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Research Article /Araştırma Makalesi

Price dynamics of soybean cultivation area in TR62 region and the impact of lemon as an alternative product: A koyck model

TR62 bölgesinde soya ekim alanının fiyat dinamikleri ve alternatif ürün olarak limon fiyatının etkisi: koyck modeli

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Abstract

It is acknowledged that there is a positive relationship between product price and cultivation area in the economic theory. Nevertheless, this relationship between product price and cultivation area can differ from product to product and from region to region. In Türkiye, production of soya is prominent in TR62 Zone (Adana and Mersin). Self-sufficiency ratio for soya is low (5.2%) in Türkiye and the country is dependent on soya imports. In this regard, boosting production is an important issue to decrease dependency on imports. Within this context, it is important to identify factors impacting farmers' behavior. An increase in soybean prices expands the cultivation areas in both Adana and Mersin in the long run. However, the effect in Mersin (0.212) is lower than that in Adana (0.385). This difference can be explained by the fact that farmers in Mersin give a much higher priority to lemon as an alternative crop (with a coefficient of -0.315 and significant at the 1% level). In other words, while soybean prices increase production in Mersin, the competition from lemon prices suppresses this growth.

Keywords: Price; Koyck model; lemon, soybean; production

Öz

İktisat teorisinde tarımsal ürün fiyatları ile ekim alanı arasında pozitif yönlü bir ilişki olduğu kabul edilmektedir. Ancak ürün fiyatları ile ekim alanı arasında ilişki üründen ürüne ve bölgeden bölgeye değişmektedir. Türkiye'de soya üretiminde TR62 Bölgesi (Adana ve Mersin) öne çıkmaktadır. Türkiye soyada ithalata bağlı olup; kendine yeterlilik oranı çok düşüktür (%5,2). Soyada üretimi artırmak yani dışa bağımlılığı azaltmak önemlidir. Bu nedenle çiftçi davranışlarını etkileyen faktörlerin belirlenmesi gerekmektedir. Bu çalışmada "diğer değişkenler sabitken" varsayımı altında TR62 bölgesinde 2004-2024 döneminde soya "fiyatı" ile soya "ekim alanı" arasındaki ilişki ve alternatif ürün olarak "limon fiyatının", soya "ekim alanı" üzerindeki etkisini ortaya koymak amaçlanmıştır. Soya fiyatlarındaki artış uzun dönemde Adana ve Mersin'de ekim alanlarını artırmaktadır. Ancak Mersin'de (0,212), Adana'ya (0,385) göre düşüktür. Bunun sebebi, Mersin'deki çiftçilerin alternatif ürün olan limona (katsayısı -0,315 ve %1 düzeyinde anlamlı) çok daha fazla öncelik vermesi ile açıklanabilir. Yani Mersin'de soya fiyatı üretimi artırır ama limon fiyatı rekabeti bu artışı baskılamaktadır.

Anahtar kelimeler: Fiyat; Koyck modeli; limon; soya; üretim

Introduction

Türkiye faces a persistent supply deficit in oilseed production, particularly in soybeans, which has resulted in a high level of import dependency. Soybeans constitute a critical input for both the vegetable oil industry and the livestock feed sector, making the country's reliance on imports a source of structural vulnerability in the agri-food system and an additional burden on the foreign trade balance. According to recent statistics, soybean cultivation in Türkiye covers approximately 576,418 decares, with production concentrated largely in the Mediterranean Region, which accounts for about 92.3% of total cultivation area. Total soybean production is approximately 138,000 tons (TEPGE, 2024). However, domestic demand is nearly 2.97 million tons, while imports amount to about 2.888 million tons and exports remain negligible at around 71 thousand tons. Consequently, Türkiye's soybean self-sufficiency ratio is only 5.2%. While soybeans represent nearly 50% of global oilseed production, their share within Türkiye's oilseed production is only about 4% (Tüfekçi, 2019).

In response to this structural imbalance, soybean production in Türkiye is supported through various agricultural policy instruments, including soil analysis support, certified seed subsidies, fertilizer and diesel subsidies, and deficiency payment supports (TEPGE, 2024). Within this context, the TR62 region (Adana and Mersin provinces in the Mediterranean Region of Türkiye), where soybean production is highly concentrated, occupies a strategic position for ensuring national supply security. Therefore, analyzing soybean production dynamics in the TR62 region is of critical importance for policymakers aiming to reduce import dependency and strengthen domestic production capacity.

