Agroholdings and Land Rental Markets: A Spatial Competition Perspective

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Abstract

With the emergence of large, horizontally integrated farm enterprises especially in Eastern European countries, the question arises whether these agroholdings exercise market power in (local) land markets. Using a theoretical framework of spatial competition that accounts for the presence of multi-farm agroholdings, we derive equilibrium prices under alternative spatial competition settings. Based on the investigation of Ukrainian farms, we provide a theoretical explanation and empirical support that farms affiliated with an agroholding possess (ceteris paribus) more land and set higher land rental prices compared to independent farms. The results indicate that agroholdings can act as price leaders in local land markets.

Key words: Land rental market, Ukraine, lokal market power

JEL classification: L13, L22, Q12, Q13

1. Introduction

Besides its importance for agricultural production, land features specific characteristics: it is immobile and spatially distributed. Additionally, agricultural production includes costs that are associated with the geographical distance between the land plot and the farmstead. As these distance or transport costs hinge on the relative location of farms to the same plot of land, i.e., farms closer to this plot will have a cost advantage over farms located more distantly (*ceteris paribus*), land markets are examples of horizontal product differentiation and the possibility to exploit local market power arises in such settings (Capozza and Van Order, 1978).

This bears particular importance in transition economies. In these countries, there is a disparity between the farm and landowner structure with large (corporate) farms and fragmented landownership (Swinnen, 2009). Consequently, land is predominantly allocated to its agricultural use via rental markets (Ciaian et al., 2012). Given the spatial structure of this market, landowners may not only have few options to select among potential tenants, but smaller farms

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might also find it difficult to participate in the land market. In fact, a number of studies attribute imperfect competition a prominent role in land markets (Ciaian and Swinnen, 2006, 2009; Kirwan, 2009; Breustedt and Habermann, 2011; Herck et al., 2013; Kirwan and Roberts, 2016) but only recently Graubner (2018) provides a conceptual investigation from a spatial competition perspective. The present paper aims to proceed this approach as well as complement it with an empirical application for Ukraine.

Ukraine is an interesting example for several reasons. After the land reform (1992-2000), 27.72 mln ha of agricultural land were distributed among 6.91 mln former members of collective farms. An average landowner holds 4.2 ha (OECD, 2004), while the average farm size in Ukraine is about 1 957 ha in 2008 (SSSU, 2009). In 2001 the moratorium for sale of agricultural land (The Land Code of Ukraine, 2002) was implemented and despite several attempts, a liberalization of the land sales market was yet unsuccessfully (Koroteyev et al., 2017). Accordingly, rental is the only option for farms and landowner to participate in the land market.

Another important aspect of Ukrainian agriculture is the role of so called agroholdings, i.e., large horizontally and/or vertically integrated farm enterprises. In 2017 about 29% of the country's agricultural land was farmed by agroholdings and they accounted for 20 (29)% of the production value in crop (animal) production (UCAB, 2018). The rise of these large agricultural enterprises in Ukraine and elsewhere in Eastern Europe increasingly attracted the attention by the scientific community, politicians and the public. However, their effects on markets, particularly the land rental market, are not well understood and less so from a conceptual perspective. The present paper aims to fill this gap.

A basic feature of most Ukrainian agroholdings are horizontally integrated subsidiaries, i.e., farms which are individually responsible for operational tasks, while strategic decisions are made centrally (Hermans et al., 2017). In this sense, agroholdings resemble multi-plant firms as frequently investigated in spatial economics literature (Holahan, 1978; Spulber, 1984; Dasci and Laporte, 2004; Lederer, 2012; Aguirregabiria and Vicentini, 2016). We therefore adopt the framework by Norman (1981), but transfer and extent it to the land market by using an input market perspective and allow for price-inelastic land supply. We investigate alternative competition settings in the land market, including spatial price leadership competition as first introduced by Anderson (1987).

With the present paper we address a number of research gaps. On the one hand, we provide a first conceptual approach to analyze strategic behavior of large, horizontally integrated farm enterprises from a spatial competition perspective. In doing so, we contribute to the literature of spatial economics, e.g., by showing that price leadership competition, in contrast to the simultaneous move game, features a price equilibrium in pure strategies. On the other hand, we contribute to a small body of literature that applies and empirically examines concepts of spatial economics to agricultural (input) markets.

In the following, we first present the theoretical framework of a spatial land rental market and we investigate alternative options to model price competition. Based on the results from the theoretical analysis we derive a set of hypotheses: (H1) Independent farms (IF) feature smaller hectar-sizes compared to farms affiliated with agroholdings (AH); (H2) AH will set higher rental prices compared to IF; and (H3) The effect on land rental prices caused by a price change in the farm output market is different for AH compared to IF. We test these hypotheses empirically by investigating farm sizes, rental prices and their determinants using farm-level accounting data of Ukrainian farms for 2005-2016, provided by the State Statistics Service of Ukraine (SSSU). The initial dataset consists of about 105 tsd. observations, where ca. 8% are agroholding subsidiaries (2016).

The results show that farms affiliated with agroholdings are larger in terms of land endowment and pay higher land rental prices compared to independent farms. We also find empirical support that agroholdings may act as price leader in local land markets.

2. Theoretical framework

The aim of this section is to provide a conceptual framework and theoretical insights into the land market under spatial price competition in the presence of agroholdings. In the following, we first present a general (monopsony) framework of spatial pricing in the land market before we investigate competition and the agroholding in terms of a multi-plant firm. Subsequently, we derive optimal prices based on a duopsony framework of local competition between two farms, which may or may not represent different organizational types, i.e., farms who are either independent or affiliated with an agroholding. In the case of competition between an independent and an subsidiary farm, the latter is presumed to act as price leader. Based on the theoretical results, we derive hypotheses that shall be tested in the empirical, second part of the paper.

2.1. The spatial land market

We first assume that agricultural land is identical except for its location and that each plot of land is accessible through the location of landowners, who are uniformly distributed along a one-dimensional unbounded line market. This differentiates each landowner by its unique location $x \in [0, \infty]$, i.e., each location is occupied by exactly one landowner, and (implicitly) allows for a two-dimensional distribution of land along the line, e.g., in terms of a *main street*. We define the land supply function dependent on the local rental price $p(x)$ and the price elasticity of land supply ε, while x measures the distance from the farmstead ($x = 0$) to the landowner's location:

$$q(x) = p(x)^{\varepsilon}. \tag{1}$$

We further assume that one unit of land can be used to produce one unit of (aggregated farm) output, which can be sold to a constant price Φ, i.e., farms are price taker in the downstream market. The marginal revenue of land is $\phi = \Phi - c$ and c are constant marginal costs of other production factors. The cultivation of land causes transport costs that proportionally increase with rate t and with distance x. The farm uses a linear price-distance function such that the local rental price is:

