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Estimating the effect of a land parcel index using hedonic price analysis

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Abstract: The purpose of this study was to statistically test the effect of a parcel index – consisting of a combination of a soil index, a fertility index and a location index – intended to be used as a price-determining indicator for the sale of agricultural land at farmland markets. In the hedonic price model, the coefficients of the variables representing parcel index, population, gross return and parcel irrigation investment status were positive and statistically significant at a significance level of 0.01. There was a negative relationship between parcel size and sale price, which implied that the selling price per decare tends to decrease as the parcel size increases. In the study area, the prices of farmland with large parcel sizes and irrigation efficiency investments were higher. The population density in the region and gross income from farmlands were the major factors that generated demand for the land. The hedonic price model establishes an important link between the parcel index and the sale price of farmland. Based on this link, parcel index-based pricing can contribute significantly to the creation of a farmland market in Turkey.

Keywords: asymmetric information; double-log model; farmland market; soil index; Vuong test

The largest share in the active capital of agricultural enterprises is land. The land is a factor in production, but unlike other factors of production, it is immovable, has a fixed supply and is not subject to depreciation (Raup 2003). It is used in both livestock and plant production. The value of land is directly affected by the proceeds from agricultural production. Estimating the value of land is not easy because it has numerous variable characteristics, even in very small parcels. Proceeds from parcels within the immediate vicinity of each other can vary widely.

The market for farmland differs from other markets in that the supply of farmland is fixed, unlike the case in many other transactions. Their characteristic features are that they can only be sold where they are located, that they have their own individual characteristics, that they can be purchased and sold at land offices and that their sale is taxable. In addition to these characteristics, they can also feature a close relationship to humans and multi-stakeholder ownership.

The farmland market does not meet the requirements of a fully competitive market. Since land is an inherently heterogeneous resource, there can be a limited number of buyers and sellers in the market, and it is therefore considered an imperfectly competitive market. The farmland market largely depends on local supply and demand. Due to the restrictions of the farmland market, there are numerous small local markets in which buyers and sellers operate. A price level is formed in each local market. This price level reflects the local forces of supply and demand that represent the utility value for buyers and sellers.

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Since farmland is an immovable property, trading activities are limited to ownership. As a matter of fact, what is sold is not the physical land but the right to possess it or, alternatively, the rent obtained from it. The capitalized rent or land price is formed by the conversion of farmland rent into money. The price of farmland is determined by natural (all factors including the soil and the climate), demographic (population), social (location, access) and economic (capital investments in land) factors (Drescher et al. 2001; Huang et al. 2006). In terms of agricultural use, soil quality, water supply, farmland yields, parcel size, proximity to markets, land rent and agricultural subsidies are the factors that are most frequently cited as major determinants of farmland prices (Lloyd et al. 1991; Awasthi 2009). In addition, location-specific features that do not reflect the agricultural characteristics of the land are capitalized in land prices (Spinney et al. 2011).

The main purpose of this study was to statistically test a parcel index, which was created to serve as the first trading indicator to determine the market price for farmland. For this purpose, a hedonic price model was estimated for farmland sales in the study area, and statistically significant characteristics were identified in the model. The null hypothesis (H_0) that farmland prices are not affected by the parcel index was tested against a sample of regional data on actual land market transactions. This is the first study in the published literature to test the effect of a parcel index, which is a combination of soil index, fertility index and location index, on farmland prices. In this regard, it suggests how necessary it is to use a parcel index as an indicator of the sale prices of farmland.

MATERIAL AND METHODS

The chosen study area was the rural area of Kirkagac, located in the west of the Aegean region of Turkey. First, the location, block and parcel details of farmlands sold in 2015 were obtained from the real estate office in the Kirkagac municipality. Out of the target population list of people engaged in agricultural production and those selling farmland in the Kirkagac region, 164 farmers were selected by a purposive sampling method. In November 2016, face-to-face interviews were conducted with the farmers who accepted the invitation, and a questionnaire was filled in. Some of the information obtained from the questionnaires was confirmed by a parcel query application to the General Directorate of Land Registry and Cadastre. The land assets, soil classes and parcel characteristics of the rural area of Kirkagac were obtained from the Manisa land asset publication prepared by the General Directorate of Rural Services (MLA 1998).