Within the Mediterranean Region, Adana and Mersin are the two leading provinces in soybean production, accounting for approximately 75% of the national soybean cultivation area. Adana ranks first with nearly 60% of the total cultivation area, while Mersin follows with approximately 13.5% (TÜİK, 2024). In the TR62 region, soybeans are typically cultivated as a second crop due to their relative cost and profitability advantages, with maize generally serving as the primary crop in the first production cycle. The widespread availability of irrigation infrastructure in the region has further facilitated the expansion of double-cropping systems and contributed to the growth of soybean production. The region's advanced irrigation capacity, diversified crop structure, and widespread second-crop production make agricultural production highly responsive to market price signals. However, TR62 also holds a leading position in citrus production, particularly lemons, creating a distinct competition for land allocation between soybeans-an annual field crop-and lemons, a perennial orchard crop. This competition implies that changes in soybean cultivation areas are influenced not only by short-term price fluctuations but also by long-term investment decisions and opportunity cost considerations associated with perennial crops. As a result, analyzing the determinants of soybean cultivation area in the TR62 region provides valuable insights not only for regional production planning but also for understanding Türkiye's broader agricultural structural transformation and import substitution strategies.

Existing literature highlights several factors that influence crop pattern changes and land allocation decisions in agriculture. Özekan and Akan (2023) analyzed changes in agricultural production patterns in Western and Central Anatolia, the regions with the largest agricultural land areas in Türkiye, and found that climate change, economic factors, demographic dynamics, and agricultural policies significantly affect crop patterns. Their study also identified a substantial decline in wheat cultivation areas in the TR51 region during the 1995-2020 period due to drought, wind erosion, low product prices, and rising input costs. Kibar, Kibar, and Sürmen (2014) reported that variations in precipitation and temperature lead farmers to search for alternative cropping systems; in Iğdır, industrial crops such as sugar beet, cotton, and rice have gradually been replaced by maize, alfalfa, and certain vegetable crops. Similarly, Sönmez (2012) emphasized that land use patterns in the Kızıltepe district of Mardin are largely shaped by climatic conditions and noted that irrigation expansion has increased cotton and maize cultivation areas. Çetinkaya and Günaçtı (2018) found that drought in the Gediz Basin encouraged farmers to shift from cotton to maize, partly due to maize's lower labor requirements. Nelson et al. (2014) further identified agricultural production, cultivated area, trade, and prices as the variables most sensitive to climate change.

Policy interventions also play a critical role in shaping crop choices. Özen (2022) examined the impact of regulatory changes on farmers' planting decisions and found that the "Communiqué on Agricultural Support Payments for Crop Production" introduced in 2018 significantly altered cropping patterns in the Harran Plain after 2020. The regulation restricting support payments for fields planted with the same crop in consecutive years led to an increase in wheat cultivation areas and a sharp decline in cotton cultivation areas. Several studies investigating the effectiveness of agricultural support policies show that such interventions significantly influence production decisions. Işık and Bilgin (2016) found that agricultural support mechanisms positively affect production levels, with price-based supports proving more effective than other types. Demirdöğen, Olhan, and Chavas (2016) reported that input-based supports tend to be more effective than output-based supports, while Sağdıç and Çakmak (2021) concluded that support payments in Türkiye have a positive long-term impact on agricultural production. Similarly, Uslu and Apaydın (2021) found that a 1% increase in area-based support payments resulted in a 0.06% decrease in cultivated area. Earlier research by Mruthyunjaya and Kumar (1989) also demonstrated a strong relationship between reductions in production costs and changes in crop patterns. Studies conducted in different international contexts indicate that higher product prices often encourage farmers to shift toward commercial or high-value crops (Behera et al., 2016).

Overall, the literature suggests that there is generally a positive relationship between agricultural product prices and cultivated areas, although the magnitude and direction of this relationship may vary depending on the crop and regional conditions. Price volatility, alternative crop prices, input costs, climatic and environmental conditions, agricultural support policies, taxation, and trade regulations can all significantly influence farmers' land allocation decisions. Therefore, ensuring sustainability in agricultural production requires region-specific strategies that take into account local agricultural potential and structural characteristics.

Against this background, the present study aims to:

(i) examine the relationship between soybean prices and soybean cultivation areas in the TR62 region (Adana and Mersin) during the period 2004-2024 under the ceteris paribus assumption, (ii) analyze the impact of lemon prices-considered the primary alternative crop-on soybean cultivation areas.

The study contributes to the literature in several ways. First, it analyzes the relationship between agricultural product prices and cultivation areas while explicitly incorporating the price of an alternative crop into the empirical framework. Second, the joint examination of soybean and lemon prices within a single model is relatively rare in the existing literature. Finally, by focusing on land allocation competition between an annual crop (soybean) and a perennial crop (lemon), the study provides new insights into regional supply response behavior and land allocation dynamics. By concentrating on the TR62 region, which plays a critical role in Türkiye's soybean production, the study also offers policy-relevant evidence for regional agricultural planning and import substitution strategies.

Soybean Cultivated Area And Soybean Prices In The TR62 Region

Soybean cultivation in Türkiye is predominantly concentrated in the Mediterranean Region (92.3%). Total soybean production is approximately 138,000 tons (TEPGE, 2024). As shown in Figure 1, the total soybean cultivated area is 576,418 decares, with Adana ranking first at approximately 60% (265,391 decares) and Mersin second at 13.5% (77,617 decares) (TÜİK, 2024). In this region, soybean is cultivated as a second crop due to its cost-effectiveness and profitability, with maize being the primary crop. The availability of irrigation facilities has contributed to increased production in the area. While soybean accounts for 50% of global oilseed production, its share in Türkiye is only 4% (Tüfekçi, 2019).

