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How Does Agricultural Mechanization Affect Agricultural Production? A Panel Data Analysis

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Abstract

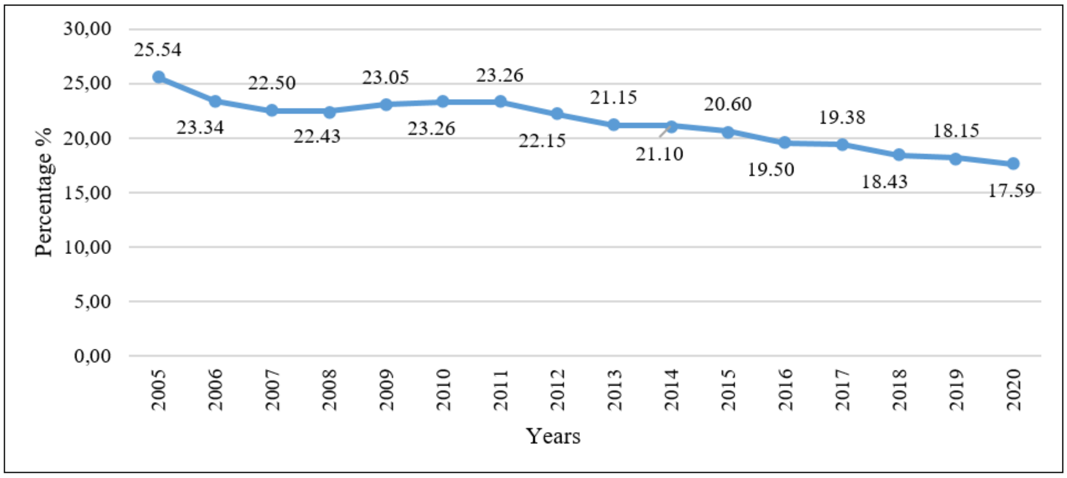
Purpose: This study aims to explain the relationship between agricultural production and mechanization in agriculture in Turkey using annual country data between the 2006 and 2019.
Design/Methodology/Approach: 12 regions under NUTS 1 and ARDL test are used for analysis. The number of machines used, labor, income and land are used as variables.
Findings: The empirical results reveal that agricultural production has a positive relationship with income, land and machine usage, but negative with labor in the long term. Although the negative impact of labor is an unexpected result, it is asserted that the machines substitute the labor in some studies. Hence, the increase in usage of machines leads to fall in the number of labor and increase the agricultural production. Results also show that the rise in income increases the agricultural production, labor and machine usage as it creates a resource for more inputs, investment and new machines. It also makes agricultural labor more attractive. On the other hand, the agricultural production is also a reason of income because the more agricultural production increases, the more profit and income farmer earn. Another causality result shows that there is an important impact of the rise in the agricultural land on the machine usage.
Originality/Value: The literature shows that there is a very limited number of studies, especially empirically, analyzing the mechanization impact on agricultural production in Turkey. Hence, this study aims to fill the gap in this field and explain the relationship between agricultural mechanization and agricultural production clearly.
Key words: Mechanization, agricultural production, sustainability, ARDL test

