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Analysis of cotton production and price relationship by Koyck model: a case study for Azerbaijan

Pamuk üretimi ve fiyat ilişkisinin Koyck modeli ile analizi: Azerbaycan için bir örnek çalışma

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ABSTRACT

Objective: The objective of this study was to examine the production quantity-price relationship in cotton production in Azerbaijan with the data of the period 1995-2022.

Materials and Methods: In this study, the data obtained from FAOSTAT and the State Statistics Committee of the Republic of Azerbaijan were analyzed. Koyck model was used to analyze the relationship between cotton production and price in Azerbaijan.

Results: It was determined that the time required for the change in cotton prices to cause a significant and perceptible effect on cotton production is 2,86 years according to the average number of lags. A one-unit increase in cotton prices increases production by 2,524 tons, while a one-unit change in prices in the previous period increases cotton production by 1,870 tons.

Conclusion: In order to sustain and increase cotton production in Azerbaijan and to create international competition opportunities, it is necessary to closely follow the developments in the production of this product and develop alternative strategies and policies.

Keywords: Azerbaijan, cotton, cotton marketing, cotton price, Koyck model

ÖZ

Amaç: Bu çalışmanın amacı, Azerbaycan'da pamuk üretiminde üretim miktarı-fiyat ilişkisini 1995-2022 dönemi verileriyle incelemektir.

Materyal ve Yöntem: Bu çalışmada FAOSTAT ve Azerbaycan Cumhuriyeti Devlet İstatistik Komitesinden elde edilen veriler analiz edilmiştir. Azerbaycan'da pamuk üretimi ile fiyat arasındaki ilişkiyi analiz etmek için Koyck modeli kullanılmıştır.

Araştırma Bulguları: Ortalama gecikme sayısına göre, pamuk fiyatlarındaki değişimin pamuk üretimi üzerinde anlamlı ve hissedilir bir etki yaratması için gereken sürenin 2,86 yıl olduğu tespit edilmiştir. Pamuk fiyatlarındaki bir birimlik artış üretimi 2,524 ton artırırken, önceki dönemde fiyatlardaki bir birimlik değişiklik pamuk üretimini 1,870 ton artırmaktadır.

Sonuç: Azerbaycan'da pamuk üretiminin sürdürülebilmesi, arttırılması ve uluslararası rekabet imkanlarının oluşturulabilmesi için bu ürünün üretimindeki gelişmelerin yakından takip edilmesi, alternatif strateji ve politikaların geliştirilmesi gerekmektedir.

Anahtar sözcükler: Azerbaycan, pamuk, pamuk pazarlaması, pamuk fiyatı, Koyck modeli

INTRODUCTION

Due to the fact that agricultural production is significantly affected by natural conditions, producers are faced to find solutions to different risks and uncertainties. The negativities in climatic conditions, diseases and pests and uncertainties about the price have an impact on production (Erdal, 2006). Farmers in Azerbaijan face significant price uncertainties due to their small lands and lack of organization. Generally, farmers take the prices of the previous year as a basis when making production decisions. This situation may cause fluctuations in production amount and price. In agricultural production, a period of time must pass for the products to come to harvest. Therefore, the supply elasticity of agricultural products is low in the short term. Therefore, farmers can show their price sensitivity in the next year's production (Erçakar & Taşçı, 2011).

Due to this structural feature of agricultural products, production quantity-price relationship can be analyzed with the help of Distributed Delay Models. In regression models using time series data, if the model includes not only the present values but also the lagged (past) values of the explanatory variables, it is called a distributed lag model (Gujarati, 2001). The Koyck model was developed to predict distributed lag models in order to eliminate the problems of multicollinearity and decreasing degrees of freedom depending on the lag length (Koyck, 1954). As a matter of fact, in many studies conducted in different countries, it is seen that the Koyck model is used in the analysis of the relationship between the production quantity and price of different crops (Yurdakul, 1998; Dikmen 2006; Erdal, 2006; Erdal & Erdal, 2008; Çetinkaya, 2012; Çelik, 2014; De Silva et al., 2014; Doğan et al., 2014; Hasan & Khalequzzaman, 2015; Mbise, 2016; Akgül & Yıldız, 2016; Al-Shamary & Mikhlef, 2017; Berk, 2017; Hasan et al., 2017; Ağazade, 2021; Avcıoğlu & Aksoy, 2021; Faied & Elshater, 2022; Turğut et al., 2023).