$$p(x) = r - \delta t x, \tag{2}$$

where r is the (base) rental price and δ some portion of the transport costs. Only if $\delta = 1$ there is no spatial price discrimination because transport costs are fully reflected in the local (rental) prices, while $\delta = 0$ represents spatial price discrimination (Phlips, 1983), typically called uniform pricing, where all landowners receive the same rental price r. Whatever price strategy the farm chooses, the local profit per unit of land is given by:

$$\pi(x) = \phi - p(x) - tx. \tag{3}$$

Finally, F represents fixed costs that are necessary to establish a farmstead and thus the farms (overall) profit is:

$$\Pi = 2\int_0^D [\phi - p(x) - tx]\,[p(x)]^{\varepsilon}\,dx - F. \tag{4}$$

D is a (maximum) distance measure and denoted as farm radius. A farm will now chose a pricing policy (r^*, δ^*) and farm radius D^* in order to maximize profit, subject to some competitive constraint that need to be specified (Norman, 1981). For instance, following Graubner et al. (2011) we can show that the profit maximizing strategy of the monopsony is given by:

$$(r^*, \delta^*, D^*) = \left(\frac{\varepsilon\phi}{1+\varepsilon}, \frac{\varepsilon}{1+\varepsilon}, \frac{\phi}{t}\right). \tag{5}$$

This price strategy is known in the literature as optimal discriminatory pricing, where profits at each point in the market as well as the farm radius is maximized (Greenhut et al., 1987). The optimal price r^* is a portion of the output price ϕ and δ^* does neither depend on ϕ nor t.

2.2. The multi-farm agroholding

In contrast to the single farm acting as monopsonist in unbounded space, the multi-plant monopsonist additionally decides over the number of plants to be establish in a region. In this case, Holahan (1978) assumes that a multi-plant monopsony aims to maximize profit per area $\Pi/2D$. Adopting this approach for agroholdings, we consider the optimal price strategy (5) in (4) and solve for the optimal radius of the subsidiary farms D^{AH}, i.e., $\partial\Pi(r^*, \delta^*)/\partial D$. After some rearrangement, the first-order condition for profit maximization per area can be written as:

$$F = \frac{\left[\phi^{\varepsilon+2} - (\phi - tD^{AH})^{\varepsilon+1}(\phi + tD^{AH}(\varepsilon+1))\right]}{t(\varepsilon+2)(\varepsilon+1)^{\varepsilon+1}} 2\varepsilon^{\varepsilon}. \tag{6}$$

This relationship is highlighted in Figure 1 and it generalizes the findings of Norman (1981), who investigates the multi-plant firm in consumer markets with $\varepsilon = 1$. First note that an agroholding will always choose $D^{AH} \leq D^*$ as D^* is the optimal (maximum) farm radius under monopsony. If fixed costs exceed a critical value $\hat{F}(\varepsilon)$ it is optimal for the agroholding to establish only one farm of size D^* according to equation (5). In other words, the single farm of an agroholding will be smaller than a monopsony farm. Second, for any level of fixed costs below $\hat{F}(\varepsilon)$, the farm radius (size) of the single farm of an agroholding increases with increasing price elasticity of supply.

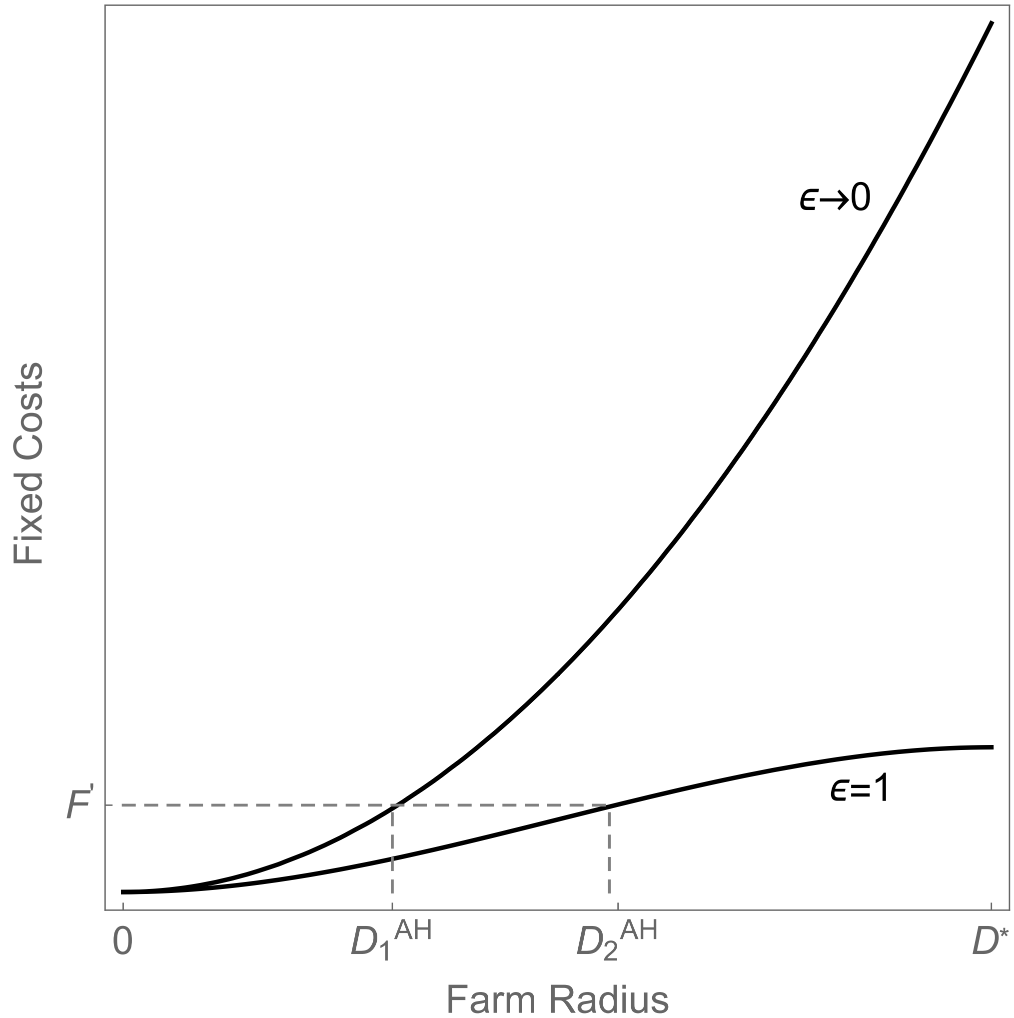

Figure 1. Optimal size of the individual farm of an agroholding for perfectly inelastic and unielastic local land supply with $\phi = t = 1$.

