Black Sea Journal of Agriculture

doi: 10.47115/bsagriculture.1836411

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 9 - Issue 2 : 172-176 / March 2026

ANALYSIS OF POTATO PRODUCTION AND PRICE RELATIONSHIP IN TÜRKIYE WITH KOYCK MODEL

Bekir AYYILDIZ[1]*

[1]*Yozgat Bozok University, Faculty of Agriculture, Department of Agricultural Economics, 66900, Yozgat, Türkiye*

Abstract: This study examines how production decisions for annual crops are largely based on price signals from previous years, which in turn lead to fluctuations in both production volume and prices, particularly in the potato sector. Using 24 years of time-series data from 2004 to 2023, the dynamic relationship between potato production volume and prices in Türkiye was analyzed through the Koyck distributed lag model. Model results indicate that potato production decisions are particularly sensitive to price developments over the previous two years. Since the variables are specified in logarithmic form, the estimated coefficients should be interpreted as elasticities. Accordingly, a 1% increase in current-year potato prices leads to an approximately 0.076% increase in potato production. However, the effects of lagged prices diminish over time: a one-period lagged price change increases production by 0.025 tons, while a two-period lagged price change increases it by only 0.008 tons. Furthermore, based on the adjustment coefficient derived from the model, it is estimated that approximately 0.490 years (around six months) are required for the full impact of a price change on production volume to be realized. This finding suggests a gradual adjustment process in producers' responsiveness to price signals.

Keywords: Potato production, Potato price, Koyck model, Türkiye

***Corresponding author:** Yozgat Bozok University, Faculty of Agriculture, Department of Agricultural Economics, 66900, Yozgat, Türkiye
E mail: bekir.ayyildiz@yobu.edu.tr (B. AYYILDIZ)
Bekir AYYILDIZ https://orcid.org/0000-0001-9333-8980

Received: December 05, 2025
Accepted: January 26, 2026
Published: March 15, 2026

Cite as: Ayyıldız, B. (2026). Analysis of potato production and price relationship in Türkiye with Koyck model. *Black Sea Journal of Agriculture*, 9(2): 172-176.

1. Introduction

Potatoes are among the most extensively produced and consumed agricultural commodities worldwide, following cereals, due to their adaptability to various climatic conditions, high yield potential per unit area, economic benefits, significant nutritional value, and ease of digestibility (Yılmaz et al., 2006; Doğan et al., 2014; Kılıçer, 2019). The crop has diverse applications, encompassing fresh consumption, processed food items, animal feed, industrial starch, bioethanol production, and seed material (Öztürk and Polat, 2017; Onwusiribe et al., 2018; Kadakoğlu and Karlı, 2021). This multifaceted role highlights the necessity of guaranteeing the sustainable and stable continuation of potato production. Potatoes are currently among the foremost crops in global agricultural production, highlighting the necessity of sustaining their growth.

In 2022, about 374.76 million tons of potatoes were grown on 17.79 million hectares around the world. China, India, Ukraine, the United States, and Russia account for the vast majority of this production. Türkiye produces 5.2 million tons of potatoes, accounting for around 1.4% of global output. In terms of productivity, Türkiye's average yield of potatoes is 3514 kg da^{-1}, which is much higher than the global average of 2177 kg da^{-1} (FAO, 2023). However, despite the relative increase in yields, potato acreage, and therefore production volume, have fluctuated over the years, both globally and in Türkiye. These production variations are influenced by the overall cultivated area as well as sector-specific risks and uncertainties. However, economic factors arising from price developments and market conditions largely determine the decline and variability in cultivated area.

Significant fluctuations are observed over the years, particularly in the production of annual crops, in many countries where agricultural enterprises are sub-optimal and an effective market structure is lacking. The primary reason for these fluctuations is that producers largely make planting decisions based on the previous year's current prices. Increases or decreases in supply play a decisive role in price formation for products with low demand elasticity, such as potatoes and onions. In other words, the most influential factor in determining product prices in the current period is supply, and in the economics literature, this process is explained within the framework of the "cobweb theorem" (Guenthner, 2010; Eraktan and Açıl, 2000; Özçelik and Özer, 2006; Yılmaz et al., 2006).