Cotton is one of the most important crops in the economy of Azerbaijan. While cotton production meets the country's needs, it also provides an important export income for the country. In 2021, 287,041 tons of cotton were produced on 100,590 hectares of land in Azerbaijan. In 2021, 38.4% of the cotton produced in Azerbaijan came from Mil-mughan, 28.3% from Karabakh and 23.4% from Shirvan-salyan economic regions. In 2022, the production area reached 104,000 hectares and the production reached 322,300 tons. About 190,000 people in the country still earn their living from cotton growing (The State Statistics Committee of the Republic of Azerbaijan, 2023).

The “State Program for the Development of Cotton Production” covering the period from 2017 to - 2022 in Azerbaijan made significant contributions. The main policy objectives set in the program are to increase cotton production, revive the ginning and processing industry, improve employment opportunities and improve exports. With this program, the government also decided to support farmers in purchasing agricultural machinery, fertilizers and other inputs (Zeynalova & Engindeniz, 2023a). Estimation studies show that cotton production in Azerbaijan will increase and it may reach 326,112 tons in 2024 (Uzundumlu et al., 2023).

In 2021, Azerbaijan exported 207,980 tons of cotton fiber and 58,115 tons of cotton fabrics to other countries such as Türkiye, Iran, Russia, Pakistan, Ukraine, Bangladesh, and Switzerland (Zeynalova & Engindeniz, 2023b). Azerbaijan exported 114,728 tons of cotton fiber and 16,186 tons of cotton fabrics to Türkiye in 2021 (The State Statistics Committee of the Republic of Azerbaijan, 2023).

The increases in cotton production and exports in Azerbaijan in recent years are significant. However, research on cotton should be continued and this sector should be followed closely in order to ensure the country's self-sufficiency and sustain the export level. In cotton production, prices received by farmers play an important role in directing production. In many studies that analyze the effect of prices on cotton production in different countries, it has been revealed that farmers plan production based on price and are affected by price fluctuations (Hudson et al., 1996; Tossi, 2013; Ahmad & Afzal, 2018; MacDonald & Meyer, 2018; Geetha & Mahe, 2019; Shahraki et al., 2019; Wang et al., 2021; Bodjongo, 2022). Increasing studies in this direction in Azerbaijan will be important in determining appropriate policies that can be implemented.

Analyzing the relationship between production quantity and price of cotton will provide important contributions in terms of revealing the sensitivity of farmers to prices and creating data for effective marketing organizations for cotton. The objective of this study was to examine the production quantity-price relationship in cotton production in Azerbaijan with the Koyck model.

MATERIALS and METHODS

Data

In the study, cotton production and cotton price data obtained from FAOSTAT and the State Statistics Committee of the Republic of Azerbaijan were analyzed. Data are annual and cover the period 1995-2022. In addition, the results of previous similar studies were also used.

Method

In order to adjust cotton current prices from the effects of inflation, the price series were converted to 1995-based fixed agricultural index values. The prepared data were regressed with the Koyck model (the distributed lag model) and analyzes were carried out. Tons (1,000 kg) are used for cotton production, and AZN (Azerbaijan Manat)/kg for cotton price. In 2022, it was 1 AZN =0.59 USD.

Koyck Model

Distributed lag models have a special importance in the economic literature in that they enable the analysis of the behavior of economic units (consumers and producers, etc.). Distributed lag models, first studied and used by Irving Fisher, include not only the present (current year) value of the explanatory variable, but also past years' values (Işyar, 1999). If the explanatory variable is not defined how far back into the past, it is called an "infinitely lag model" and is shown as follows;

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \ldots\ldots\ldots + u_t \quad (1)$$

If the number of years to go back to the past for the explanatory variable is determined by k, this is called the “finite distributed lag model” and is defined as follows;

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \ldots\ldots\ldots + \beta_k X_{t-k} + u_t \quad (2)$$

In model, the dependent variable Y (Y_t ……. Y_{t-k}) is affected not only by the present value (X_t) of the explanatory variable X, but also by its past values (X_{t-1} ……. X_{t-k}). Most of the time, Y reacts to X after a while, this time is called lag (lag length) (Dikmen, 2006).