2.3. Monopsonistic competition

Instead of an agroholding, the region could accommodate a group of independent farms under monopsonistic competition. In this case, free entry drives profits to zero, but each farm can employ the profit maximizing monopsonistic price strategy (cf. Claycombe, 1990) over landowners that locate within their farm radius D, i.e., $\Pi(r^*,\delta^*)=0$, which yields:

$$F=\frac{\phi^{\varepsilon+2}-(\phi-tD^{IF})^{\varepsilon+2}}{t(\varepsilon+2)(\varepsilon+1)^{\varepsilon+1}}2\varepsilon^{\varepsilon}. \tag{7}$$

With equation (6) and (7) we obtain:

$$(\phi-tD^{IF})\left(\frac{\phi-tD^{IF}}{\phi-tD^{AH}}\right)^{1+\varepsilon}=\phi+(1+\varepsilon)tD^{AH}. \tag{8}$$

Defining $\beta\equiv(\phi-tD^{IF}/\phi-tD^{AH})^{1+\varepsilon}$ we write:

$$\phi(\beta-1)=(1+\varepsilon)tD^{AH}+\beta tD^{IF}. \tag{9}$$

Because β, ϕ and the right hand side of this equation are positive,[1] condition (8) requires that $D^{IF}\le D^{AH}$. This is also highlighted in Figure 2, where the farm radius of independent farms under monopsonistic competition D^{IF} is compared with D^{AH} in the case of perfectly inelastic local land supply. As stated in equation (5), the price strategy is independent of cost conditions and identical for both the agroholding and independent farms. Due to $D^{IF}\le D^{AH}$ for any level of fixed costs, agroholdings will feature larger farms in terms of land endowment compared to independent farms under monopsonistic competition.

Besides the two presented scenarios in which a region is either covered by independent farms *or* subsidiary farms of an agroholding, other options include cooperative or non-cooperative competition between farms of different or the same organizational types. In such settings, optimal discriminatory pricing might not be the equilibrium strategy (Espinosa, 1992; Graubner et al., 2011) or farms (under cooperative competition) might find it administratively challenging to establish this price regime. A common alternative is uniform pricing where $\delta=0$. Equation (2) reduces to $p(x)=r$. Besides the advantage of uniform pricing in terms of an easy administration, it also does not considerable deviate from the profit maximizing strategy (cf. δ^* in (5)) if price elasticity of supply is low, which is a reasonable assumption for land markets (Salhofer, 2000; Abler, 2001; OECD, 2008). One issue that typically afflicts the analysis of competition under uniform pricing is the non-existance of Nash-equilibria in pure strategies (d'Aspremont et al., 1979). Although a mixed strategy equilibrium exists (Beckmann, 1973), an intuitive transfer to respective applications is often difficult and one can argue that such an equilibrium represents an undesirable source of uncertainty and foregone profits both farms may want to avoid. Cooperative competition is therefore a reasonable alternative assumption. Additionally, one farm, e.g., because of their affiliation to an agroholding, might be in a position of a price leader. In either case, an equilibrium in pure strategies can be established (Gronberg and Meyer, 1981; Anderson, 1987) and we subsequently transfer those concepts to the land market setting.

[1] Note that neither farm radius will exceed D^* as otherwise local profits become negative.

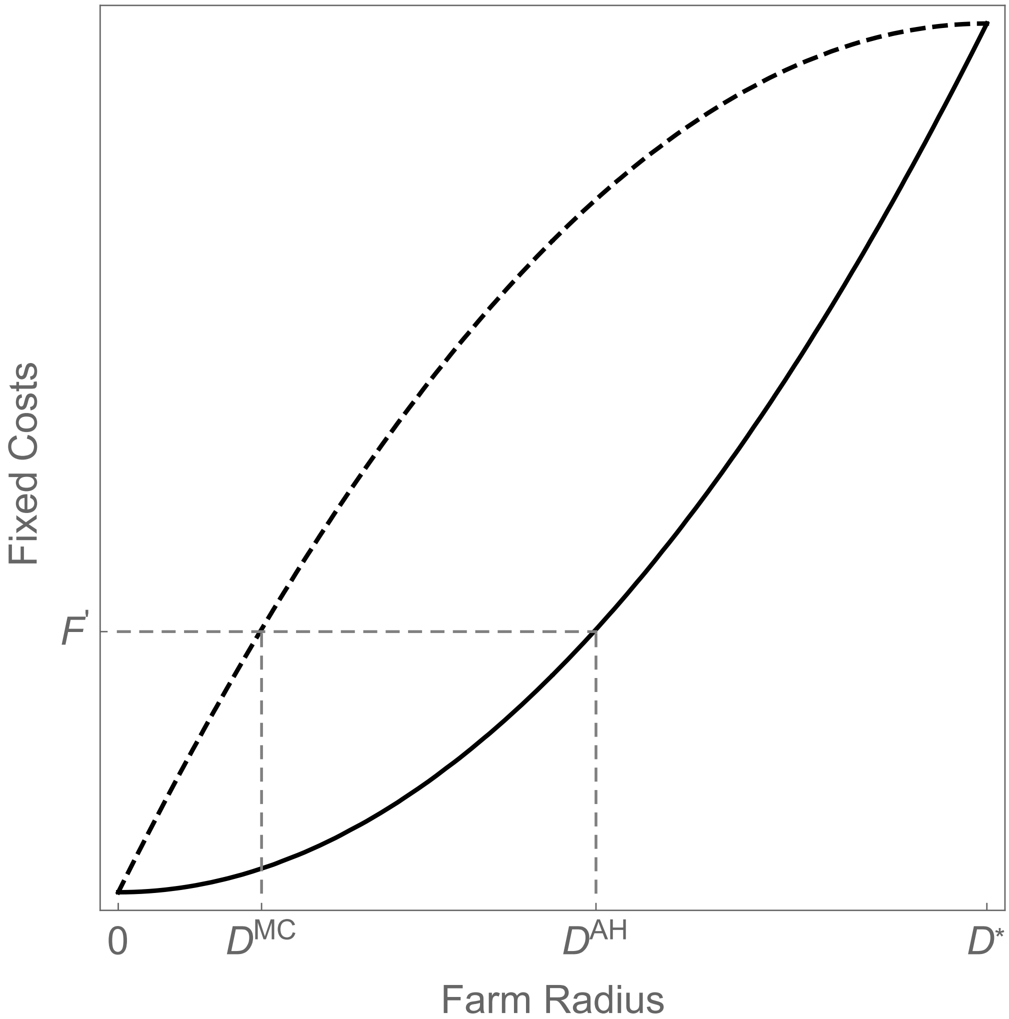

Figure 2. Farm size of independent farms under monopsonistic competition compared to farms affiliated with an agroholding if land supply is perfectly price-inelastic ($\varepsilon = 0$).

2.4. Cooperative competition and uniform pricing

To investigate alternative options of competition between farms on the land market, we follow the literature and use a duposony framework where two (otherwise) identical farms are located at the endpoints of the line segment $x \in [0, 1]$ with $x_A = 0$ and $x_B = 1$ are the location of farm A and B, respectively. Both farms use uniform pricing and compete for land along the line segment. Otherwise, we keep the beforehand made assumptions.