Tarımsal Makineleşme Tarımsal Üretimi Nasıl Etkiler? Bir Panel Veri Analizi
Özet

Amaç: Bu çalışma, Türkiye'nin bölgesel düzeydeki 2006-2019 dönemi yıllık verilerinden yararlanarak tarımın makineleşmesi ve üretimi arasındaki ilişkiyi açıklamayı amaçlamaktadır.
Tasarım/Metodoloji /Yaklaşım: Analiz için İBBS 1 altındaki 12 bölge ve ARDL testi kullanılmıştır. Değişken olarak kullanılan makine sayısı, emek, gelir ve arazi kullanılmıştır.
Bulgular: Ampirik sonuçlar, uzun vadede tarımsal üretimin gelir, arazi ve makine kullanımı ile pozitif, emek ile negatif bir ilişkisi olduğunu ortaya koymaktadır. Emeğin olumsuz etkisi beklenmedik bir sonuç olsa da bazı çalışmalarda makinelerin emeğin yerini aldığı ileri sürülmektedir. Dolayısıyla makinelerdeki artış, işgücü sayısında azalmaya neden olmakta ve tarımsal üretimi artırmaktadır. Ayrıca sonuçlar, gelirdeki artışın daha fazla girdi, yatırım ve yeni makineler için kaynak yarattığından dolayı daha çok tarımsal üretkenliğe, işgücüne ve makine kullanımına neden olduğunu göstermektedir. Bu durum tarım işçiliğini daha çekici kılmaktadır. Öte yandan, tarımsal üretim de bir gelir nedenidir çünkü tarımsal üretkenlik arttıkça kâr ve gelir de artar. Diğer bir nedensellik sonucu göstermektedir ki tarım arazilerindeki artışın makine kullanımı üzerinde önemli bir etkisi vardır.
Özgünlük/Değer: Literatür incelendiğinde, Türkiye'de tarımsal üretim üzerinde makineleşmenin etkisini özellikle ampirik olarak ele alan çok az çalışma olduğu görülmektedir. Bundan dolayı, söz konusu çalışma bu alandaki boşluğu kapatmayı ve tarımsal makineleşme ile tarımsal üretim arasındaki ilişkiyi açıklamayı amaçlamaktadır.
Anahtar kelimeler: Makineleşme, Tarımsal üretim, sürdürülebilirlik, ARDL test

1.INTRODUCTION

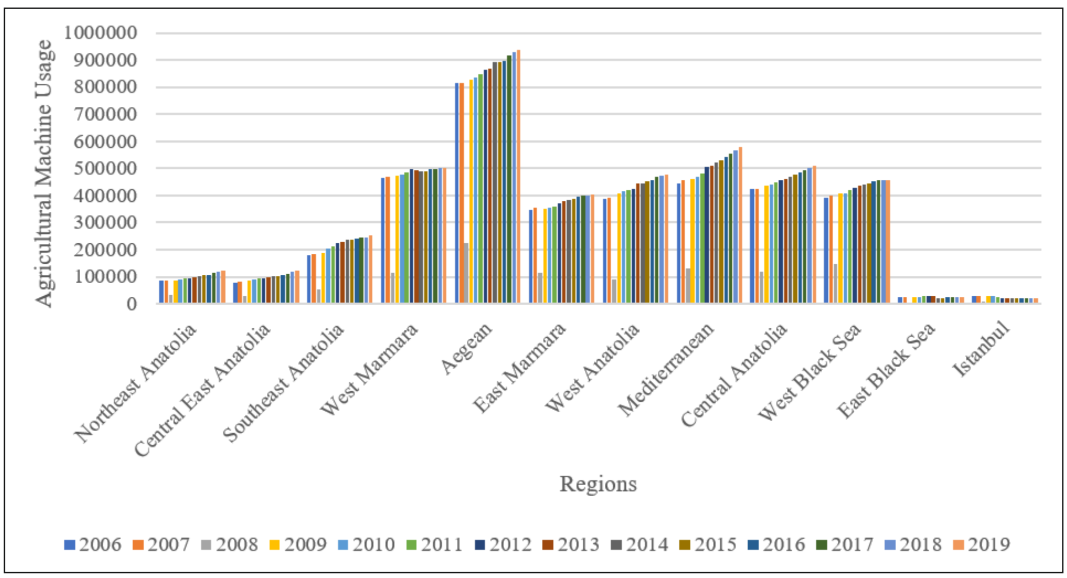
Increasing urbanization and global health crises, agriculture becomes more of an issue for the societies and the economies with the climate changes (Bayrac and Dogan, 2016; Hayaloglu, 2018). Although the need for agriculture is increasing, the number of agricultural workers in Turkey has been decreasing for years. Requiring more manual effort than other sectors, the rise in the input prices, changing climate conditions and the fall in income are supportive factors for labor to shift to other sectors. The share of employment in agriculture was 25.5% in 2005 but had gone down to 17.6% in 2020 as shown in Figure 1 (TUIK, 2021a). The fall in the agricultural employment does not only impact the agricultural production negatively but sustainable agriculture as well.