In distributed lag models, unknown parameters (α, β_0,…., β_k) can be estimated by the classical least squares method (Alt, 1942; Gujarati, 2001). However, there are some drawbacks of model-specific estimation in distributed lag models. One of these drawbacks is that the model does not have any preliminary information about how lag length will be. Another drawback is that the degrees of freedom of the parameters decrease gradually in statistical significance tests, when a data set that can estimate a large number of lags cannot be generated. Another drawback, and the most important one, is that the variables determined as explanatory variables are in a multicollinearity.

A method was developed by Koyck in order to overcome the above-mentioned drawbacks in distributed lag models (Koyck, 1954). In this method, which is referred to as the Koyck model, based on the assumption that the lags of the independent variable affect the dependent variable at a certain weight and that the weights of the lags decrease geometrically, the regression equation is estimated by making the model reduced (Dikmen, 2006). To arrive at the reduced model, in an infinitely distributed lag model, Koyck assumes that all β's are of the same sign, decreasing geometrically as shown below;

$$\beta_k = \beta_0 \lambda^k \qquad k = 0,1,\ldots\ldots \quad (3)$$

Here, λ ($0 < \lambda < 1$) denotes the rate of decrease or decrease of the distributed delay, $1-\lambda$ denotes the rate of adaptation. β_k is the value of the lag coefficient. The lag coefficient value (β_k) depends on λ' other than β_0. The closer λ is to 1, the lower the rate of decrease in β_k, while the closer λ is to zero, the faster the decrease in βk (Gujarati, 2001). In other words, the fact that λ is close to 1 indicates that the values of the explanatory variable in the distant past have a significant effect on the dependent variable, and the fact that λ is close to zero indicates that the effects of the values of the explanatory variable in the distant past on the dependent variable disappear very quickly. The average number of lags is the weighted average of all lags. It is calculated for the Koyck model as follows;

$$\text{Average lag} = \frac{\lambda}{1-\lambda} \tag{4}$$

The average number of lags shows the time period that must pass for a one-unit change in the explanatory variable X to have a noticeable effect on the dependent variable Y (Yurdakul, 1998; Dikmen, 2006).

In the light of these explanations, the infinite lag model is constructed as follows;

$$Y_t = \alpha + \beta_0 X_t + \beta_0 \lambda X_{t-1} + \beta_0 \lambda^2 X_{t-2} + \dots\dots\dots + u_t \tag{5}$$

Linear regression analysis cannot be applied to the regression equation 5, since it contains infinite lag and the λ coefficients are far from linearity. In order to eliminate this problem, the following regression model was obtained by withdrawing the model for a period by Koyck;

$$Y_{t-1} = \alpha + \beta_0 X_{t-1} + \beta_0 \lambda X_{t-2} + \beta_0 \lambda^2 X_{t-3} + \dots\dots\dots + u_{t-1} \tag{6}$$

When the equation 6 is multiplied by λ, the equation 7 below is reached;

$$\lambda Y_{t-1} = \lambda\alpha + \lambda\beta_0 X_{t-1} + \lambda^2 \beta_0 X_{t-2} + \lambda^3 \beta_0 X_{t-3} + \dots\dots\dots + \lambda u_{t-1} \tag{7}$$

When the equation 7, whose lag is withdrawn for 1 period, is subtracted from the equation 5, whose delay is infinite, the following equation is obtained;

$$Y_t - \lambda Y_{t-1} = \alpha(1-\lambda) + \beta_0 X_t + (u_t - u_{t-1}) \tag{8}$$

If the equation 8 is rearranged, the following equation 9 is reached. The $v_t = (u_t - \lambda u_{t-1})$ in the equation represents the moving average of u_t and u_{t-1}.

$$Y_t = \alpha(1-\lambda) + \beta_0 X_t + \lambda Y_{t-1} + v_t \tag{9}$$

The process described above is known as the Koyck transform, and the equation 9 is defined as the Koyck model. In the Koyck model, variables containing the lagged values of the explanatory variables were not defined, so the multicollinearity problem was solved in a sense. On the other hand, while there is an obligation to predict α and an infinite number of β in the infinitely distributed model, in the Koyck model, distributed lag model analysis can be performed by estimating only α, β_0 and λ.