We first consider the case where both farms are of the same organizational type, i.e., either both farms are independent farms or both belong to the same or different agroholdings. Under cooperative competition a farm matches the competitor's price and may additionally minimize transport costs by renting only at locations that are closest to their own farmstead, which can be labeled as *full cooperation* (Gronberg and Meyer, 1981). In this case, each farm would rent land up to the center of the region and we can reformulate (4) to:

$$\Pi_c = \int_0^{\frac{1}{2}} (\phi - r_c - tx) r_c^{\varepsilon} dx - F \tag{10}$$

Maximization with respect to r_c yields the optimal cooperative rental price:

$$r_c = \frac{(4\phi - t)\varepsilon}{4(1+\varepsilon)}. \tag{11}$$

If both farms are not able to agree on exclusive farm areas, *price matching* causes that landowners may randomly decide on the tenant. In the case of high transport costs, a farm may not want to rent every land plot though. In fact, local profits of farm A at and close to the competitors location $x_B = 1$ are negative for any price r_A if $t > \phi$. The same is true for B concerning land close to A's location. Accordingly, there are exclusive regions for each farm close to the own location, e.g., $x \in [0, 1-(\phi - r)/t]$ from A's perspective. Around the market center, however, both farms can profitably rent land and share the land supply equally at these locations. For lower transport costs, exclusive regions do not exists. Accordingly, we distinguish two cases under price matching (cf. Graubner, 2018):

$$\Pi_m = \begin{cases} \frac{1}{2}\int_0^1 (\phi - r_m - tx) r_m^{\varepsilon} dx & \text{if } 0 < t/\phi \leq 1, \\ \int_0^{1-\frac{\phi - r_m}{t}} (\phi - r_m - tx) r_m^{\varepsilon} dx + \frac{1}{2}\int_{1-\frac{\phi - r_m}{t}}^{\frac{\phi - r_m}{t}} (\phi - r_m - tx) r_m^{\varepsilon} dx - F & \text{if } 1 < t/\phi \leq \theta. \end{cases} \tag{12}$$

With $\theta \equiv 4/(\varepsilon + 2)$ marking the limit between duopsony and two spatially separated monopsonies.[2] The equilibrium rental price under price matching is:

$$r_m = \begin{cases} \frac{(2\phi - t)\varepsilon}{2(1+\varepsilon)} & \text{if } 0 < t/\phi \leq 1, \\ \frac{2(1+\varepsilon)(\phi - t) + \sqrt{2\varepsilon(2+\varepsilon)t^2 + 4(\phi - t)^2}}{2(2+\varepsilon)} & \text{if } 1 < t/\phi \leq \theta. \end{cases} \tag{13}$$

Comparing equation (11) with (13), it is possible to show that $r_c > r_m$. If the agroholding deviates from profit maximization per area as outlined in Section 2.2,[3] full cooperation, i.e., a (transport) costs minimizing land allocation is a likely outcome. In contrast, independent farms (even under cooperative competition) might not be able to perfectly coordinate towards the same land allocation. Hence, competition among independent farms might rather resemble price matching. Therefore, farms affiliated with an agroholding set higher land rental prices under full cooperation compared to independent farms under price matching.

2.5. Price leadership competition

If one of both farms is affiliated with an agroholding, we may assume that any strategic decision by an agroholding, including the choice of the common rental price, can serve as a signal to

[2]We obtain θ from $2D_u^*(r_u) = 1$ and D_u^* is the optimal farm radius of the monopsony under uniform pricing with $r_u = \varepsilon\phi/(2+\varepsilon)$, i.e., if the relation t/ϕ is sufficiently large, both farms can act as local monopsonies because their optimal farm radii do not overlap.

[3]One reason might be the acquisition of a formally independent farm.

other market participants. Consequently, a subsidiary farm acts as a price leader in the local land market. We follow Anderson (1987) and adopt his spatial price leadership framework except that we consider uniform pricing and price-elastic land supply. In general, the price leader has to foresee the price decision r_f by the follower in setting its own optimal price r_l. Beside the follower's response, the optimal price of the leader also depends on the relation of transport costs and output price ϕ. Defining $\pi_u = \phi - r - tx$, we can distinguish the following cases:

$$\Pi_l = \begin{cases} \int_0^1 \pi_u(x) r_l^\varepsilon dx - F & \phi - t \geq r_l > r_f \quad (14a) \\ \int_0^{\frac{\phi - r_l}{t}} \pi_u(x) r_l^\varepsilon dx - F & \phi - t < r_l > r_f \quad (14b) \\ \frac{1}{2}\int_0^1 \pi_u(x) r_l^\varepsilon dx - F & \phi - t \geq r_l = r_f \quad (14c) \\ \int_0^{1-\frac{\phi - r_l}{t}} \pi_u(x) r_l^\varepsilon dx + \frac{1}{2}\int_{1-\frac{\phi - r_l}{t}}^{\frac{\phi - r_l}{t}} \pi_u(x) r_l^\varepsilon dx - F & \phi - t < r_l = r_f \quad (14d) \\ 0 - F & \phi - t \geq r_l < r_f \quad (14e) \\ \int_0^{1-\frac{\phi - r_f}{t}} \pi_u(x) r_l^\varepsilon dx - F & \phi - t < r_l < r_f \quad (14f) \end{cases}$$

In the following we refer to the agroholding farm (AH) as price leader and the independent farm (IF) as the price follower. In the first two cases, AH sets a higher price than IF and captures all (14a) or most (14b) of the locations. Case (14c) and (14d) represent price matching with and without exclusive market areas as discussed in the previous section. In the last two cases, the price leader sets lower prices than the follower. As we will show, only (14b) yields the equilibrium strategy for the price leader.

First, consider that the price leader cannot assume to set a price such that the residual land supply of the follower is zero (cf. Eaton and Lipsey, 1978). In fact, due to transport costs neither farm can profitably rent land at all (most distant) locations if the rental price level (of the competitor) is sufficiently high. If there is such residual market area close to the farm's location, i.e., $1-(\phi - r_{-i})/t > 0$, it is possible to set a monopsonistic rental price in this area and cover at least part of fixed costs. Accordingly, both farms have an incentive to raise prices up to a level that guarantees a residual market area. We therefore exclude case (14a) and (14e).

Second, price matching cannot be an equilibrium strategy under non-cooperative competition because the follower will always be better off by setting a price (slightly) higher than r_l instead of matching it (Beckmann, 1973). This eliminates cases (14c) and (14d). The two remaining options (14b) and (14f) are typically used to derive the upper and lower price limit of the mixed-strategy equilibrium under non-cooperative competition if firms set prices simultaneously (Beckmann, 1973; Shilony, 1981; Zhang and Sexton, 2001). In fact, the upper price limit is the equilibrium strategy of the price leader AH in our sequential framework, while the follower's (IF's) optimal choice is the lower limit price.