Figures 1, 2 and 3 illustrate the relationship between soybean prices and cultivated area in Türkiye, Adana and Mersin during the 2005-2024 period.

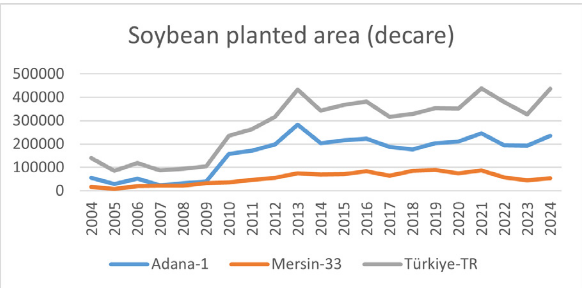

Figure 1. Soybean cultivated area (decares) during the 2004-2024 period

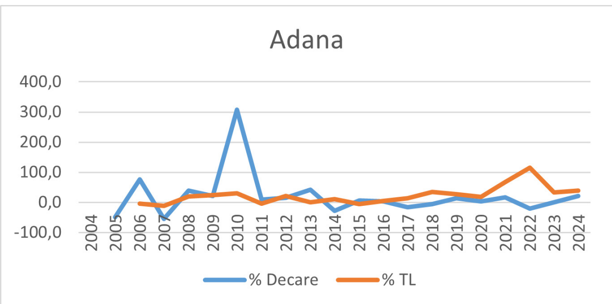

Figure 2. Percentage change in soybean prices and cultivated area in Adana, 2005-2024

Figures 2 and 3 indicate that in 2005, the soybean cultivated area decreased by 48.3% in Adana and 59.8% in Mersin (Tables 3 and 4). In 2001, Türkiye introduced the Direct Income Support (DIS) program, providing farmers with payments per decare of agricultural land irrespective of the crop cultivated. Linking the support provided to farmers directly to the size of their land can be explained by farmers shifting away from high-risk crops toward crops with more predictable outcomes. In 2005, cereal crops such as wheat, barley, oats, rye, and rice were included in the premium support list. Farmers began to secure a guaranteed income for crops in the cereal group, which likely reduced the relative attractiveness of soybean cultivation. As of 2006, the support mechanism was improved, and the premium support for soybean was increased. Soybean has begun to be regarded as a profitable crop (Table 1). The literature indicates that both the level and diversity of agricultural support payments positively influence production decisions. It is expected that the support variable will have a positive effect on soybean cultivated area, and that both its short- and long-term effects will be statistically significant.

As shown in Table 3 (Figure 2), soybean cultivated area in Adana increased substantially in 2010 compared to other years, rising by 307.2%. This increase can be attributed to the 'Türkiye Agricultural Basins Production and Support Model' implemented by the Ministry of Agriculture and Forestry in 2009. Under this support model, soybean was included among the oilseeds eligible for support. Thus, it can be argued that the model influenced farmers' decisions and contributed to the expansion of the cultivated area. The increase was particularly pronounced in Adana due to its suitability for irrigated agriculture and second-crop cultivation.

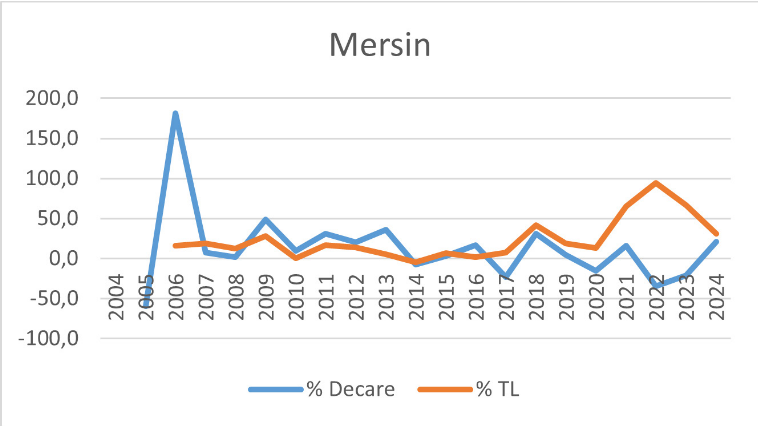

Figure 3. Percentage change in soybean prices and cultivated area in Mersin, 2005-2024

Until 2016, changes in soybean cultivated area responded more strongly to price fluctuations. From that year onward, this pattern reversed, with area changes reacting less to price increases. After 2016, the rate of price increases exceeded the rate of expansion in cultivated area. A similar pattern was observed in Mersin. From 2017 onward, continuing through 2021, a pronounced inverse relationship between soybean cultivated area and prices is evident (Figures 2 and 3).