RESULTS and DISCUSSION

Changes in cotton production and cotton prices in Azerbaijan in the period 1995-2022 are presented in Figure 1. According to the figure, cotton production, which fluctuated over the years, reached the lowest level in 2009, and significant increases were recorded in production, especially with the policies implemented after 2017. In 2020, the highest production level of this period was reached. It is observed that the current cotton prices received by the farmers have increased over the years.

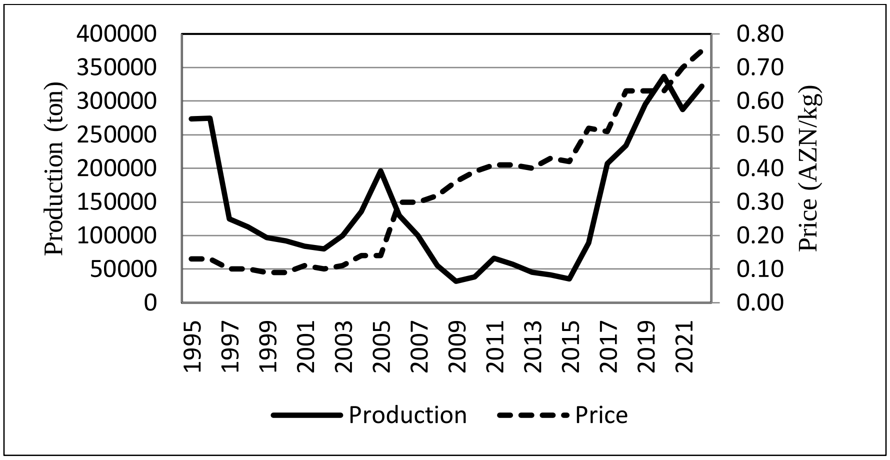

Figure 1. Developments in Cotton production and cotton price in Azerbaijan

Şekil 1. *Azerbaycan'da pamuk üretimi ve pamuk fiyatındaki gelişmeler*

Source: FAOSTAT, 2023; The State Statistics Committee of the Republic of Azerbaijan, 2023.

To determine the level of relationship between cotton production and cotton prices in the examined period, correlation analysis was performed and the correlation coefficient was calculated as 0,701. As a result, it has been determined that there is a sufficient and high level of interest between cotton production and its prices. This result reveals that the quantity-price relationship in cotton can be examined with the Koyck model. The distributed lag model for cotton is constructed as follows;

$$Q_t = \alpha + \beta_0 P_t + \beta_1 P_{t-1} + \beta_2 P_{t-2} + \ldots\ldots\ldots + \beta_k P_{t-k} + u_t \qquad (10)$$

In the model (equation 10): Q_t = Cotton production (tons) in period t, P_t = Cotton price (AZN/kg) in period t.

To create the Koyck model, it is necessary to determine the lagged value (lag length) of the Cotton price series. Schwarz criterion (SC) is commonly used to determine the lag length in a distributed lag model (Dikmen, 2006). Schwarz suggests minimizing the following function (Çetinkaya, 2003);

$$SC = \ln \sigma^2 + m \ln n$$

In the function: σ^2 = Sum of squared errors / n, m = Lag length, n = Number of observations.

A regression model is used with various lag values (m), and the m value that makes the Schwarz Criterion value the smallest is chosen (Gujarati, 2001). At this stage, without any limitation on the form of the distributed lag, starting with a very large m value, it is observed whether the model undergoes a significant deterioration when this time is shortened (Davidson & Mackinnon, 2021).

The Schwarz Criterion values determined at different lag lengths for equation 10 in the study are given in Table 1.