To ensure market stability, develop functional support policies, and establish effective market structures, analyzing the lagged effects of prices on agricultural production for future periods is of great importance. In this context, there are many studies in the literature that examine the dynamic relationship between production amount and prices for various agricultural products. It is seen that a significant part of these studies utilize the Koyck model, which is widely used among distributed lag models (Yurdakul, 1998; Karkacıer, 1999; Erdal, 2006; Özçelik and Özer, 2006; Erdal and Erdal, 2008; Doğan and Onurlubaş, 2016; Ağazade, 2021; Çukur et al., 2023). Similarly, studies in the international literature apply the Koyck lag model to analyze the relationship between price and production in various agricultural products. For example, Hasan et al. (2017) on ginger production in Bangladesh, Mbise (2016) on corn production in Tanzania, and De Silva et al. (2014) examined the lagged effects of prices on black tea production in Sri Lanka using the Koyck model.

While prior research has examined the quantity–price relationship for potatoes, the significant growth in the crop's usage—from conventional food consumption to diverse industrial applications—has raised the necessity for revised analyses utilizing current data sets and sophisticated econometric techniques. This study use the Koyck model to analyze the dynamic link between potato output and pricing in Türkiye from 2004 to 2023. The growing incorporation of potatoes into various industrial sectors highlights the need for steady and dependable production, with balanced price formation being essential for maintaining sectoral viability. This study's conclusions are anticipated to offer an analytical basis for stakeholders, institutions, and policymakers aiming to formulate measures that improve market structure efficiency. This research addresses a significant gap in the literature and provides strategic insights that could enhance the predictability and stability of the potato market. While previous studies have examined the production–price relationship for potatoes using distributed lag models, most of them are limited to shorter time periods or regional analyses. This study provides an original contribution by analyzing the dynamic relationship between potato production and prices in Türkiye at the national level using a long and up-to-date dataset covering the period 2004–2023. By explicitly estimating the lagged adjustment mechanism through the Koyck model, the study reveals both the magnitude and timing of producers' responses to price signals, thereby offering new empirical evidence for agricultural market stabilization policies.

2. Materials and Methods

This study primarily utilizes secondary data sourced from the Turkish Statistical Institute (TUIK, 2024), encompassing potato production (tons/year) and price (TL/year) series for the period 2004–2023 in Türkiye. Both time series were transformed into logarithmic form prior to their utilization in the analysis.

In the production of agricultural products, it is known that not only the current price of the product but also past prices affect production decisions. Therefore, distributed lag models are widely used in studies examining the production-price relationship. Distributed lag models are divided into two categories: finite and infinite lag models. When a specific lag length is assigned to the independent variable, the model is called a "finite lag model," while when the lag limit for the past periods of the independent variable is not defined, the model is referred to as an "infinite lag model" (Dikmen, 2006; Kutlar, 2009). Equations (1) and (2) provide general representations for finite and infinite lag models.

$$Y_t = \alpha + \beta_0\, Xt \; + \; \beta_1\, X_{t-1} + \beta_2\, X_{t-2} + \ldots + u_t \tag{1}$$

$$Y_t = \alpha + \beta_0\, Xt \; + \; \beta_1\, X_{t-1} + \beta_2\, X_{t-2} + \ldots \beta_k\, X_{t-k} + \; u_t \tag{2}$$

While distributed lag models can be estimated using the least squares method (LSM), uncertainty in determining the appropriate lag length, the decrease in degrees of freedom due to an increase in the number of lags, and multicollinearity issues can lead to biased and inconsistent estimates (Davidson and MacKinnon, 1993; Gujarati, 2001; Dikmen, 2006). Various alternative methods have been developed to address these problems. In this study, the Koyck model, a distributed lag model, was chosen to more accurately demonstrate the production-price relationship. In the Koyck approach, all β coefficients in equation (3) are assumed to have the same sign and to exhibit a decreasing pattern as the lag increases (Koyck, 1954).

