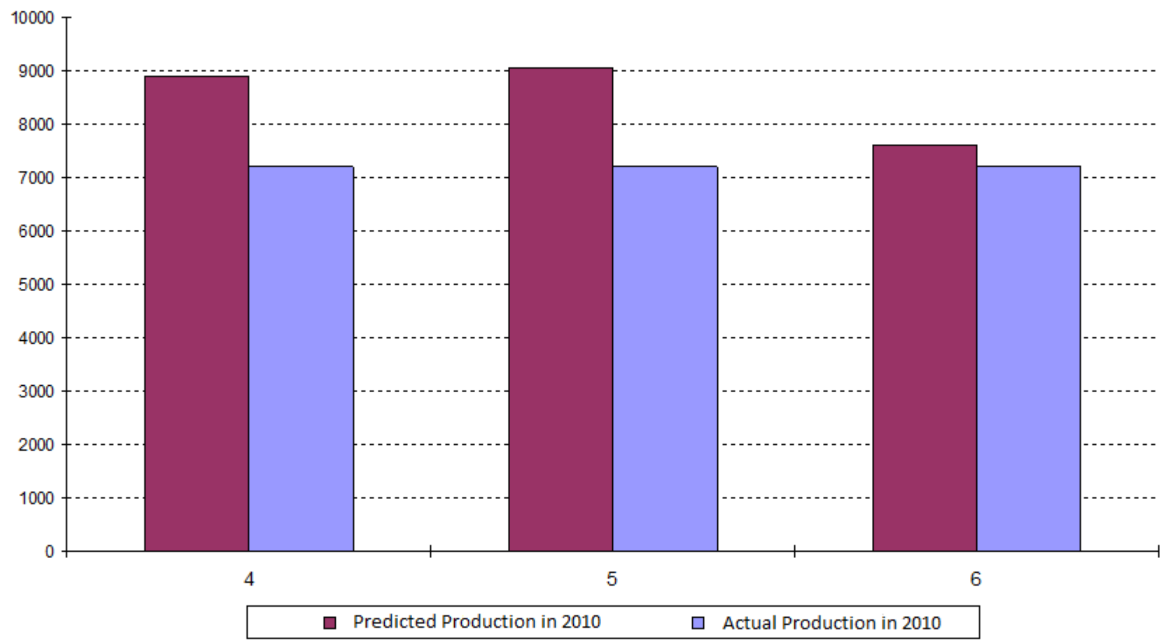
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 6. Rice 6 Point Predictions



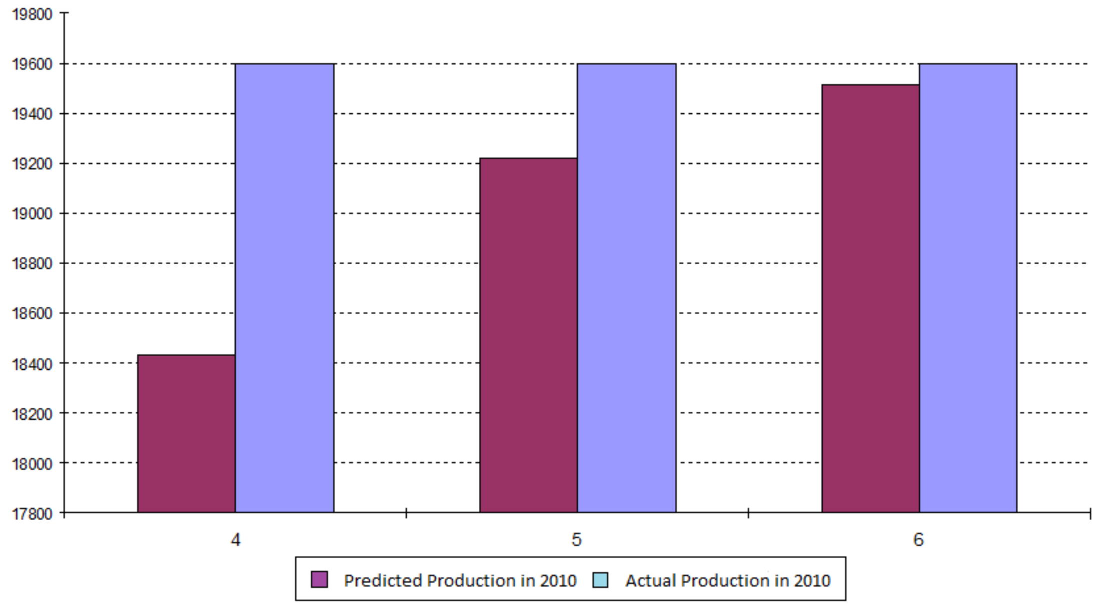
Source: Calculated by the authors.
Notes: Actual and predicted production values were measured as 1000 tons.