Table 1. Schwarz criterion values according to lag lengths

Çizelge 1. *Gecikme uzunluklarına göre Schwarz kriteri değerleri*

Lag length	SC value
k=0	23,61
k=1	21,97
k=2	22,02
k=3	22,27
k=4	22,63

As can be seen from Table 1, the lowest Schwarz Criterion value was obtained with 1 lag length. Accordingly, the effect of cotton prices on cotton production becomes zero after 1 year. According to the determined lag length, the relationship between cotton production and price in the examined period was estimated as follows using the equation 10 using the classical least squares method;

$$Q_t = -221002{,}6 + 34{,}187\ P_t + 44{,}867\ P_{t-1} \quad (11)$$

t ⟶ (-3,393) (1,765) (2,531)

p ⟶ (0,002) (0,090) (0,018)

$R^2 = 0{,}68$ F = 15,69 (p=0,000)

According to the results of equation 11, cotton price in period t and 1 period ago affects cotton production positively. Partial regression coefficients in the model were found to be statistically significant. The model as a whole is also statistically significant. The multiple determination coefficient of the model was found to be 0,68 and this means that 68% of the changes in cotton production are explained by the cotton price and its lagged distribution.

Although the model as a whole is statistically significant, two important problems in distributed lag models have to be discussed in terms of the reliability of the model. The first problem is the multi-correlation problem, since the lagged values of the price variable are taken into account in the model. The second problem is the loss of observation that occurs in the set of lagged values. If the number of data in the created series is not very large, the prediction values may show inconsistency due to lags.

To eliminate these two important problems, estimation was made using the Koyck Model. The estimation results of the regression equation 11 obtained by Koyck Model are given below;

$$Q_t = -71974{,}4 + 2{,}524\ P_t + 0{,}741\ Q_{t-1} \quad (12)$$

t ⟶ (-1,601) (2,095) (6,092)

p ⟶ (0,122) (0,047) (0,000)

$R^2 = 0{,}88$ F = 43,66 (p=0,000)

In the model (equation 12): Q_t = Cotton production (tons) in period t, P_t = Cotton price (AZN/kg) in period t, Q_{t-1} = Cotton production (tons) in period before period t.

The model as a whole was found to be statistically significant. According to the model results, 1 AZN increase in cotton price increases cotton production by 1,524 tons, while 1 ton increase in cotton production in the previous period increases cotton production by 0,741 tons.

Based on the model results (equation 12), the average number of lags was calculated as follows;

Number of average lag = $\lambda / 1\ (1 - \lambda) = 0{,}741 / 1\ (1 – 0{,}741) = 2{,}86$

According to the average number of lags, the time required for a change in cotton prices to have a significant and perceptible effect on cotton production is 2,86 years. This result shows that farmers react quickly to price changes in cotton farming in Azerbaijan.

Based on the Koyck model, the equation 11 can be reached as follows. If the Koyck model is rewritten;

$Q_t = \alpha + \beta_0 P_t + \lambda Q_{t-1} + u_t$ and $\beta_k = \lambda^k \beta_0$

Since $0 < \lambda < 1$, the equation 11 is reached with the following calculations;

$\beta_k = \lambda^k \beta_0$

$\beta_0 = \lambda^0 \beta_0 = (0{,}741)^0 (2{,}524) = 2{,}524$

$\beta_1 = \lambda^1 \beta_0 = (0{,}741)^1 (2{,}524) = 1{,}870$

$\alpha_0 = \alpha / (1- \lambda) = -71974{,}4 / (1- 0{,}741) = -277893{,}4$

With these results, when the regression equation derived from Koyck's model is rewritten, the following equation is obtained;

$Q_t = \alpha_0 + \beta_0 P_t + \beta_1 P_{t-1} + u_t$

$$Q_t = -277893{,}4 + 2{,}524 P_t + 1{,}870 P_{t-1} \quad (13)$$

In the equation 13 above, which expresses a distributed lag model derived from the Koyck model, it can be stated that lagged cotton prices have a decreasing effect on cotton production since the coefficient λ is $0< \lambda< 1$. The fact that the parameters of the lagged prices gradually decrease is due to the fact that the coefficient λ creates a limiting effect in the model.

Based on the regression equation 13, one-unit increase in cotton prices in the current year increases production by 2,524 tons, while a one-unit change in prices in the previous period increases cotton production by 1,870 tons.