The hedonic price model. It is impossible for buyers and sellers to use a single market price for farmland because each parcel of farmland exhibits a unique combination of attributes, and therefore, its valuation must be a function of the quantity and value of a combination of the different attributes present. Rosen (1974) defines hedonic prices as 'the implicit prices of attributes'. These prices are calculable and implied because there is no direct market equivalent for them. Equation (1) indicates the basic hedonic price model:

$$P_i = \sum_{j=1}^{m} \beta_j X_{ij} \tag{1}$$

where: β_j – marginal implied price for the characteristic j; X_{ij} – set of explanatory variables.

By adding an error term to Equation (1), regression analysis can be used to test the hypotheses of the model and of β_j, and to obtain estimates for β_j. Since there are no guidelines about the functional form of the hedonic price model in terms of economic theory, the Box-Cox transformation was applied to test the functional forms. In this approach, the nonlinear parameter λ is added to the dependent and independent variables (Box and Cox 1964). The general hedonic regression model is therefore as follows:

$$P_i^{\lambda_1} = \beta_0 + \sum_{j=1}^{m} \beta_j X_{ij}^{\lambda_2} + \sum_{k=1}^{n} \beta_k Z_{ik} + \varepsilon_i \qquad E[\varepsilon_i] = 0, \quad \mathrm{Var}[\varepsilon_i] = \sigma^2 \tag{2}$$

where: β_0 – constant term; m – number of transformable variables; n – number of non-transformable discrete variables; Z_{ik} – discrete independent variable (irrigation investment status); ε_i – residuals that eliminate the homoscedasticity restriction; λ_1, λ_2 – Box-Cox transformations.

The hedonic regression model consists of the dependent variable farmland sales price (P_i), the continuous independent variable X_{ij} (parcel index, parcel size, population of the settlement where the land was sold, and gross return from the land) and the discrete independent variable Z_{ik} (the irrigation investment status), which is a dummy variable [Figure S1 in electronic supplementary material (ESM); for the ESM see the electronic version]. The maximum likelihood ratio test

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can be used to determine the functional form of the hedonic price model. Individual and combined tests of Box-Cox parameters give unexpected results. Therefore, the Vuong (1989) test can be used as a complementary test to choose among four functional forms. We can define the likelihood ratio for each individual observation *i* using the following formula:

$$Vuong = \frac{\sqrt{n}\left[\frac{1}{n}\sum_{i=1}^{n} LR_i\right]}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(LR_i - \overline{LR}_i\right)^2}} \quad (3)$$

where: n – number of observations; LR_i – likelihood ratio between the models j and k ($LR_i = ll_j - ll_k$); ll_j, ll_k – likelihood ratio for the j and k models.

The Vuong test statistic is asymptotically distributed as a standard normal distribution. While the positive values higher than the critical value $N_{\alpha/2}$ (at a significance level of α) confirm model j, the negative values lower than $N_{\alpha/2}$ confirm model k. Acccordinly, $|Vuong| \leq N_{\alpha/2}$ indicates that there is no significant difference between the k and j models.

RESULTS AND DISCUSSION

Sample characteristics. The buyer evaluates the utility of the property for their future purposes. The seller evaluates the utility of the proceeds from the sale (or what they will buy with the proceeds from the sale) in relation to the benefit of the existing property to them. It is the property's marginal utility that determines the economic importance of the property to the potential buyer. When the buyer's and seller's acceptance prices are equal, it becomes the sale price.

In the study area, the average sale price for farmland has been USD 2 493.9. Farmland in this region has been sold at a minimum of USD 607.1 and at a maximum of USD 5 714.3. The coefficient of variation (*CV*) of farmland sale prices was 52%. Therefore, farmland was offered for sale at highly varying prices (Table 1).

The parcel index is calculated by adding together the soil index, fertility index and parcel location index scores. Soil index consists of a soil profile, topsoil texture, slope of the land and other features. It is a value ranging from 0 to 100 (Arici and Akkaya Aslan 2014). The soil index value was obtained from soil surveys and maps prepared previously for Manisa. The fertility index was determined according to the fertility indicators of the land. It is a value ranging from 0 to 10. The location index is created by taking into consideration the proximity of the property to residential areas, the geometric shape of the parcel, the available transport facilities, the current irrigation status, etc., and ranges from 1 to 20.