Source: TUIK (2021a)

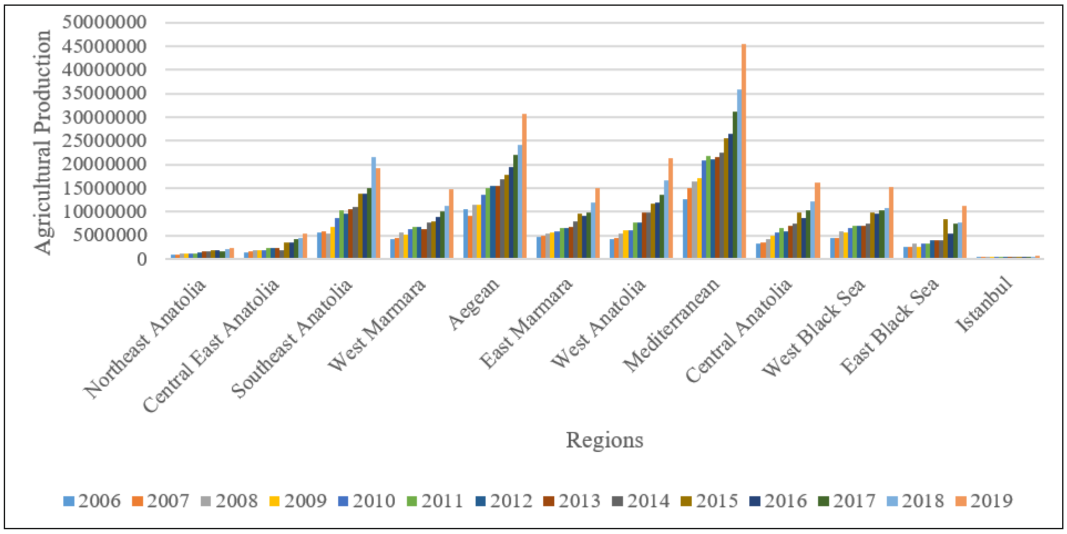
Figure 1. Agricultural employment share in total employment

In this sense, the mechanization plays a crucial role for the agricultural production and sustainability. Agricultural mechanization is very useful in terms of both the labors and the economies. It has many advantages such as getting more output per production input, making production quality better, easing planting, preventing the yield loss in the planting and harvest processes. While these advantages prevent the labor shifts from the rural area to urban area, they also contribute to the economies to a large extent. Despite of all these advantages, the adoption process and usage of new technologies and machines take time. Hence, many studies have tried to examine the reasons and obstacles of adoption and usage and solve it since the study of Griliches (Griliches, 1957; Feder, 1985; Dinar, 1992; Zilberman, 1997; Wilson, 2001; Rehman et al., 2016). The research until today show that there are many reasons to adopt and use the technology such as income, education, learning, social capital, norms, farm size, input prices and credit accessibility (Tandogan and Gedikoglu, 2020). Hence, the numbers of mechanization changes depending on many factors. This study analyzes machine utilization on a regional base because it also shows the difference between the regions as shown in Figure 2. While the highest machine usage is seen in Aegean and Mediterranean Regions, the lowest usage is in Istanbul and East Black Sea Region. Depending on many factors such as mechanization, the agricultural production also changes among regions as shown in Figure 3. Figure 3 shows that while the regions having the most agricultural production are Mediterranean and Aegean Regions, the regions having the least agricultural production are Istanbul and Northeast Anatolia Regions. Hence, it is clear that there is a relationship between agricultural machine usage and production when considering the regions having the most machine usage and production.