$$\beta_k \;=\; \beta_0 \lambda^k; \quad k = 0,1, \ldots;\;\; 0 < \lambda < 1 \tag{3}$$

λ represents the rate of decrease, and 1-λ represents the rate of adaptation. Every value of β_k, except β_0, depends on the value of λ. As λ approaches 1, the value of βk is observed to decrease slowly. This means that the effect of this delay on Y decreases as we move farther into the past. The average delay is found by dividing the rate of decrease by the rate of adaptation (equation 4).

$$Y_t \;=\; \alpha \;+\; \beta_0 X_t \;+\; \beta_0 \lambda X_{t-1} \;+\; \beta_0 \lambda^2 X_{t-2} \;+\; \beta_0 \lambda^3 X_{t-3} + \ldots + u_t \tag{4}$$

However, the model's infinite lag structure and the nonlinear definition of the λ coefficients make it difficult to apply direct linear regression analysis. To address this issue, Koyck developed an alternative regression form that converts the model to a linear structure by lag-lagging it one period. In this context, the Koyck transformation is expressed by the lag regression model shown in equations (5)–(8) below.

$$Y_{t-1} \;=\; \alpha + \; \beta_0 X_{t-1} + \beta_0 \lambda X_{t-2} + \beta_0 \lambda^2 X_{t-3} \;+\; \ldots \;+\; u_{t-1} \tag{5}$$

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

$$Y_t - \; \lambda Y_{t-1} \;=\; \alpha(1 - \lambda\,) \;+\; \beta_0 X_t \;+\; (\,u_t \;-\; u_{t-1}) \tag{7}$$

$$Y_t \;=\; \alpha\,(1 - \lambda) \;+\; \beta_0 X_t \;+\; \lambda Y_{t-1} \;+\; v_t \tag{8}$$

v_t = (u_t - λu_{t-1}) is defined as a moving average of the error terms $u_t$and u_{t-1}. The procedure described above is known as the *Koyck transformation*, and the resulting specification is referred to as the *Koyck model*. Because the Koyck model does not explicitly include lagged values of the explanatory variables, it effectively mitigates problems of multicollinearity. Furthermore, whereas infinite distributed lag models require the estimation of α and an infinite number of β coefficients, the Koyck model allows the distributed lag structure to be represented simply by estimating α, β_0, and λ (Gujarati, 2001; Dikmen, 2006). Accordingly, the Koyck model was adapted in the study as in equation 9.

$$Q_t = \alpha + \beta_0 Pt + \beta_1 P_{t-1} + \beta_2 P_{t-2} + \dots + \beta_k P_{t-k} + u_t \tag{9}$$

3. Results and Discussion

To determine whether the relationship between production quantity and price for potatoes is suitable for distributed lag models, the correlation coefficient between the variables was examined, and it was determined that the correlation coefficient found to be 0.716 was sufficient to be applied to the distributed lag model. The lag length necessary for formulating the Koyck model was ascertained through the Schwarz Information Criterion (Schwarz, 1978), which revealed that the optimal lag length for potato prices is two (2) (Table 1).

Table 1. Lag length values according to schwarz information criteria

Lag Length	SIC
k=1	-1.385541
k=2	-1.737962*
k=3	-1.494428
k=4	-1.313255

* Optimal lag length for potato prices.

In accordance with the selected lag length, the effect of potato prices on production was estimated using the Ordinary Least Squares (OLS) method, and the results of the model are presented in equation 10.

$$\begin{aligned} Q_t &= 15.391 + 0.002\,P_t + 0.110\,P_{t-1} + 0.037\,P_{t-2} \\ &\quad (0.000)\quad (0.923)\quad (0.037)\quad (0.162) \\ t &\quad 1713.708\quad 0.098\quad 2.304\quad 1.474 \\ R^2 &= 0.820\quad F = 21.271\quad (P=0.000) \end{aligned} \tag{10}$$