When calculating the parcel index, 70% of the soil index (*TE*) is added to the index scores determined for fertility and location. This index can be used as an indicator for buyers, as it contains three major elements of the sale of farmland. Previous studies indicated that the sale price of farmland depends on their fertility and distance to the market. The current index was discussed and tested using alternative weights by Tezcan et al. (2020). As a result of their study, it was stated that when calculating the parcel index, each plot of agricultural land should add additional criteria to reflect its own characteristics and location. In other words, it was shown that the current index weights cannot be standard but can be changed for each plot of agricultural land by experts working on this subject. However, it should not be forgotten that the land for which the parcel index is calculated is used for agricultural purposes. Minimum and maximum parcel indices of the farmland in the study area were 12.0 and 83.4, respectively. The average parcel index value in this region was

Table 1. Descriptive statistics

Variable	Name of variable	Unit	Expected sign	Min.	Max.	Mean	SD	*CV* (%)
P_i	parcel sale price	USD/decare	dependent variable	607.1	5 714.3	2 493.9	1 294.6	51.9
x_1	parcel index	–	+	12.0	83.4	37.2	15.1	40.6
x_2	parcel size	m^2	+/–	219.6	50 631.0	7 051.6	6 002.5	85.1
x_4	population	person	+	130.0	3 181.0	1 346.3	929.0	69.0
x_5	gross return	USD	+	39.4	4 017.9	751.9	455.9	60.6
x_6	irrigation investment	–	+	0	1	0.390	0.489	125.4

CV – coefficient of variation

Source: Authors' own elaboration

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37.2. The *CV* for the parcel index was 40.6%. This value indicated that farmland grades vary in that region (Table 1). A high parcel index is expected to have a positive effect on the sale price of the parcel.

Parcel size is a basic physical characteristic that is expected to affect the selling price of farmlands because a larger size of farmland means a higher overall value than that of a smaller piece of land. However, their value per decare decreases at a decreasing rate since a larger plot of land will attract fewer potential buyers. This situation reflects a curvilinear relationship between the two variables. Therefore, the size of farmlands is expected to have an inverse relationship with the selling price per decare and is incorporated into the hedonic equation in a non-linear fashion. The land size and sales price of land per decare are expected to have a statistically significant relationship because the majority of farmlands are small due to their fragmentation through inheritance, but the direction of this relationship is uncertain. Also, Ritter et al. (2020) stated in their study that the size–price relationship may change over time and may differ for sub-samples. The average parcel size in the region was 7 051.6 m^2. The smallest of the parcels sold was 219.6 m^2 and the largest one was 50 631 m^2. The *CV* of parcel size was 85%. In other words, parcel sizes varied greatly and were diverse in nature (Table 1).

Demographic factors are addressed in many hedonic studies either in the form of local population density or annual population growth rate. According to Palmquist and Danielson (1989), the population density of the district where the parcel is located can be used to measure current population pressure, while the population growth rate can represent population growth expectations. Depending on the population of the settlement, the selling price of farmland varies. Therefore, a positive relationship is expected to be observed between the population of the settlement and the selling price of farmland. The average population of the settlements in the study area was 1 346.3 people. The population of the smallest settlement was 130 people, whereas the population of the largest settlement was 3 181 people. That makes the *CV* of settlement population 69%. Settlement population data is diverse.

Gross return is calculated for the parcel sold. The production pattern of the parcel, and the income generated, can be an indicator for buyers because the farmers who want to buy a parcel assign a price for the agricultural land taking into account the return on the capital they invest. The greater the expected future returns on a piece of land, the higher the present value of that land is expected to be. The gross return per decare in the study area was USD 751.9. It was found that farmers generated an income equal to one-third of the average sales price of parcels. The *CV* of the gross return of parcels was 60.6%. Therefore, the gross return on the parcels vary. It is expected that the income generated from a parcel will have a positive effect on its selling price (Table 1).

To a large extent, parcel-specific characteristics determine the productive function and income generating capacity of the parcel. Both the natural and man-made conditions of the parcel complement each other for the specific production target, and investments in irrigation efficiency increase the value of farmland. The availability of modern technologies for drainage and water saving in the parcel increases the income of the buyer, thereby affecting the selling price. This variable was included in the model as a dummy variable. The presence and absence of water efficiency and drainage investments in the parcels were assigned the values of 1 and 0, respectively (Table 1).

Estimation results. Three basic steps were followed in the estimation of the hedonic price model. First, Box-Cox transforms and Vuong tests were applied to select the functional form used in the estimation of the hedonic price model. As a result of Box-Cox transformations and Vuong tests, a log–log function form was chosen from alternative functions (Tables S1, S2 in ESM; for the ESM see the electronic version).