Because the analytical details to calculate these price limits of the mixed strategy are presented in the aforementioned literature and because we use a general specification of the land supply function, which mostly prevents analytical solutions, we refrain from a full characterization. Instead, we present a graphical explanation of the equilibrium strategies using Figure 3. In doing so, we rely on insights from prior work where the upper and lower price limits are derived for selected values of the (local) supply elasticity ε. For instance, Zhang and Sexton (2001) used unit-elastic supply ($\varepsilon = 1$) while Graubner (2018) investigated perfectly inelastic supply ($\varepsilon = 0$).

First suppose that AH wants to set the higher price to rent at all locations where this is profitable given the own price r_l. This represents case (14b). From (4), it is possible to verify that the profit maximizing uniform price is $r_u^* = \varepsilon\phi/(2+\varepsilon)$. Accordingly, rising the price above this level decreases profits and because $D_r = (\phi - r)/t$, the maximal farm radius decreases, while simultaneously the residual market area $1 - D_r$ increases. Let us assume that AH decides to set a uniform rental price r', which yields a farm radius of D'. Incorporating the price decision of the follower, the leader has to consider whether the price follower will find it profitable to marginally overbid r' or set a monosponistic price in the residual market area $x \in [D', 1]$. If the follower would overbid, the leader's effective farm radius is only $1 - D_f$ and r' is no longer the profit maximizing rental price in this area. In fact, AH could rise its profit by setting a monopsonistic (lower) price in $1 - D_f$. As a consequence, if AH wishes to establish the higher price relative to IF to capture most of the region's land supply, IF must not have an incentive to overbid AH. For instance, this holds if AH sets r_l in Figure 3 where IF is indifferent between overbidding or setting a monopsonistic low price r_f within the residual market area $x \in [D_l, 1]$, formally $\hat{\Pi}_f(\hat{r}_f | r_f > r_l) = \check{\Pi}_f(\check{r}_f | r_f < r_l)$. Any price below r_l will provoke overbidding by IF, while any price above r_l increases the residual market area and IF's profits, but it decreases the profit of AH. Thus, r_l is the equilibrium price of AH while IF's optimal response to r_l is r_f and $r_l > r_f$.

For perfectly inelastic local land supply, i.e., $\varepsilon = 0$ and each landowner possesses exactly one land plot, we can invoke the results for the upper and lower price limit, i.e., r_l and r_f, as presented in Graubner (2018).[4] The equilibrium prices of both farms are:[5]

$$r_l = \left[3\phi - v - t - \sqrt{(\phi - v + t)^2 - 2t^2}\right]/2, \tag{15}$$

$$r_f = v. \tag{16}$$

[4]Because of the (potentially too) price-elastic supply in Zhang and Sexton (2001) and due to their assumption of buyer arbitrage, both might not apply to most land markets, we refer to the results presented by Graubner (2018).

[5]See equations 18 and 21 in Graubner (2018).

Here, v is a non-negative reservation price of the landowners and without loss of generality we can set this reservation price to zero. We therefore conclude that AH will set higher rental prices and captures a higher share of the regional land supply compared to IF.

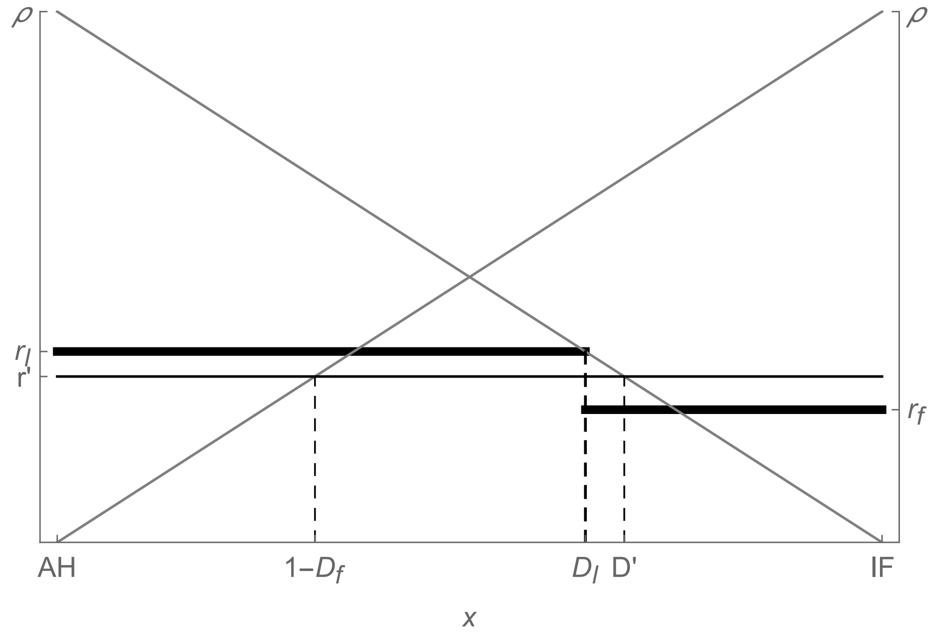

Figure 3. Equilibrium prices and land allocation if a farm affiliated with an agroholding is the price leader and the independent farm is the price follower.

2.6. Summary of the theoretical findings

In the previous sections we used a multi-plant framework of spatial competition to grasp the presence of agroholdings in the land market, i.e., a conglomerate of individual and spatially distributed farms that cooperate in strategic pricing. We showed that the isolated agorholding will use the same price strategy but features larger farms in terms of hectare-size compared to independent farms under monopsonistic competition. Compared to the single plant monopsony, however, the individual farm of an agroholding is smaller.

Under cooperative competition and because of the possibility to coordinate towards a transport cost minimizing land allocation, agroholdings can set higher rental prices than independent farms. Furthermore, we established that a farm affiliated with an agroholding and acting as price leader in the regional land market sets higher rental prices and therefore obtains a larger share of the regional land supply compared to an independent competitor.

We can derive further insights by analyzing the comparative statics of the obtained rental prices under the different competitive settings. For instance, if we investigate the output price effect on (optimal or equilibrium) rental prices, i.e., $\partial r/\partial \phi$ we find that this effect only depends on the price elasticity of land supply and is

$$\frac{\partial r}{\partial \phi} = \frac{\varepsilon}{1+\varepsilon} \tag{17}$$

in case of an (isolated) agroholding as well as under monopsonistic or cooperative competition (see equation (5), (10) and (13) if $t \leq \phi$). Under price matching and if $1 < t/\phi \leq 4/(2+\varepsilon)$, we yield:

$$\frac{\partial r_m}{\partial \phi} = \frac{(1+\varepsilon) + \frac{2(\phi - t)}{\sqrt{2\varepsilon(\varepsilon+2)t^2 + 4(\phi-t)^2}}}{2+\varepsilon}. \tag{18}$$

It is possible to show that (17) $\leq$ (18), i.e., given sufficiently high transport costs, a change in the output price has a larger effect under price matching compered to the alternative settings. Under price leadership competition, this effect is even different for both competitors. In the case of (perfectly) price-inelastic land supply and price leadership competition, we obtain from (15) and (16):[6]

$$\frac{\partial r_l}{\partial \phi} = \frac{1}{2}\left(3 - \frac{\phi + t}{\sqrt{(\phi+t)^2 - 2t^2}}\right) \tag{19}$$

$$\frac{\partial r_f}{\partial \phi} = 0. \tag{20}$$

Hence, the effect of an output price change on the equilibrium price of the price leader (the agroholding farm) is higher compared to the price follower (the independent farm). If we contrast this with alternative competition settings, we postulate that this effect is uniform for both farm types under monopsonistic competition, but different if agroholding farms operate under full cooperation, while independent farms compete according to price matching. Based on these and the above mentioned results we state the following hypotheses:

H1: Independent farms (IF) feature smaller hectar-sizes compared to farms affiliated with agroholdings (AH).