Source: TUIK (2021b)

Figure 2. Agricultural machine usage in regional level of Turkey



Source: TUIK (2021c)

Figure 3. Agricultural production in regional level of Turkey

Regarding the impacts of agricultural mechanization, Lingard and Bagyo (1983) investigated the impact of agricultural mechanization on production and employment by taking the rice areas of West Java as an example. Using the 1979-1980 data and different methods, it was concluded that mechanized farms used less labor, pesticides and more fertilizers than non-mechanized farms, but had higher yields on hectare basis. Also, although they were much larger than the non-mechanized ones, they had a lower cropping intensity. Singh (2006) analyzes the estimation of mechanization index and its effects on the economic and production factors by using multiple linear regression as the method and India as a sample. The study uses fertilizer, irrigation and farm power as variables and concludes that human labor cost has the biggest share in the cost of cultivation in that particular crop which is the most highly mechanized one in India. Human and animal energy costs constitutes 85.5% of the operational costs. It is also shown that the states which have higher mechanization indices have a lower cost of cultivation based on the increased yield. Srisompun et al. (2019) focus on the adoption of mechanization labor production and household income by taking rice production in Thailand as an example. The findings of the study indicate that while large farms have a positive relationship with machine labor to the workforce, there is an inverse relationship between the average rice planting workforce and labor production. It is also found that mechanization level has an impact on the rice yield, labor usage and labor production of farmers.

When considering the literature in Turkey, most studies are about the agricultural mechanization level (Atasoy, 2002; Kocturk and Avcioglu, 2007; Onurbas and Ozguven et al. 2010; Eryilmaz et al., 2014; Altuntas, 2016). Other studies are mostly presented in the way of general evaluation rather than empirical analysis. Dogan (2005) evaluates the impact of tractor and harvester for Turkey in the general context. The results exhibit that these machines enable saving time, employing less labor, obtaining higher efficiency and new employment opportunities. Akdemir (2013) touches upon the indicators, problems, and solutions of agricultural mechanization in Turkey. While the study states that Turkey lags behind developed countries in terms of agricultural mechanization, suggests helping farmers to mechanize might provide better yield and quality. Yurtlu et al. (2012) evaluate the risk perception of the farmers using agricultural machinery by face-to-face survey method. The study indicates that accident risks are important in machine usage however it is thought that pre- training and briefings about machine usage will decrease the risks. Kilavuz and Erdem (2019) focus on the agriculture 4.0 applications in the world and its transformation and importance in Turkey. According to the descriptive statistics, it is asserted that Turkey is not a self-sufficient agriculture country anymore, it is foreign-dependent. This foreign dependency requires agricultural reforms including transition to technological agricultural applications, providing information to farmers at each production stage, constituting better cooperation systems.

Regarding agricultural production, there are very few empirical studies. Among them, Or Ceyhan (2017) analyzes the impact of climate change on agricultural production by using Panel Data Analysis. The findings reveal that while the changes in the temperature and other variables have a positive impact on agricultural production, the changes in the precipitation and diurnal temperature have a negative impact on agricultural production. Duramaz and Tas (2018) evaluate the impact of agricultural credits having been granted by the public, private and foreign capital bank on agricultural production. The study uses Panel Data Analysis as a method and Aegean Region as data. According to the results, the increase in public bank credits, private bank credits and foreign bank credits by 10 percent increases agricultural production by 3.2%, 0.4% and 0.1% respectively. More similarly to the present paper, the study of Kan (2019) focuses on the relationship among the agricultural production value, participation of women's labor force and capital stock. For the analysis, Panel Data Analysis and regional level of Turkey are preferred and the results show that participation of women labor force and the presence of the tractor affect the agricultural production value positively.

In this context, this paper aims to analyze the impact of machine utilization on the agricultural production at the level of regions of Turkey. By using annual data for the 2006-2019 period, the regions are classified according to the Nomenclature of Territorial Units for Statistics 1 (NUTS 1). These 12 regions are Northeast Anatolia, Central East Anatolia, Southeast Anatolia, Istanbul, West Marmara, East Marmara, Aegean, West Anatolia, Mediterranean, Central Anatolia, West Black Sea and East Black Sea Regions. Agricultural production is examined with Panel Data Analysis (Autoregressive Distributed Lag-ARDL). Variables used in this study are the number of machines used, labor, income and land. When reviewing the literature, it is seen that there are very few studies, especially empirically, handling the mechanization impact on agricultural production in Turkey. Hence, it is expected that this study will help fill the gap in this field. The paper consists of four sections. This introduction is the first section. In the second section, the data and methodology are explained in detail. The third section gives the results obtained from the empirical study and finally the fourth section concludes the study by interpreting the results.