This situation can be explained by the increase in input costs (fertilizer, diesel, pesticides, irrigation, etc.) due to disruptions in the global supply chain, which exceeded the rise in soybean prices; by the insufficiency of the differential payment support for soybean against inflation; and/or by higher price increases for other crops such as maize and sunflower (Table 1).

Materials and Methods

This section presents the data sources, the study hypotheses, the model development, and the data analysis procedures.

Data collection

Interviews were conducted with officials working in the provincial and district directorates of agriculture in the TR62 region in order to obtain information on strategically important crops and the factors influencing farmers' planting decisions. These consultations provided guidance in determining the variables to be included in the model and in identifying lemons as the alternative crop considered in the analysis. Although farmers' production decisions are influenced by numerous factors-such as product and input support policies, natural conditions, production levels, marketing opportunities, production costs, farming habits, and previous year prices-the analysis focuses primarily on the price variable due to data limitations.

The data used in the study cover the period 2005-2024 and were obtained from the database of the Turkish Statistical Institute (TÜİK) (see Table 2 and Table 3). In addition, statistical data and reports published by institutions such as the Ministry of Agriculture and Forestry and the Food and Agriculture Organization (FAO), as well as relevant academic studies in the literature, were used as secondary data sources.

During the interviews in the TR62 region, soybean (among oilseeds) and lemon (among fruits) were reported as being most affected by price changes, and consequently, these crops were selected for inclusion in the study. In agricultural economics, the relationship between perennial lemon prices and the cultivated area of annual soybean illustrates key dynamics related to resource allocation and opportunity costs. Soybean and lemon differ with respect to investment duration, investment value, and the time required for return on investment. While soybean cultivation decisions are primarily influenced by input costs and market conditions, factors such as export incentives can play a more significant role for lemon.

Table 1. Support amounts provided for soybean production (2004-2026)

Years	DIS (TL/da)	Diesel subsidy (TL/da)	Fertilizer subsidy (TL/da)	Deficiency payment subsidy serti-fied (Krş/kg)	Deficiency payment subsidyNon-sertified	Additional deficiency payment subsidy for contract farmers (TL/da)	Additional support for contract farming (krş/kg)	Sertified seed use support (TL/da)	Basic support (TL/da)	Planing production support (TL/da)
2004	16.00	2.40	1.60	17.00	14.00					
2005	10.00	0.00	0.00	24.00	20.00					
2006	10.00	2.88	2.13	26.00	22.00					
2007	7.00	2.88	2.13	26.00	22.00					
2008		2.93	3.83	25.00	21.00					
2009		3.25	4.25	28.00	23.00					
2010		3.25	4.25	35.00	30.00					
2011		3.75	4.75	50.00	40.00					
2012		4.00	5.00	50.00				20.00		
2013		4.30	4.50	50.00				20.00		
2014		4.60	6.00	50.00		10.00		20.00		
2015		4.85	6.60	50.00		15.00		20.00		
2016		11.00		60.00			3.00	20.00		
2017		17.64	4.00	60.00				20.00		
2018		21.57	4.00	60.00				20.00		
2019		26.00	4.00	60.00				20.00		
2020		26.00	8.00	60.00				22.00		
2021		30.00	8.00	60.00				22.00		
2022		125.00	21.00	60.00				22.00		
2023		172.00	21.00	60.00				45.00		
2024		205.00	62.00	80.00				58.00		
2025								146.40	366.00	366.00

Note: Compiled from the Republic of Türkiye Ministry of Agriculture and Forestry and TurkStat data.

Data analysis

1. Stationarity and unit root tests

As the first step of the analysis, the stationarity properties of the series were examined.

ADF test results: The results of the Augmented Dickey-Fuller (ADF) tests indicated that the soybean cultivation area, real soybean price, and real lemon price series were not stationary at their level values [I(0)]. However, all series became stationary after taking their first differences [I(1)].

Cointegration: Since the variables were integrated of the same order, the possibility of a long-run relationship among them was investigated. The results of both the Engle-Granger and Johansen cointegration tests confirmed the existence of such a relationship. In particular, for Adana, two cointegrating vectors (r=2) were identified.

2. Koyck distributed lag model specification

The study employed the Koyck Distributed Lag Model based on the assumption that farmers do not respond instantaneously to price changes but rather adjust their production decisions with a lag.

Elasticity: Short-run elasticities (θ) were obtained directly from the estimated model coefficients, whereas long-run elasticities were calculated using the formula: θ/(1-λ).