CONCLUSION

In this study, the relationship between cotton production quantity and prices in Azerbaijan was analyzed using the Koyck model, one of the distributed lag models. In the model, cotton production was considered as the dependent variable, cotton price and lagged values of cotton price were considered as explanatory variables. The study was carried out with data from the period 1995-2022.

In the period examined in Azerbaijan, a 70% correlation was determined between cotton production quantity and prices, and as a result, it can be stated that the quantity-price relationship could be examined with the Koyck model.

The lag length was determined as 1 using the Schwarz Criterion for the estimation of unknown parameters in the Koyck model. By using this lag length, a distributed lag model was created for cotton production amount and price in the examined period and regression analysis was performed. Although the obtained model is statistically significant as a whole, the model has been subjected to Koyck transformation due to the problem of multiple correlations in the model. In the Koyck model, in which the relationship between cotton production and price was examined, the multiple determination coefficient was 88%, and it was determined to be statistically significant at the 1% level with the whole model. It has been determined that the time required for the change in cotton prices to cause a significant and perceptible effect on cotton production is 2,86 years according to the average number of lags. Based on the results of the Koyck model, the 1 year lag-derived Koyck model parameters were calculated. Accordingly, a one-unit increase in cotton prices in the current year increases production by 2,524 tons, while a one-unit change in prices in the previous period increases cotton production by 1,870 tons.

It is also useful to compare the results in Azerbaijan with other countries. For example, according to the results of the koyck model created with the data of 1985-1997 in Türkiye an increase of 1 unit per kg in the cotton price in the t period increases the cotton production in the t period by 12,6 tons (Yurdakul, 1998). In another study, according to the results of the koyck model created with the data of 1991-2018 in Türkiye, it was determined that a 1% change in the real cotton price affected the cotton production amount by 0.31% in the same year. In the study, the average time required for the reflection of the change in the real price of cotton to the amount of cotton production was calculated as 4,99 years (Ağazade, 2021).

According to the data of the International Cotton Advisory Committee (ICAC), Azerbaijan ranks 30th in the world in terms of cotton (lint) production. According to ICAC data, 68,000 tons of cotton (lint) were produced in Azerbaijan in 2021, 30,000 tons of this was reserved for domestic use and 38,000 tons were exported (ICAC, 2023). However, there are problems encountered in cotton production and need to be resolved in Azerbaijan. Cotton production can be improved if sufficient training is provided to cotton farmers on production technologies, varieties, irrigation and plant protection by extension organizations in Azerbaijan. Currently, up-to-date information on modern cotton production is lacking and needs improvement. Farmers especially need appropriate financing and training. The emergence of companies that produce cotton under contract with farmers helped to resolve some of the problems. They help local farmers overcome transition challenges by providing finance and technology. But even these large cotton companies are currently struggling to reach skilled agronomists (Zeynalova & Engindeniz, 2003a).

In 2021, cotton was produced in 6.1% of the total cultivated area (1.6 million ha) and in 82.5% of the industrial crops area (121,992 ha) in Azerbaijan. However, in the research conducted for the same year, the net income of the farmers was 228 AZN/ha for cotton, 869 AZN/ha for tobacco and 1,389 AZN/ha for sugar beet (Zeynalova et al., 2023). It has also been revealed in previous studies that cotton farmers in Azerbaijan have difficulties in paying their production costs and can earn less income than other crops (Prikhodko et al., 2019; Tagiyeva, 2020). These results show that cotton farmers should be supported by price and non-price methods in order to sustain production.

As a matter of fact, some measures were taken for cotton production upon the instruction of President Ilham Aliyev. According to the measures, cotton production and processing companies decided to increase their cotton purchase prices just before the harvest. According to the agreement reached between the companies, the current cotton purchase prices have been increased by 50 AZN/ton for the 2022 harvest. Cotton production is also supported by the government. As of 2022, subsidies of 170 AZN have been paid to farmers for each ton of cotton delivered to supply points (Azerbaijan Republic Ministry of Agriculture, 2023).

As a result, in order to sustain and increase cotton production in Azerbaijan and to create international competition opportunities, it is necessary to closely follow the developments in the production of this crop, to reveal the problems encountered and to develop alternative strategies and policies.

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