2. MATERIAL and METHODS

Material

For the empirical analysis, the annual data between 2006 and 2019 are used. To see the impact on agricultural production, the study uses four variables, income, labor, land and number of machines. The regions are classified according to the Nomenclature of Territorial Units for Statistics 1 (NUTS 1). These 12 regions are Northeast Anatolia, Central East Anatolia, Southeast Anatolia, Istanbul, West Marmara, East Marmara, Aegean, West Anatolia, Mediterranean, Central Anatolia, West Black Sea and East Black Sea.

Methods

In this study, logarithm of agricultural production can be expressed as a function given of the mentioned variables;

$$\ln(AP) = f(\ln(INC), \ln(LABOR), \ln(LAND), \ln(MACH)) \qquad (1)$$

where *AP* denotes the agricultural production, *INC* is income, *LABOR* is the number of labor, *LAND* is the agricultural land used and *MACH* is the number of agricultural machines.

For the long-term relationship analysis, firstly cross-section dependency should be tested as it is a prerequisite for the unit root tests. Additionally, if the cross-section dependency is not considered, results can be misleading (Chudik and Pesaran, 2013). Hence, the cross-section dependency test is implemented by using Breusch-Pagan LM and Pesaran CD tests (Breusch and Pagan, 1980; Pesaran, 2004). Homogeneity is evaluated by panel cross-section heteroskedasticity LR Test.

In analyzing the series, stationarity is very important in terms of preventing biased results and spurious regression, hence the unit root tests are implemented. Among the unit root tests, second generation CADF panel unit root test which is appropriate for the cross-section dependency is selected (Pesaran, 2007). The equation of the cross-sectionally augmented Dickey-Fuller (CADF) test can be expressed as given in Equation 2.

$$y_{i,t} = \alpha_i + \gamma_i y_{i,t-1} + \cdots + \delta_{i0}\bar{y}_t + \delta_{i1}\bar{y}_{t-1} + \cdots + \delta_{ip}\bar{y}_{t-p} + \varepsilon_{i,t} \qquad (2)$$

Determination of long-term relationship among the series is analyzed with Durbin-Hausman cointegration test developed by Westerlund (2008). The reason for choosing this test is to test the stationarity of more than one variable at the level. This test enables the cross-section dependency and the heterogeneity of slope coefficients.

The long-term impact is evaluated by ARDL model because this model gives reliable results for small samples. ARDL notations in this study can be shown as given in Equation 3.

$$\begin{aligned} AP = \beta_0 &+ \sum_{i=1}^{m} \beta_{1i}\,\Delta AP_{t-i} + \sum_{i=1}^{m} \beta_{2i}\,\Delta INC_{t-i} + \sum_{i=1}^{m} \beta_{3i}\,\Delta LABOR_{t-i} + \sum_{i=1}^{m} \beta_{4i}\,\Delta LAND_{t-i} \\ &+ \sum_{i=1}^{m} \beta_{5i}\,\Delta MACH_{t-i} + a_1 AP_{t-i} + a_2 INC_{t-i} + a_3 LABOR_{t-i} + a_4 LAND_{t-i} \\ &+ a_5 MACH_{t-i} + u_i \qquad (3) \end{aligned}$$

Accordingly, the Granger Causality test is used to see if the causality relationship between the variables is implemented.

3. FINDINGS

When analyzing Table 1, it is shown that probabilities are statistically significant ($p<0.01$) and so the null hypothesis is rejected which means that there is a cross-section dependency. Interaction between the regions makes the results significant. This presents that there is an interaction among the regions and the changes in the regions affect each other.

Table 1. Cross-section dependency

Test	Statistic	Prob.
Breusch-Pagan LM	328.6259	0.0000
Pesaran scaled LM	22.85865	0.0000
Pesaran CD	14.19319	0.0000

The result of the homogeneity test in Table 2 rejects the null hypothesis because the probability is statistically significant, hence the residuals are heteroskedastic. Because of the differences between the regions and geographical locations, stemming from the process of technology adoption and usage, the heterogeneity in the agricultural applications is an expected result.