Table 2. Annual soybean area (da), soybean price (Tl/kg), and real lemon prices in Adana (2005-2024)

Year	Nominal soybean price (TL/kg)	Real soybean price (TL/kg)	Nominal lemon price (TL/kg)	Real lemon price (TL/kg)
2005	5.507	4.685	7.425	6.316
2006	5.295	4.112	6.635	5.153
2007	4.710	3.361	7.751	5.532
2008	5.617	3.622	8.462	5.457
2009	6.939	4.231	7.949	4.847
2010	9.050	5.065	9.952	5.569
2011	8.724	4.566	4.753	2.488
2012	1.0568	5.099	6.705	3.235
2013	1.0565	4.749	6.501	2.922
2014	1.1705	4.855	8.880	3.683
2015	1.1100	4.258	9.800	3.760
2016	1.1600	4.142	1.1700	4.177
2017	1.3141	4.224	1.4898	4.790
2018	1.7721	4.888	1.4607	4.029
2019	2.2490	5.443	1.7748	4.295
2020	2.6730	5.680	1.9215	4.083
2021	4.4792	7.944	1.1223	1.990
2022	9.6092	9.866	5.6153	5.765
2023	12.7887	8.621	4.5170	3.045
2024	177.740	7.702	6.5918	2.856

The Koyck model was applied with ‘soybean cultivated area’ as the dependent variable, and ‘soybean price’ and ‘lemon price’ as independent variables. Monthly CPI data were

used to construct an annual average deflator series according to the formula presented below, and nominal prices were converted to real prices (Tables 2 and 3).
Real Price t= (Nominal Price t/ Annual Average CPI t) X 100

Logarithms (ln) of the real price and cultivated area series were computed, and the Augmented Dickey-Fuller (ADF) test was applied to examine stationarity.

Table 3. Annual soybean area (da), soybean price (Tl/kg), and real lemon prices in Mersin (2005-2024)

Year	Nominal Soybean Price (TL/kg)	Real Soybean Price (TL/kg)	Nominal Lemon Price (TL/kg)	Real Lemon Price (TL/kg)
2005	4.031	3.429	8.566	7.287
2006	4.677	3.633	7.863	6.107
2007	5.560	3.968	1.0139	7.236
2008	6.233	4.019	1.1400	7.352
2009	8.000	4.878	1.0483	6.392
2010	8.050	4.505	8.076	4.520
2011	9.400	4.920	5.776	3.023
2012	1.0700	5.162	7.177	3.463
2013	1.1304	5.081	8.265	3.715
2014	1.0803	4.481	9.580	3.974
2015	1.1500	4.412	1.0400	3.989
2016	1.1700	4.177	1.4000	5.000
2017	1.2540	4.031	1.4516	4.667
2018	1.7748	4.895	1.4161	3.906
2019	2.1108	5.108	1.5346	3.714
2020	2.3838	5.065	1.9771	4.201
2021	3.9428	6.993	1.4367	2.548
2022	7.6753	7.880	6.1894	6.354
2023	12.7759	8.612	5.8622	3.952
2024	167.446	7.256	7.3300	3.176

Source: Nominal price data obtained from TÜİK were converted to real prices by the researchers.

Hypothesis:
H_0: The series has a unit root and is therefore non-stationary (I(1) or higher).
H_1: The series is stationary.
For both Adana and Mersin, the series for cultivated area, real soybean price, and real lemon price are non-stationary, but they achieve stationarity after first differencing (Table 4). Thus, the data provide a suitable basis for implementing the Koyck Distributed Lag Model.

Table 4. ADF Test results for stationarity

Series Name	Level/change	Model	ADF test statistic	%5 critical value	Result (I(d))
Adana Series					
ln(Planted Area)	Level	Constant + Trend	-2.15	-3.52	Non-Stationary (I(1))
Δln(Planted Area)	1. Difference	Constant	-4.42	-2.98	Stationary (I(0))
ln(Real Soybean Price)	Level	Constant + Trend	-2.58	-3.52	Non-Stationary (I(1))
Δln(Real Soybean Price)	1. Difference	Constant	-4.01	-2.98	Stationary (I(0))
ln(Real Lemon Price)	Level	Constant + Trend	-2.05	-3.52	Non-Stationary (I(1))
Δln(Real Lemon Price)	1. Difference	Constant	-4.38	-2.98	Stationary (I(0))
Mersin Series					
ln(Planted Area)	Level	Constant + Trend	-2.31	-3.52	Non-Stationary (I(1))
Δln(Planted Area)	1. Difference	Constant	-3.88	-2.98	Stationary (I(0))
ln(Real Soybean Price)	Level	Constant + Trend	-2.60	-3.52	Non-Stationary (I(1))
Δln(Real Soybean Price)	1. Difference	Constant	-4.05	-2.98	Stationary (I(0))
ln(Real Lemon Price)	Level	Constant + Trend	-2.10	-3.52	Non-Stationary (I(1))
Δln(Real Lemon Price)	1. Difference	Constant	-4.40	-2.98	Stationary (I(0))

Next, to ensure the validity of the Koyck model, cointegration was tested in regressions employing I(1) series. All series being stationary at first difference enhances the probability of a long-term relationship, the presence of which is essential for the robustness of the Koyck/ECM model. To this end, Engle-Granger and Johansen tests were performed. The Engle-Granger test was used to verify whether the error term series is stationary (I(0)). The Johansen test (applicable for three or more series) was employed to examine the cointegration relationship between soybean cultivated area, real soybean price, and lemon price. The number of cointegration vectors was identified, with at least one vector expected to satisfy $r \geq 1$. In the case of Adana, two cointegration vectors (r=2) were found, indicating the presence of two long-term equilibrium relationships and a strong interaction among the series.