H2: AH will set higher rental prices compared to IF.

H3: The effect on land rental prices caused by a price change in the farm output market is different for AH compared to IF.

In the remainder of the paper, we aim to test these hypotheses and investigate farm sizes, rental prices and their determinants in Ukraine.

3. Data

We use the longitudinal dataset provided by the State Statistics Service of Ukraine (SSSU). It consists of approx. 105 tsd. observations (farm-level accounting data) for the years 2005-2016 and differentiates production volumes with regard to particular crop and animal products,

[6] Again these results are analogue to Graubner (2018).

costs, revenues, and farm structure. We additionally include information on farms' affiliation to agricultural holdings. The original data were provided by the Ukrainian Agribusiness Club Association (UCAB) for the years 2011-2016. We crosschecked and extended this dataset in order to cover the period of 2005-2010 using SPARK (Interfax) and YouControl databases, which contain information on firm owners. After merging these databases, holding-affiliated farms represent between 2% (2005) and 8% (2016) of the total number of observations annually.

In a first step, data cleaning was performed in order to eliminate missing values and outliers. We excluded farm data from further analysis if (i) there was no information on region, crop production value, material, capital, land costs, and amount of land in operation; (ii) the region of registration changed during the considered time period; (iii) a farm is registered in Crimea or Kiev;[7] (iv) the values of selected variables exceed a predefined threshold. In the latter case, we used three standard deviations from the mean value and histogram analysis. In total, we excluded about 40% of observations from the original sample.[8] The descriptive statistics for selected variables of the cleaned dataset (unbalanced panel) is presented in Table 1, while those of the balanced panel are shown in the appendix Table A1. Because we use a one year lagged price index (see equation (21)), only data from 2007 to 2017 are used for the analysis.

Table 1. Descriptive statistics, unbalanced panel

Variable		Mean	St. Dev.	Min	Max
Rental price (UAH/ha)	r	0.585	0.538	0.010	4.943
Output price index	$\hat{\phi}$	1.221	0.374	0.500	3.957
Material and capital costs (UAH/ha)	$\hat{c}$	3.260	2.966	0.101	19.994
Share of crop production in total production	s_{cp}	0.859	0.227	0.000	1.000
Share of cash crops in crop production	s_{cc}	0.790	0.216	0.003	1.000
Subsidy recipient (0/1)	ρ_s	0.173	0.378	0.000	1.000
VAT recipient (0/1)	ρ_v	0.248	0.432	0.000	1.000
Holding affiliation (0/1)	HA	0.083	0.276	0.000	1.000
Farm size (1000 ha)	FS	2.580	4.671	0.004	156.459
Farm size class (1,2,3,4)	SC	2.683	1.082	1.000	4.000
Farm density (# of farms per 1000 ha)	FD	0.511	0.134	0.236	2.376
Holding density (1,2,3,4)	HD	2.596	1.107	1.000	4.000

Source: State Statistics Service of Ukraine (SSSU). Unbalanced panel with 42,489 observations for the years 2007-2016.

On average, the share of crop production in farms' total production (s_{cp}) is about 86% and for the most part (79%, cf. s_{cc}), this is attributed to *cash crops*, which are wheat, barley, corn,

[7]There are no reliable statistics of farms based in Crimea after the occupation of the territory. Farms registered in Kiev were excluded because it is not possible to assign agricultural land to these farms.

[8]Mostly, data were excluded because of missing regional information or because farms only had animal production, but no land.

sunflower, soybean, and rapeseed. Accordingly, the output price index $\hat{\Phi}$ is calculated using a weighted price change of these crops:

$$\hat{\phi}_{i,t} = \sum_j \frac{\omega_{i,j,t-1} V_{i,j,t-1}}{\omega_{i,j,t-2} V_{i,t-1}}. \tag{21}$$

In the first term of the equation, we use a one-year lag concerning the farm-level price $\omega_{i,j}$ of crop j (UAH per ton) in $t-1$ relative to the price in $t-2$. One reason for this construction is to consider inertia of price adjustments in the land market (Hendricks et al., 2012). The second term in (21) represents crop j's share of the production value of all cash crops, i.e., $V_{i,j,t-1}/V_{i,t-1}$. The output price index as well as material and capital costs ($\hat{c}$) will serve as proxy for the marginal revenue of land. Together with the holding affiliation (HA), these are the major variables of interest to link the rental price determinants to the theoretical framework.

We furthermore control for production orientation (i.e., s_{cp}) and the effect of subsidy payments (dummy variable ρ_s and ρ_v) on rental prices. Farm size is considered either in terms of total land endowment (FS) or farms belonging to one of four size classes (SC) defined by the quartiles of the farm-size distribution.[9] To account for the nature and intensity of competition, we use the number of farms in the region (i.e., farm density FD) and the share of land operated by agroholdings in this region (HD).[10] Finally, time and regional effects are considered by the categorical variables year (t) and oblast (Ob).

4. Empirical approach

To test the theoretical hypotheses we first separate the dataset based on the variable holding affiliation (HA) to identify differences between both groups. In order to test empirically the differences in the output price effect on land rent payments between agroholding subsidiaries and non-holding farms, we utilize panel regressions with random- and fixed-effects. Both the balanced and unbalanced panels are analyzed to identify effects caused by farm entry and exit.

Because HA is coded as dummy and has low variability, the selection of the estimator is not straightforward. In general, a fixed-effects estimator is recommended if unobserved individual characteristics may impact the outcome and/or bias the result of the estimation (see Petrick and Zier, 2011). It is assumed that individual differences are captured by the time-constant term, unique for each individual. Consequently, it is not possible to account for time-invariant characteristics, since they are collinear with individual fixed effects.

In case of a random-effect estimator it is assumed that the individual error term does not correlate with predictors. This allows to control for time-invariant characteristics but disre-

[9] With $SC = \{1,2,3,4\}$, we have (in 1000 ha) $SC_1 = [0, 0.720)$, $SC_2 = [0.720, 1.454)$, $SC_3 = [1.454, 2.580)$, and $SC_4 = [2.580, \infty)$.