Table 2. Homogeneity test

	Value	Probability
Likelihood ratio	129.4507	0.0000

According to the results of the unit root test in Table 3, while income and labor are stationary at level with constant, labor and land are stationary at level with constant and trend. While all variables are stationary at first difference with constant, only land and machines are stationary at first difference with constant and trend.

Table 3. CADF unit root tests

	Level (Constant)			Level (Constant and Trend)		
	t-bar	Z(t-bar)	P value	t-bar	Z(t-bar)	P value
AP	-1.830	-0.319	0.375	-2.149	0.348	0.636
INC	-2.207	-1.515	0.065*	-2.268	-0.024	0.491
LABOR	-2.456	-2.307	0.011**	-2.784	-1.636	0.051*
LAND	-2.105	-1.191	0.117	-3.356	-3.420	0.000***
MACH	-1.806	-0.243	0.404	-1.831	1.338	0.910
	First Difference (Constant)			**First Difference (Constant and Trend)**		
AP	-2.155	-1.352	0.088*	-2.093	0.520	0.698
INC	-2.546	-2.160	0.005***	-2.626	-1.142	0.127
LABOR	-2.932	-3.819	0.000***	-2.834	-1.790	0.037
LAND	-3.568	-5.841	0.000***	-3.674	-4.412	0.000***
MACH	-2.401	-2.131	0.017**	-3.152	-2.784	0.003***

*Note: *, **, *** implies significance at 10%, 5% and 1% respectively.*

The result of Durbin-Hausman cointegration test in Table 4 indicates that there is cointegration between the agricultural production, income, labor, land, and machine because the p-values are significant at 5% level. This means that these variables are in interaction with each other in the long term.

Table 4. Durbin-Hausman cointegration test

	Statistic	P value
Variance ratio	-1.599	0.05

When analyzing Table 5, the probability of income and labor is found to be significant. While income, land and machine usage have a positive relationship with agricultural production, labor has a negative effect. If the income is increased by one percent, agricultural production will be increased by 1.151 percent. However, the increase in labor by one percent causes the decrease in agricultural production by 0.181. Although the negative impact of labor is an unexpected result, some studies state that machines substitute the labor. Hence, the more amount of labor decreases, the more machine usage increases. The production of machines is more than the labor so it has a positive impact on the agricultural production.

Table 5. ARDL test

Variable	Coefficient	Prob.
LNINC	1.151294	0.0000***
LNLABOR	-0.180995	0.0003***
LNLAND	0.268235	0.3226
LNMACH	0.038255	0.3308

*Note: *, **, *** implies significance at 10%, 5% and 1% respectively.*

Table 6 presents the statistically significant causality results because the probabilities are smaller than 0.05. According to the results, income is the reason for agricultural production, labor, and machine because income provides more inputs and investment on new machines. Its increase makes working in agricultural sector attractive. It has a bidirectional relationship with agricultural production, the more agricultural production increases, the more income increases. If the land usage becomes larger, using machines become more important and necessary hence the reason for using machines is also land usage.

Table 6. Granger causality test

Causality	F-Stat	Prob
INC ➔ AP	8.706437	0.0129
AP ➔ INC	6.992962	0.0303
INC ➔ LABOR	7.011808	0.0300
INC ➔ MACH	83.51421	0.0000
LAND ➔ MACH	20.61559	0.0000

*Note: *, **, *** implies significance at 10%, 5% and 1% respectively.*

Figure 4 summarizes the causality relationship among the variables. While land causes only the machine, income affects both machines, labor and agricultural production. As income has an impact on agricultural production, agricultural production also causes more income.