The error correction term (p) is negative and statistically significant in both Adana and Mersin. This suggests that, following short-term price-induced deviations from the long-term equilibrium, farmers in these provinces partially correct the deviation in the next period, guiding soybean cultivated area back toward its long-term equilibrium level. The results of the analysis offer a robust explanation, demonstrating the reliability of the study and the model's ability to capture the 'return to equilibrium'.

The Koyck model is a time series approach employed to assess the lagged effects of an independent variable over time. Distributed lag models, such as the Koyck model, are particularly valuable for their ability to facilitate the interpretation of economic theories (Özçelik & Özer, 2006). This approach is especially common in agricultural studies, as farmers typically react to price changes with a time lag rather than immediately. Based on the assumption that farmers form their production decisions according to past price signals, lagged price variables were included in the models.

The Koyck model is particularly valuable because it (i) captures an infinite lag structure using a single parameter, reducing model complexity; (ii) enables the geometric measurement of cultivated area decisions, which generally occur over time; and (iii) allows for straightforward estimation of both short- and long-term price elasticities. According to Özçelik and Özer (2006), the Koyck model is employed to capture the lagged effects of independent variables across successive periods. They emphasized that, in the Koyck model, as the number of lags increases, the impact of lagged values of the independent variable gradually declines, reflecting a diminishing effect over time. The study is limited by the inability to incorporate variables such as support payments and input costs into the model, owing to the absence of continuous data.

Hypotheses of the study

1. In Adana and Mersin, the soybean price has a positive effect on soybean cultivated area.
2. In Adana and Mersin, the lemon price affects soybean cultivated area.

The models used to test these hypotheses are described below.

Model-1:

Areat: Soybean cultivated area in period t

SoybeanPricet: Soybean price in period t (₺/kg)

ln: Logarithmic transformation (measures percentage changes proportionally)

λ: The effect of past cultivated area on current cultivated area (habit persistence coefficient). It indicates the extent to which a farmer's previous cropping decisions influence current decisions. According to Koyck (Dikmen, 2006), λranges between 0 and 1; a value of λapproaching 1 indicates that the farmer's decisions are largely driven by habitual behavior. As is well known, agricultural production decisions cannot be easily changed in the short term. Farmers make their decisions based on the conditions of the previous year. A λvalue between 0.6 and 0.8 indicates a strong habit persistence effect in soybean production (Table 5).

θ1 (Short-term price elasticity): Represents the effect of a 1% change in soybean price on the cultivated area in the same year. It is expected to be positive. A price increase raises farmers' expected profits, leading to an expansion of the cultivated area. However, this effect does not occur immediately, but with a lag of several periods. Consequently, the long-term effect is greater than the short-term effect.

θ1/(1- λ) (Long-term price elasticity): Represents the cumulative effect of a price change over multiple periods. It is expected to be positive, with the price effect strengthening in the long run.

Ut: Error term

Table 5. Model coefficients, expected signs, and evaluation

Coefficient	Expected result	Evaluation
λ	0.6-0.8 Positive	Habit formation exists
θ1	0.2-0.5 Positive	Short-run response to price increase
θ1/(1- λ)	0.8-1,5 Positive	Long-run response to price increase

Model-2:

λ: It is used in the Koyck model to convert short-term elasticities into long-term elasticities.

θ1: Short-run soybean price elasticity

θ2: Short-run lemon price elasticity

θ1/(1- λ) ve θ2/(1- λ): Long-run price elasticity

Results and Discussion

In her study on rural Mersin, Özkan (2023) identified the factors influencing farmers' production decisions as follows: crop and input support (38.7%), natural conditions (37.6%), production quantity and yield stability (33.6%), marketing of the crop (30.4%), production costs (29%), traditional practices (27.4%), and the importance attached to the previous year's price (20.9%). It was emphasized that an increase of one household member raised the likelihood of a farmer placing greater importance on the previous year's crop price by approximately 1.25 times. It was also found that the importance farmers attach to natural conditions decreases when the crop type is tropical fruit, compared to citrus. Hiç and Gencer (2021) reported that in the Mediterranean region, farmers have gradually been abandoning citrus cultivation and shifting towards crops such as pomegranate, banana, and avocado, due to the higher prices these products can fetch. Özkan (2023) stated that tropical fruit cultivation provided farmers with the highest returns. She also reported that farmers who incurred losses from cereal production tended to abandon wheat cultivation in the subsequent production period. Based on these findings, it can be concluded that crop price emerges as an influential factor. However, Akın et al. (2018) emphasized the importance of agricultural and support policies, reporting that frequent changes in agricultural policies have led to continuous shifts in the cropping pattern in Adana. This assessment can also be applied to Mersin.