According to Equation (10), potato prices in the current period, as well as those from one and two periods earlier, have a positive effect on potato production. Both the overall model and the individual regression coefficients were found to be statistically significant. The coefficient of determination (R^2=0.82) indicates that 82% of the variation in potato production is explained by current and lagged potato prices. Despite the model's statistical significance as indicated by the F-test statistic, the implementation of distributed lag models presents two primary concerns. The initial issue is multicollinearity, arising from the inclusion of lagged values of the independent variables in the model. The second issue is the loss of observations; especially when the data points are few, this loss can result in inconsistent parameter estimates. The Koyck model was utilized for estimation to resolve these issues. The estimation results of the Koyck model are presented below.

$$\begin{aligned} Q_t &= 10.307 + 0.076\,P_t + 0.329\,Q_{t-1} \\ &\quad (0.000)\quad (0.000)\quad (0.051) \\ t &\quad 4.309\quad 4.810\quad 2.106 \\ R^2 &= 0.665\quad F = 15.900\quad (P=0.000) \end{aligned} \tag{11}$$

The regression equation (11), estimated using the Koyck model, was found to be statistically significant. According to the model results, Given the logarithmic specification of the model, the estimated coefficients represent elasticities rather than absolute changes. Accordingly, a 1% increase in potato prices leads to an approximately 0.076% increase in potato production, indicating a positive but relatively moderate price responsiveness., while a one-unit increase in the previous period's production raises current production by 0.329 tons. Based on these findings, the average lag length of the model (λ/(1-λ) was calculated as 0.49 years. The estimated average lag length of 0.490 years does not reflect the biological production cycle of potatoes. Instead, it represents the time required for producers to perceive price signals and adjust their production decisions accordingly. In annual crops such as potatoes, this lag primarily corresponds to the planning and decision-making phase—such as determining planting area and input use—rather than the physical cultivation or harvest period. Accordingly, the analyses based on the Koyck model need to be reconsidered by taking this lag structure into account. Based on the estimated Koyck model, the short-run and distributed lag coefficients were derived using the expression $\beta_k = \lambda^k \beta_0$, valid under the condition $0 < \lambda < 1$. Accordingly, the contemporaneous price coefficient is calculated as given in equations 12-15:

$$\beta_0 = \lambda^0\,\beta_0 = (0.329)^0\,(0.076) = 0.076 \tag{12}$$

$$\beta_1 = \lambda^1\,\beta_0 = (0.329)^1\,(0.076) = 0.025 \tag{13}$$

$$\beta_2 = \lambda^2\,\beta_0 = (0.329)^2\,(0.076) = 0.008 \tag{14}$$

$$\alpha_0 = \alpha \,/\, (1 - \lambda) = 10.307 \,/\, (1 - 0.329) \tag{15}$$

The long-run intercept is obtained as given in equations 16 and15:

$$\alpha_0 = \frac{\alpha}{1-\lambda} = \frac{10.307}{1-0.329} = 15.362 \tag{16}$$

$$Q_t = 15.362 + 0.076\,P_t + 0.025\,P_{t-1} + 0.008\,P_{t-2} \tag{16}$$

Equation (11), obtained using the Koyck model, provides an important framework for understanding the dynamic relationship between potato production and prices. The coefficient λ in the model, which ranges between 0 and 1, indicates that the impact of lagged prices on production gradually diminishes over time. This indicates that producers react to historical price signals over time, although this effect diminishes geometrically with each subsequent lag period. Consequently, although price sensitivity in potato production is significant, it seems to lack a lasting effect over extended periods.

The results shows that a one-unit increase in current potato prices raises production by 0.076 tons. This effect demonstrates that the price signal is rapidly reflected directly in production decisions. A one-unit increase in prices lagged by one period increases production by 0.025 tons. This finding indicates that producers are sensitive not only to current prices but also to recent price levels in their planting decisions. A one-unit increase in prices lagged by two periods increases production by 0.008 tons, demonstrating that the effect diminishes rapidly. This decrease is fully consistent with the geometric distribution assumption of the Koyck model and confirms the greater short-term weight of price effects.