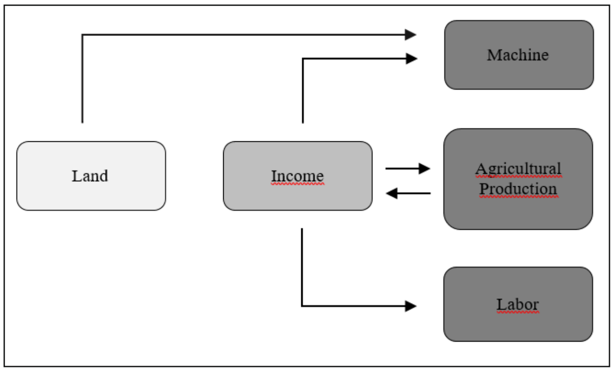


Figure 4. Causality relationship among variables

4. DISCUSSION and CONCLUSIONS

Agriculture has become more important with the climate changes, increasing urbanization and global crises. Although Turkey is an important agricultural country, there is a great decrease in the number of agricultural workers, despite agriculture's increasing importance. The reasons for this fall in the numbers can be explained by expensive input prices, changing climate conditions, work requiring more effort than many other sectors, and low wage and income. However, agricultural production is very important in terms of the economy especially for agricultural countries such as Turkey. Hence, mechanization plays a crucial role in providing sustainability and higher agricultural production.

While it relieves the labors' burden to a great extent, it helps getting more output per production input, make production quality better, ease planting, prevent yield loss in the planting and harvest process. However, the literature especially the empirical ones about the relationship between agricultural machine usage and agricultural production in Turkey is very few. In this sense, this study aims to fill the gap in the literature and explain the relationship by using annual data for the 2006-2019 period at the regional level of Turkey. For the analysis, 12 regions under NUTS 1 and Panel Data Analysis are used. Variables used in this study are number of machines that are used, labor, income and land.

Cross-section dependency test results indicate that there is cross-section dependency and it means that there is the interaction between the regions as expected. The heteroskedasticity of residuals confirms the differences between the regions and geographical positions. Durbin-Hausman cointegration test presents the cointegration between the agricultural production, income, labor, land and machine. ARDL test results reveal that agricultural production has a positive relationship with income, land and machine usage, but negative with labor in the long term. Although the negative impact of labor is an unexpected result, it is asserted that machines substitute the labor in some studies. Hence, the fall in the number of labor leads to increase in machines and it increases the agricultural production. The results of the Granger Causality test show the importance of income on the agricultural production, labor and machine because it creates a resource for more inputs, investment and new machines. It also makes agricultural labor attractive. On the other hand, the agricultural production is also a reason of income because the more agricultural production increases, the more profit and income increases. Another causality result shows that the rise in the agricultural land causes the machine usage.

All the results indicate that machine usage has a positive impact on the agricultural production but income and land are important factors for the machine because while the rise in income makes machines more accessible, the land makes it necessary. In the regional base, Figure 2 and Figure 3 also shows the similarity between the agricultural machine usage and agricultural production. Hence, its usage becomes more significant.

Although there are very few empirical studies focusing on the topic of the present paper, when compared to the literature, the results are consistent with those studies. As indicated in the study of Dogan (2005), there is a negative relationship between labor amount and agricultural production because the machines enable employing less labor. New employment opportunities which are provided by using agricultural machines and saving time causes more income. This is interpreted as a positive impact of agricultural mechanization on income and the positive impact of income on agricultural production. In line with the study of Duramaz and Tas (2018), providing more financial opportunities such as credits has a positive impact on agricultural production because a rise in income increases the purchasing power and investment on agricultural machines. The results relating to the agricultural machines are consistent with Kan's study (2019). The presence of agricultural machines, specified as tractor in Kan (2005), increases agricultural productivity. More generally, the positive impact of agricultural mechanization on agricultural production is emphasized in the study of Akdemir (2013).

Considering the importance of agriculture for society and economies, providing sustainability in the agriculture is very important especially for the agricultural countries like Turkey. This study shows that income is a strong reason of machines because the agricultural machines are expensive. Although agricultural machines have many advantages as mentioned above, the ability to have these machines is not easy for Turkish agricultural labors. Hence, the government should support farmers to invest in machines easier and cheaper. Farmers also should be informed and encouraged to use the new machines. The adoption programs should be arranged to alleviate anxiety about its risk and usage. Otherwise, the fall in the number of labors and production makes Turkey foreign-dependent and damage Turkish economy to a great extent.

Conflict of Interest Statement

The author of the article declares that there is no conflict of interest and does not plagiarize.

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