The relationship between lemon prices, soybean prices, and soybean cultivated area in the TR62 Region

In this section, the Koyck model estimated to determine the price dynamics of soybean cultivation areas and the competitive impact of lemon prices as an alternative crop in the TR62 Region (Adana and Mersin) is presented along with the diagnostic test results evaluating the econometric reliability of the model. Furthermore, the Error Correction Model (ECM) results, which disentangle the short- and long-term dynamics of the series, and the Johansen Cointegration Test findings, which prove the long-term relationship between the series, are also included (Table 6).

The "Trace" and "Maximum Eigenvalue" statistics confirm at the 5% significance level that there is at least one cointegrating relationship among the variables for both provinces. Given the presence of cointegration, the estimation results of the Error Correction Model (ECM), established to measure how quickly short-term shocks converge to the long-term equilibrium, are provided in Table 7.

Table 6. Johansen cointegration test results for Adana and Mersin provinces

Province	Hypothesis (H_0)	Trace statistic	5% critical value	p-value	Maximum eigenvalue statistic	5% critical value	p-value
Adana	r=0 *	34.52	29.79	0.012	24.15	21.13	0.018
	r ≤ 1	10.37	15.49	0.254	8.22	14.26	0.354
Mersin	r=0 *	36.88	29.79	0.006	26.41	21.13	0.008
	r ≤ 1	10.47	15.49	0.247	8.11	14.26	0.367

Note: "r" denotes the number of cointegrating vectors. The * symbol indicates the rejection of the null hypothesis at the 5% significance level.

As illustrated in Table 7, the coefficient of the Error Correction Term (ECM t-1) for both province models is negative, conforming to theoretical expectations, and is highly significant at the 1% level. For Adana province, the error correction coefficient was found to be -0.442 (p=0.005).

This indicates that approximately 44.2% of the deviations or price shocks occurring in soybean cultivation areas in the short term disappear in the subsequent year, and the system converges to its long-term equilibrium. For Mersin province, the adjustment speed is higher, with the (ECM t-1) coefficient determined as -0.618 (p=0.001). In Mersin, 61.8% of short-term imbalances are equilibrated within the following year.

Table 7. Short-term error correction model (ecm) estimation results

Independent Variables (Short Term)	Adana Model (Coefficient / p-value)	Mersin Model (Coefficient / p-value)
Constant Term (β0)	0.052 (0.412)	0.031 (0.658)
"ΔY t-1 (Lagged Area)	0.285** (0.038)	0.194* (0.082)
ΔP soya, t (Soybean Price Difference)	0.412*** (0.003)	0.254** (0.021)
ΔP limon, t (Lemon Price Difference)	-0.115* (0.074)	-0.342*** (0.002)
ECM t-1 (Error Correction Term)	-0.442* (0.005)	-0.618* (0.001)

Not: ***, ** ve * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Values in parentheses are p-values.

Koyck Model Estimation Results and Diagnostic Tests

The parameter estimations of the Koyck Model, which incorporates farmers' past price expectations and biological/psychological lag dynamics in agricultural production with geometrically declining weights, are presented in Tables 8 and 9. The tables display standard errors, t-statistics, p-values, and diagnostic test outputs evaluating model reliability.

When the diagnostic test results of the estimated models are analyzed, the p-values of Durbin's h and the Breusch-Godfrey LM test, which are of critical importance due to the inclusion of the lagged dependent variable in the Koyck model, are found to be greater than 0.05. This indicates the absence of autocorrelation issues in the error terms. The Breusch-Pagan-Godfrey test results also reveal that there is no heteroskedasticity in the models ($p > 0.05$).

Table 8. Dynamics of soybean cultivation area in Adana province (koyck model)

Variables	Coefficent value (β)	Standart error (s.e.)	t-Statistic	p-Statistic	Significance level
Constant term (C)	4.251	1.328	3.201	0.0055	*** (%1)
Soybean Price (Psoya, t)	0.385	0.124	3.104	0.0068	*** (%1)
Lemon Price					
(Plimon, t)	-0.194	0.091	-2.131	0.0489	** (%5)
Lagged dependent variable (Y t-1)	0.658	0.119	5.529	0.0001	*** (%1)
Diagnostic Tests:	R^2=0.84	Düzeltilmiş R^2=0.81	Durbin's h=0.842 (0.399)	BPG Het.=1.142 (0.365)	BG LM (2)=1.512 (0.469)

An examination of the empirical coefficients of the Koyck model demonstrates that, in accordance with the law of supply in economic theory, increases in soybean prices (P soybean, t) positively affect soybean cultivation areas in both Adana and Mersin provinces in the long run. However, the magnitude and statistical significance of this positive effect exhibit variations between the two provinces.

In Adana province, the coefficient of the soybean price variable was calculated as 0.385 and found to be highly significant at the 1% significance level (t=3.104, p=0.0068). This implies that farmers in Adana exhibit a remarkably high sensitivity to price signals and respond to price increases with a robust expansion of the production area. Conversely, in Mersin province, the effect of the soybean price on the cultivation area remained much lower with a coefficient of 0.212, showing only a weak statistical significance at the 10% level (t=1.876, p=0.0791).