[10] This holding density is also modeled as factor variable in terms of quartiles, i.e., $HD = \{1,2,3,4\}$ with $HD_1 = [0, 0.09)$, $HD_2 = [0.09, 0.18)$, $HD_3 = [0.18, 0.33)$, and $HD_4 = [0.33, 1]$.

gards unobserved characteristics and, thus, increases the risk of obtaining inconsistent estimates (Greene, 2008). In the context of our model, this means that fixed-effects estimation sacrifices observations for which the holding affiliation dummy does not change over time.[11] Accordingly, only farms that became affiliated with agroholdings (or became independent) at some point of time (within the period of analysis) could be considered. In contrast, the results of the random-effects estimation could be interpreted, relying on the assumption that unobserved characteristics have no strong impact on the coefficients.

Due to the aforementioned reasons, we compare the results of different specifications, while following the standard procedure of estimator selection. The specification of the fixed-effects (FE) model is:

$$\begin{aligned} r_{i,t} = \beta_1 \hat{\phi}_{i,t} + \beta_2 HA_{i,t} + beta_3 HA_{i,t} \times \hat{\phi}_{i,t} + \beta_4 \hat{c}_{i,t} + \beta_5 HA_{i,t} \times \hat{c}_{i,t} + \beta_6 s_{cp\ i,t} + \\ + \beta_7 \rho_{s\ i,t} + \beta_8 \rho_{v\ i,t} + \beta_9 SC_{i,t} + \beta_1 0 FD_{i,t} + \beta_1 1 HA_{i,t} \times FD_{i,t} + \beta_1 2 HD_{i,t} + \alpha_i + u_{i,t}, \end{aligned} \tag{22}$$

where β's are the coefficients to be estimated, "$\times$" denotes interaction term, α_i is the unknown intercept for each farm i and $u_{i,t}$ is the error term.

We specify the random-effects (RE) model as:

$$\begin{aligned} r_{i,t} = \beta_1 \hat{\phi}_{i,t} + \beta_2 HA_{i,t} + beta_3 HA_{i,t} \times \hat{\phi}_{i,t} + \beta_4 \hat{c}_{i,t} + \beta_5 HA_{i,t} \times \hat{c}_{i,t} + \beta_6 s_{cp\ i,t} + \\ + \beta_7 \rho_{s\ i,t} + \beta_8 \rho_{v\ i,t} + \beta_9 SC_{i,t} + \beta_1 0 FD_{i,t} + \beta_1 1 HA_{i,t} \times FD_{i,t} + \beta_1 2 HD_{i,t} + \alpha + u_{i,t} + \varepsilon_{i,t}. \end{aligned} \tag{23}$$

In this case, $u_{i,t}$ denotes the between-entity error term, and $\varepsilon_{i,t}$ is the within-entity error.

Before we analyze RE and FE models with different specifications for both unbalanced and balanced panels, we first use the Breusch-Pagan Lagrange multiplier (LM) test to investigate the variances across farms. The aim is to check whether RE regression is more expedient compared to ordinary least squares (OLS) estimation. In a second step, we use a Hausman specification test to determine whether the FE model is more efficient and consistent compared to the RE model. Third, we run Modified Wald statistics for group-wise heteroscedasticity. Finally, time fixed effects were analyzed by using a linear Wald test on the year dummies. This method allows to test the hypothesis that the coefficients for all years are jointly equal to zero and therefore justify the control for time effects in our model.[12]

5. Results

Table 2 provides the summary statistics differentiated by farm type for the group of independent and agroholding farms. Apparently, farms affiliated with an agroholding pay higher land prices ($r_{AH} = 0.832$ UAH/ha, while $r_{IF} = 0.563$ UAH/ha) and feature larger farm sizes ($FS_{AH} =$

[11] The unbalanced (balanced) sample contains 103 (79) holding affiliated farms in 2007, while the maximal number of affiliated farms was 519 (249) in 2012.

[12] For more details on the test strategy see Hausman (1978) and Greene (2008).

Table 2. Summary statistics by farm type (unbalanced panel, 2007-2016)

		Agroholding farms ($n = 3,536$)				Independent farms ($n = 38,953$)			
		Mean	**St. Dev.**	**Min**	**Max**	**Mean**	**St. Dev.**	**Min**	**Max**
r	UAH/ha	0.832	0.680	0.010	4.937	0.563	0.517	0.010	4.943
$\hat{\phi}$	-	1.239	0.415	0.500	3.924	1.219	0.370	0.500	3.957
$\hat{c}$	UAH/ha	4.920	3.376	0.163	19.928	3.109	2.879	0.101	19.994
s_{cp}	(%)	0.874	0.215	0.000	1.000	0.858	0.229	0.000	1.000
s_{cc}	(%)	0.813	0.207	0.008	1.000	0.788	0.217	0.003	1.000
ρ_s	(0/1)	0.089	0.285	0.000	1.000	0.181	0.385	0.000	1.000
ρ_v	(0/1)	0.219	0.414	0.000	1.000	0.250	0.433	0.000	1.000
HA	(0/1)	1.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000
FS	Tsd ha	7.636	13.316	0.021	156.459	2.121	2.275	0.004	145.320
SC	{1,2,3,4}	3.445	0.850	1.000	4.000	2.614	1.074	1.000	4.000
FD	#/Tds ha	0.497	0.130	0.236	2.107	0.512	0.134	0.236	2.376
HD	{1,2,3,4}	3.183	0.971	1.000	4.000	2.542	1.103	1.000	4.000

Source: Own calculation

7.636 Tsd ha compared to $FS_{IF} = 2.121$ Tsd ha). While this provides empirical support for our hypothesis H1 and H2, we also observe that, on average, independent farms produce less intensive ($\hat{c}_A H > \hat{c}_I F$) and the greater share of these farms receive subsidy payments. Other variables do show no or only small differences between both farm groups, e.g., production orientation (s_{cp}) or farm density (FD).

The correlation coefficients among the selected variables indicate that they are suitable for further analysis (3 and A2). In order to test whether independent and agroholding farms differ regarding the effect of output price changes on the rental price, we conduct several tests using Stata 15.1. First, we performed a Breusch-Pagan Lagrange multiplier (LM) test on both the unbalanced and balanced samples. In neither case we could not reject the null hypothesis that the variances (differences) across farms is zero (i.e., no panel effect). Results are presented in Table 4.

The Hausman test was used to compare the models based on different estimators. According to the results, in both cases (i.e., for unbalanced and balanced panels) we accept the alternative hypothesis that the difference in coefficients is systematic. Thus, fixed-effects (FE) estimation is recommended for our analysis. However, considering our empirical setting, it is necessary for us to control for time-invariant variables. For this reason, we also report the results of the random-effects estimation. The Modified Wald test indicates the presence of heteroscedasticity. In order to overcome this problem, we use robust standard errors.