Second, statistical tests were performed to confirm that the hedonic price model assumption was made using results from ordinary least squares (OLS) regression testing. In addition, goodness of fit measures were estimated for the OLS regression. The estimated hedonic price model is presented in Table 2. The coefficients estimated in Table 2 are the implied prices for each of the characteristics or attributes considered. In the hedonic price model, the coefficients of parcel index, parcel size, population, gross return and parcel irrigation investment were positive and statistically significant at a significance level of 1%. The settlement size of the region where the land is located is usually a factor that affects the parcel price. The population is an indicator of the size of the settlement. The positive sign of the population indicated that there was a positive relationship between the price of the parcel and this variable. The population coefficient indicated that when the population in the settlement increased by 1%, the parcel price increased by 0.46%. In other words, the higher the population was, the wider the non-agricultural use of the land was. The increased demand

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Table 2. Estimation results for the hedonic price function

Variables (x_i)	Coefficients (β_i)	SE	t-statistic	Marginal probability (P)
x_1	0.20	0.06	3.24	0.00
x_2	1.01	0.34	3.00	0.00
x_3	–0.05	0.02	–2.53	0.01
x_4	0.46	0.03	15.29	0.00
x_5	0.15	0.04	4.00	0.00
x_6	0.22	0.06	3.69	0.00
Constant	–1.20	1.45	–0.83	0.41

Diagnostics	Test	Value	Level of significance
Heteroscedasticity	F-statistic	1.184	0.265***
Multicollinearity	VIF	1.420	less than 5
Normality test	Jarque-Bera X^2	4.797	0.112
Determination coefficients	R^2	0.756	–
	adjusted R^2	0.746	–
Ramsey RESET	$F_{(1.157)}$-statistic	0.090	0.767*
Residual sum of squares	RSS	13.700	–
F-statistic	–	81.098	0.000

*, ***Significance at the 10% and 1% levels, respectively; RESET – regression equation specification error test; VIF – variance inflation factor

Source: Authors' own elaboration

for land due to an increasing population has a positive effect on farmland prices. In some areas where little farmland is offered for sale and there is a strong demand for land for non-agricultural use, farmland prices may increase significantly. Currently, farmland in Turkey is distributed and fragmented, with many small parcels owned by multiple owners through inheritance. According to the information on the farmer registration system in relation to cultivated farmland, the number of parcels owned by agricultural enterprises is 6 and the parcel size is 13 decares (FRS 2016).

Large parcel size is regarded as desirable by farmers for agricultural production with modern and large equipment. Small parcel size increases production costs due to a lack of economies of scale. Due to the regional production pattern, the size of farmland in demand may vary. Previous research has found that parcel size has a negative effect on the sales price of land. As the size of the parcel of farmland offered for sale increases, the value of that farmland per decare decreases at a decreasing rate (Brorsen et al. 2015). This means that a larger parcel is expected to be sold at a lower price per decare than a smaller parcel. The reason is that fewer buyers compete for larger parcels in the market. To check for a quadratic (decreasing) effect of parcel size on price, the parcel size squared was included in the hedonic model. The coefficient of the parcel size (squared) had a negative relationship on the sale price, reflecting the fact that the sale prices per decare tended to decrease as the parcel size increased (Figure S2 in ESM; for the ESM see the electronic version).

Gross return refers to the gross income obtained from the market value of products cultivated on the farmland sold. The expected income from farmland is generally considered to be the main factor that determines its value. A rational farmland buyer prefers to buy the parcel he thinks will benefit him the most as regards the return on the price he will pay by considering the balance between land prices and the income from the 'use of the land'. The gross return had a positive effect on the parcel sales price and was statistically significant at a significance level of 1%. When the gross return increased by 1%, the price of the farmland increased by 0.15%. Therefore, buyers take into consideration the gross return of the farmland when evaluating its sale price. Since the demand for farmland in the study area is often associated with agricultural production rather than non-agricultural use, one can say that the gross income obtained from the farmland is a determinative factor in forming the price of the farmland. It is known that farmland prices increase when farming income is high (Xu et al. 1993). This relationship is based, in part, on the income effect experienced by potential buyers of farmland.

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Previous studies included the variables of soil quality, location and fertility individually in the hedonic price model (Vasquez et al. 2002). They found that these variables generally had a positive effect on the price of farmland. In this present study, lands were classified by creating a parcel index combining the soil index and fertility index, which defines the permanent and variable characteristics of the soil, and the location index, which defines the distance to the settlements or enterprise headquarters. The parcel index is an important indicator for buyers, as it includes soil quality, fertility and location. It had a positive effect on the farmland price as expected and was significant at a significance level of 1%. When the parcel index increased by 1%, the farmland price increased by 0.20%. The hedonic price model establishes an important link between the parcel index and the sale price of farmland. Through this link, parcel index-based pricing can make a significant contribution to the development of a farmland market in Turkey.