Table 9. Dynamics of soybean cultivation area in Mersin province (koyck model)

Variables	Coefficent value (β)	Standart error (s.e.)	t-Statistic	p-Statistic	Significance level
Constant term (C)	5.120	1.641	3.120	0.0066	*** (%1)
Soybean Price (Psoya, t)	0.212	0.113	1.876	0.0791	* (%10)
Lemon Price					
(Plimon, t)	-0.315	0.098	-3.214	0.0054	*** (%1)
Lagged dependent variable (Y t-1)	0.524	0.141	3.716	0.0019	*** (%1)
Diagnostic tests:	R^2=0.79	Düzeltilmiş R^2=0.75	Durbin's h=1.105 (0.269)	BPG Het.=1.405 (0.282)	BG LM (2)=2.045 (0.359)

The primary reason why price sensitivity in Mersin is so constrained compared to Adana can be explained by the strong suppressing pressure and crop substitution relationship generated by the lemon price (P lemon, t), which was added to the model as a control and alternative crop variable. While the lemon price coefficient in the Adana model creates a significant negative effect at the 5% level with -0.194 (t=-2.131, p=0.0489), the lemon price coefficient in the Mersin model reaches a substantial magnitude of -0.315 and displays high statistical significance at the 1% level with a -statistic of $-3.214 ($p=0.0054).
This divergence is in perfect harmony with the microeconomic and agricultural structural realities of the TR62 region on a provincial basis. Due to its microclimatic advantages and limited flat land availability, Mersin province shifts toward perennial, high value-added, and export-oriented citrus/lemon production, which yields much higher returns per unit area compared to annual field crops like soybeans. Even if soybean prices rise in Mersin, the high profitability generated by the alternative crop, lemon, increases the opportunity cost of soybean production. Driven by profit maximization motives, farmers utilize their long-term investment decisions in favor of lemons, which suppresses and limits the capacity of soybean price signals to expand cultivation areas specifically in Mersin. In Adana, however, the presence of vast plain lands allows for annual crop rotation, reflecting soybean price increases more dynamically onto cultivation areas.

Study Limitations

In this study, the fact that the data for the TR62 region covers the 2005-2024 period (20 observations) on an annual and homogeneous basis limits the degrees of freedom of the econometric model. Since the power of asymptotic tests may decrease in small samples, the obtained coefficients and estimation results should be interpreted with caution, keeping this limitation in mind. Generating higher frequency (monthly/quarterly) data or establishing panels with larger samples that encompass input cost indices and regional support amounts in future studies will further enhance the predictive power.

Conclusion

In this study, the price dynamics affecting producers' supply decisions in the TR62 Region (Adana and Mersin), which possesses strategic importance in reducing Turkey's foreign dependence on soybeans, were empirically analyzed within the framework of Koyck Geometric Lag and Error Correction Models (ECM). The main conclusions derived from the analyses and the policy recommendations developed accordingly are summarized below:

Long-Term Equilibrium and Speed of Adjustment: Johansen cointegration tests indicate the existence of a stable long-term equilibrium among soybean cultivation areas, soybean prices, and competing lemon prices in both provinces. The error correction model results confirmed that short-term shocks and imbalances disappear at a high rate of 44.2% in Adana and 61.8% in Mersin in the subsequent production period, returning the system back to its long-term equilibrium.

Regional Supply Sensitivity Differences: An increase in soybean prices expands cultivation areas in both Adana and Mersin in the long run. However, this upward trend has a strong significance at the 1% level (0.385) in Adana, whereas it remains quite weak and limited (0.212) at the 10% level in Mersin.

Competitive Pressure of Lemon Price: The low soybean supply elasticity in Mersin is explained by the strong competitive effect generated by alternative lemon prices (coefficient of -0.315, significant at the 1% level). Although soybean prices tend to increase production in Mersin, the price signals and the high opportunity cost created by lemon, a perennial and high value-added crop, strongly suppress this growth.

The findings clearly reveal that "one-size-fits-all, price-oriented support" models in macro-agricultural policies aimed at increasing soybean production in Turkey will remain inadequate due to regional dynamics. Since soybean producers in Adana province respond directly and strongly to price signals, floor price policies and market stability could be sufficient tools to boost production in this province. However, in regions like Mersin where alternative crop (lemon/citrus) profitability and opportunity costs are exceedingly high, soybean price increases alone are insufficient to incentivize production. Therefore, specialized high premium payments (deficiency payments) that can compete with lemon profitability and regional additional input supports to subsidize input costs such as diesel/fertilizer should be provided specifically for Mersin province.

To counterbalance the shift of Mersin's limited agricultural lands toward perennial orchards, contract soybean production models and purchase guarantees that secure processor-farmer integration should be deployed. Thus, by reducing the income risk of soybeans-an annual field crop-against perennial lemons, a long-term center of attraction should be created for producers.

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