These results show that potato farmers react quickly to changes in price, and that short-term price changes have a big effect on their decisions about how much to grow. The price sensitivity seen in production could make the market more unstable. Price shocks, especially for goods with low demand elasticity like potatoes, can quickly change production decisions. This can cause supply to be too high or too low in the next period. This situation illustrates the supply-demand imbalance elucidated in literature through the "cobweb theorem.

Furthermore, the positive but gradually decreasing nature of lagged price effects suggests that price changes create a gradual adjustment process in agricultural production behavior. This finding demonstrates that achieving price stability will strengthen the sustainability of agricultural production and that reducing market volatility is an important policy area. Potatoes are a crop that is very sensitive to short-term price changes, so support policies need to be carefully watched to make sure they are put in place at the right time and for the right reasons.

4. Conclusion

In this study, the dynamic relationship between potato production and prices in Türkiye was examined using the Koyck model, and the findings indicate that approximately six months are required for price changes to exert a noticeable impact on production. This result suggests that price signals influence production decisions with a temporal lag and that producers' responses materialize primarily in the subsequent production period. The fact that fluctuations in prices lead to corresponding variations in production constitutes a significant challenge for market stability.

Accordingly, there is a clear need for mechanisms that can mitigate fluctuations in both prices and production and promote a more predictable agricultural market structure. Incorporating the price–product relationship systematically into production planning processes and agricultural support policies is essential. Moreover, in the context of the increasingly widespread contract farming arrangements in recent years, enhancing price-setting mechanisms and improving price-based guarantees would help stabilize producer income and strengthen long-term production sustainability.

The findings underline the importance of concrete policy instruments aimed at reducing price volatility in the potato market. In this context, price band mechanisms could help limit excessive price fluctuations, while premium support schemes should be designed by considering the lagged effects of prices on production decisions. Intervention purchases may serve as an effective short-term tool during periods of extreme price movements. Moreover, expanding contract farming arrangements could enhance income predictability for producers and contribute to a more stable and sustainable production structure.

The relatively low price elasticity of potato production suggests that, although producers respond to price signals, production decisions are constrained by structural factors such as land availability, crop rotation requirements, and input costs. This moderate responsiveness implies that short-term price shocks may lead to supply fluctuations without proportional adjustments in production, a mechanism consistent with the cobweb phenomenon in agricultural markets characterized by low demand elasticity.

Overall, the study provides a scientific foundation for designing policies aimed at enhancing price stability and reducing production volatility in the potato market, thereby contributing to the development of a more predictable and stable production and marketing environment for all relevant stakeholders.

Author Contributions

The percentages of the author' contributions are presented below. The author reviewed and approved the final version of the manuscript.

	B.A.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

References

Ağazade, S. (2021). Analysis of the Relationship Between Cotton Production and Prices by using Koyck Approach in Türkiye. *Journal of Tekirdag Agricultural Faculty, 18*(3), 386–399. https://doi.org/10.33462/jotaf.681808

Çukur, T., Işın, F., & Çukur, F. (2023). Analysis of Walnut Production and Price Relationship. *Gaziosmanpasa Journal of Scientific Research, 12*(1), 101–106.

Davidson, R., & MacKinnon, J. G. (1993). Estimation and inference in econometrics (Vol. 63). Oxford.

De Silva, M. S. K., Jayasinghe-Mudalige, U. K., Edirisinghe, J. C., Herath, H. M. L. K., & Udugama, J. M. M. (2014). Assessing the production vs. price relationship of black tea in Sri Lanka: an application of Koyck's geometric-lag model. *Sri Lanka Journal of Economic Research, 2*(2), 43-53. https://dx.doi.org/10.4038/sljer.v2i2.91

Dikmen, N. (2006). Koyck Almon yaklaşımı ile tütün üretimi ve fiyat ilişkisi. *Çukurova University Social Sciences Institute Journal, 15*(2), 153–168.

Doğan, H. G., & Onurlubaş, E. (2016). The examination with the aid of Almon approach of cobweb theorem to tomato production in Türkiye. *Çankırı Karatekin University Journal of the Institute of Social Sciences, 7*(1), 259–272.