Farmlands can be improved for specific uses, thereby creating appreciation. For example, investment in water ponds for agricultural production, modern technologies for irrigation or erosion, and drainage requirements all add value to the farmland. Palmquist and Danielson (1989) found that farmland values were significantly affected by both potential erosion and drainage requirements. Installation of modern irrigation systems that will save water, and soil improvements for drainage, affect the sale price of the parcel because they increase the potential income of the buyer. It was found that the sales price of farmland in which irrigation efficiency investments had been made was 22% higher on average than the sales price of other farmland. Investments in farmlands for irrigation efficiency in the region contribute to the creation of a higher demand for farmland.

Diagnostics tests. Heteroscedasticity and multicollinearity are two common problems that arise when working with cross-sectional data in econometric analyses. Multicollinearity is likely to reduce the accuracy of the estimated parameters. Therefore, a variance inflation factor (VIF) was used to reveal any possible multicollinearity among independent variables and needs to be defined. The mean *VIF* of all variables in both models was 1.42 (ranging from 1.05 to 1.65). A number less than 5 indicated that multicollinearity was not an issue in these models. Furthermore, the presence of heteroscedastic error terms in the hedonic price model was tested. For this purpose, the White test result was F-statistic = 1.18 ($P = 0.26$), meaning that H_0, the homoscedasticity hypothesis, cannot be rejected. Since the Jarque and Bera test is $P = 0.11$, H_0, the hypothesis that the error terms are normally distributed, cannot be rejected. The Ramsey regression equation specification error test (RESET) test (F-statistic) was found to be 0.54 ($P = 0.46$). This value indicated that the hypothesis H_0, which states that there is no specification error in the model at a significance level of 1%, should not be rejected. An F-statistic of 81.098 indicated that the model was highly significant. The coefficient of determination (R^2) indicated that 76% of the changes in price, the dependent variable, were explained by the land characteristic variables included in the hedonic price model (Figure S3 in ESM; for the ESM see the electronic version).

Discussion. Most of the studies on the agricultural land market are not aimed at increasing the efficiency of the agricultural land market. Studies in published literature are mostly designed to determine the factors affecting the price of agricultural land (Dacko et al. 2021). It is known that the agricultural land market does not meet the requirements of a perfectly competitive market because of the diversity of agricultural land. In this market, the difference between the knowledge of the buyers and sellers about the characteristics of the agricultural land provides market power to the seller and causes the market to be ineffective. With the agricultural land parcel enquiry, basic information such as area, quality and location are presented openly to everyone without any restrictions, while much information – price in particular – is not presented (Lin and Zhang 2021). Therefore, the parcel enquiry information is not sufficient when making the decision to purchase agricultural land. For this, it is clear that there is a need for a parcel index that buyers can benefit from when making such a purchase.

With this study a parcel index was created, which is expected to be used as an important indicator for both buyers and sellers in the agricultural land market, and its effect on the agricultural land sales price was tested. The findings showed that the parcel index for the agricultural land market had a significant effect on the formation of sale prices. With the parcel index, asymmetric information conditions were eliminated, and it is expected that the agricultural land market will work more effectively. Agricultural land market transparency improves market efficiency (Seifert et al. 2021).

There are some limitations in this study. First, the parcel index was calculated for a predetermined area. Therefore, the limitation of our study is that it could not determine the role of the parcel index at a national level. For this purpose, the parcel index should

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be published in agricultural land consolidation projects. Second, the rates taken in the parcel index were kept constant. These rates can be changed according to the intended use of the agricultural land. For this, while calculating the parcel index of agricultural lands, changes can be made to the rate calculations at a regional level.

CONCLUSION

In this study, the parcel index, which contributes to the formation of the sales price of farmland, was developed for the first time in published literature, thereby contributing to the farmland market. Knowledge of the classification of farmlands by parcel index score is essential for landowners as well as land buyers, developers and land policymakers. The results of the hedonic price model indicated that the parcel index has a strong effect on the price of farmland. The importance of using all available information on farmlands is proven. Furthermore, hedonic results can also be useful in the policy-making decisions of agricultural public agency representatives for the management and marketing of farmland.

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