Figure 7. Predictions of barley production in 2010



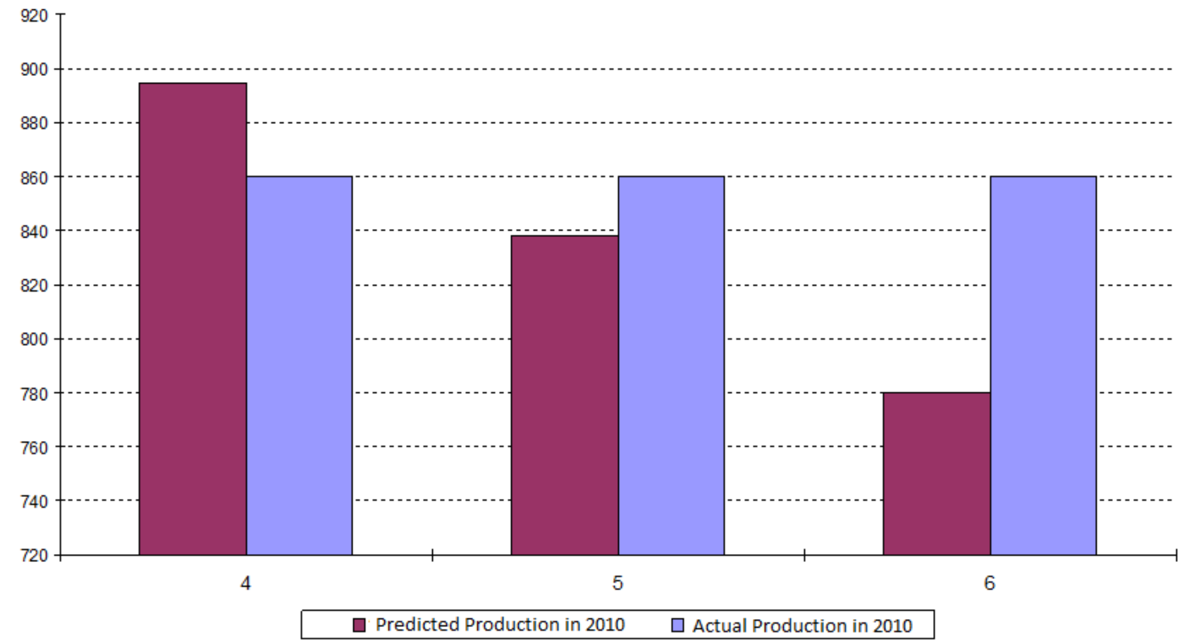
Source: Actual production data in 2010 is obtained from TÜİK 2011 Bulletin**.**
Notes: Actual and predicted values are measured as 1000 tons.

Figure 8: Predictions of wheat production in 2010



Source: Actual production data in 2010 is obtained from TÜİK 2011 Bulletin**.**
Notes: Actual and predicted values are measured as 1000 tons.

Figure 9: Predictions of rice production in 2010



Source: Actual production data in 2010 is obtained from TÜİK 2011 Bulletin**.**
Notes: Actual and predicted values are measured as 1000 tons.