Doğan, H. G., Gürler, A. Z., Ayyıldız, B., & Şimşek, E. (2014). An analytical evaluation of production-price relation in potato production using koyck approach (the case of TR 71 Region). *Turkish Journal of Agricultural and Food Science Technology, 2*(1), 42–46. https://doi.org/10.24925/turjaf.v2i1.42-46.53

Eraktan, S., & Açıl, F. (2000). Ekonomi. Ankara University Faculty of Agriculture Publications.

Erdal, G. (2006). Tarımsal ürünlerde üretim–fiyat ilişkisinin Koyck yaklaşımı ile analizi (domates örneği). *Journal of Agricultural Faculty of Gaziosmanpaşa University, 23*(2), 21–28.

Erdal, G., & Erdal, H. (2008). Kuru soğanda üretim-fiyat etkileşimi. *Journal of Agricultural Faculty of Gaziosmanpaşa University, 25*(1), 33-39.

FAO. (2023). The Food and Agriculture Organization: Food and Agriculture Organization of the United Nations Statistics Division. http://faostat.fao.org (accessed on 12 August 2025).

Guenthner, J. F. (2010). Past, present and future of world potato markets: An overview. *Potato Journal, 37*(1–2), 1–8.

Gujarati, D. N. (2001). Basic econometrics (Ü. Şenesen & G. G. Şenesen, Trans.). Literatür Publishing.

Hasan, M. K., Haque, M. M., & Rabbani, M. G. (2017). Production and price relationship of ginger (Zingiber officinale) in Bangladesh: A distributed lag model. *The Agriculturists, 15*(1), 01-09.

Kadakoğlu, B., & Karlı, B. (2021). Türkiye'de patates üretimi, ihracatı ve destekleme politikalarının değerlendirilmesi. *Ziraat Fakültesi Dergisi, 16*(1), 7–16.

Karkacıer, O. (1999). Genel ekonomi (İktisada giriş). Gaziosmanpaşa University Faculty of Agriculture Publications.

Kılıçer, E. (2019). Patates üreticiliği yapan çiftçilerin üretim maliyetlerine ilişkin algılarını belirlemeye yönelik bir araştırma: Niğde ili örneği. *MANAS Journal of Social Studies, 8*(4), 3399–3415. https://doi.org/10.33206/mjss.506626

Koyck, L.M. (1954). Dstrbuted Lags and Investment Analyss. Amsterdam: North-Holland Publishing Company.

Kutlar, A. (2009). Applied econometrics (3rd ed.). Nobel Publications.

Mbise, M. (2016). Influence of expected farm-gate price on maize production in Ludewa district of Njombe region, Tanzania: estimation of koyck lag model. *International Journal of Advanced Research, 4*(12), 292-299. https://dx.doi.org/10.21474/IJAR01/2393

Onwusiribe, C. N., Mbanasor, J. A., & Agwu, N. M. (2018). Long-run and short-run macroeconomic determinants of potato export in Nigeria. *Nigeria Agricultural Journal, 49*(1), 117–124.

Özçelik, A., & Özer, O. O. (2006). Koyck modeliyle Türkiye'de buğday üretimi ve fiyatı ilişkisinin analizi. *Journal of Agricultural Sciences, 12*(4), 333–339.

Öztürk, E., & Polat, T. (2017). Tohumluk patates yetiştiriciliği ve önemi. *Alınteri Journal of Agriculture Science, 32*(1), 99–104.

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics, 6*(2), 461-464.

TUIK. (2024). Turkish Statistical Institute: Official website of the Turkish Statistical Institute. http://www.tuik.gov.tr (accessed on 17 August 2025).

Yılmaz, H., Demircan, V., & Erel, G. (2006). Bazı önemli patates üreticisi illerde patates üretim maliyeti ve gelirinin karşılaştırmalı olarak incelenmesi. *Süleyman Demirel University Journal of Agricultural Faculty, 1*(1), 22–32.

Yurdakul, F. (1998). Pamuk üretimi ile pamuk fiyatları arasındaki ilişkinin econometrik analizi: Koyck ve Almon yaklaşımı. *Çukurova University Journal of Economics and Administrative Sciences, 8*(1), 343–351.