Table 3. Correlation matrix (unbalanced panel)

	HA	$\hat{c}$	$\hat{\phi}$	s_{cp}	ρ_s	ρ_v	SC	FD	HD
HA	1.000								
$\hat{c}$	0.169	1.000							
$\hat{\phi}$	0.021	0.220	1.000						
s_{cp}	0.020	0.166	0.042	1.000					
ρ_s	-0.067	-0.279	0.024	-0.184	1.000				
ρ_v	-0.020	-0.130	-0.127	0.136	-0.103	1.000			
SC	0.212	0.012	0.120	-0.042	0.132	0.008	1.000		
FD	-0.031	0.048	0.071	-0.169	0.017	-0.087	-0.193	1.000	
HD	0.160	0.322	0.034	-0.069	-0.286	0.010	-0.086	-0.122	1.000

Source: Own calculation.

Table 4. Breusch-Pagan Lagrange multiplier test

	Unbalanced panel		Balanced panel	
	Var	St. Dev.	Var	St. Dev.
r	0.289	0.538	0.287	0.535
e	0.074	0.272	0.072	0.268
u	0.065	0.255	0.037	0.193
χ^2	11888.730		7276.330	
Prob> χ^2	0.000		0.000	

Source: Own calculation.

Table 5. Hausman test and modified Wald test for groupwise heteroskedasticity

	Hausman test of FE vs RE		Modified Wald test	
	UP	BP	UP	BP
χ^2	316.970	168.050	4.0e+37	1.7e+35
Prob> χ^2	0.000	0.000	0.000	0.000

Source: Own calculation.

Based on Table 6, the null hypothesis that time effects are equal to zero is rejected, and thus we need to control for fixed time effects. The results of the regressions are presented in the Table 7. In the table, we present results of random- (RE), fixed-effects (FE) models with different specifications both for unbalanced and balanced panels. Time- and regional-specific effects are compressed. As the results show, both coefficients as well as the levels of significance of key variables are similar, highlighting that the results are mostly robust across the different specifications.

Table 6. Results of time fixed effects test

	Unbalanced panel	Balanced panel
F	1792.980	947.850
Prob$>F$	0.000	0.000

Source: Own calculation.

6. Discussion of the results

Considering the results in Table 7, we first note that higher material costs and capital per hectare ($\hat{c}$) has a positive effect on land rental prices per hectare in the case of independent farms. The interaction term of the holding dummy (HA) and ($\hat{c}$) shows that this effect is higher for farms affiliated with an agroholding. This indicates that cost and/or revenue structures of both farm groups are not identical.[13] This clearly violates the assumption made in the theoretical part of the paper and will be addressed below.

The effect on land rent payments due to the one-year lagged change of weighted output prices, i.e., the output price index $\hat{\phi}$, is not different from zero for independent farms. However, this effect is positive and statistically significant for the group of farms affiliated with agroholdings. Figure 4 depicts the relation for different model specification, which highlights that the differences between the two groups (i.e., holding and independent farms) are stable and consistent.

The result of a significant difference between both groups of farms provides empirical support for our hypotheses H3, such that agroholding farms may indeed possess the potential to act as price leader in local land markets. This is also consistent with the finding of larger farm sizes as well as higher rental prices of agroholding farms compared to independent farms. The results need to be interpreted with caution though. On the one hand, the considerable larger hectare-sizes of farms affiliated with an agroholding can only partially be explained by our theoretical framework of price leadership. Indeed, cost functions and revenue structures between farms of alternative organizational type might differ considerably. For instance, agroholdings (or

[13]Findings of prior work support this conclusion, e.g., Graubner and Ostapchuk (2018); Walther (2014); Byerlee et al. (2012); Rylko et al. (2008).

larger farms in general) might benefit from cost degressions due to economies of scale and size, lower transaction costs (per hectare) in land markets, and better access to capital or output markets (Hermans et al., 2017). In fact, these cost advantages may provide a justification why agroholdings can act as price leader.

On the other hand, there is evidence that rental payments do not reflect the full amount of benefits, landowners receive from tenants (Gagalyuk et al., 2018; Gagalyuk and Valentinov, 2019). Some portion of the land rental might be settled non-monetary among farms and landowner. If this is a systemic characteristic, our results might not be affected but there can as well be a difference between agroholdings and independent farms in the handling of such non-monetary compensations.

According to the results in Table 7, a higher density of farms (FD), which (*ceteris paribus*) translates to fiercer competition in land markets, is associated with higher land rent payments for the group of independent farms. While this seems the common theoretical prediction, spatial economics also presents instances where this common wisdom can be violated.[14] It is interesting, though, that in the case of agroholding farms, increasing competition also translates in higher land payments, but this effect is lower compared to independent farms. This again might indicate that agroholdings operate in a different competitive setting (either as price leader or under full cooperation) than independent farms.

7. Conclusions

In the last two decades, the rise of large agricultural enterprises or so called agroholdings in Eastern Europe increasingly attracted attention by the scientific community, politicians and the public. However, their effects on markets, particularly the land rental market, are not well understood and less so from a conceptual perspective. The present paper aims to contribute to this discussion, particularly, whether or not agroholdings exploit (local) market power and if to what extent.

Because of the specific characteristics of land markets (in transition economies), we use a spatial economics framework and investigate price competition of independent and agroholding farms under different settings. Building on and extending prior theoretical analysis on land markets (Graubner, 2018), we model agroholdings in terms of multi-plant firms (Holahan, 1978; Norman, 1981) and also consider the possibility of price leadership (Anderson, 1987) by these farms. Our theoretical results show that agroholdings operate larger farms and pay higher land rental prices compared to independent farms and that – depending on the competitive setting – farm output prices will affect equilibrium rental prices differently for both farm types.

[14] See, e.g., Katz (1980); Gronberg and Meyer (1981), or Alvarez and Zhang (2000) for an agricultural economics application.

Table 7. Estimation results

	Unbalanced panel					Balanced panel				
	RE	FE	RE^a	RE^{a,b}	FE^b	RE	FE	RE^a	RE^{a,b}	FE^b
HA	0.036	0.015	0.009	0.009	0.015	0.099**	0.064	0.068	0.068	0.064
$\hat{c}$	0.023***	0.023***	0.022***	0.022***	0.023***	0.034***	0.032***	0.032***	0.032***	0.032***
$HA\|\hat{c}$	0.029***	0.032***	0.030***	0.030***	0.032***	0.025***	0.028***	0.026***	0.026***	0.028***
$\hat{\phi}$	0.008	0.006	0.004	0.004	0.006	0.015**	0.011	0.009	0.009	0.011*
$HA\|\hat{\phi}$	0.053***	0.051***	0.055***	0.055***	0.051***	0.066***	0.065***	0.069***	0.069***	0.065***
s_{cp}	0.029**	-0.048***	0.012	0.012	-0.048*	0.050***	-0.073***	0.020	0.020	-0.073**
ρ_s	0.001	0.006	0.006	0.006	0.006	0.001	0.010	0.007	0.007	0.010*
ρ_v	0.007*	0.003	0.006	0.006	0.003	0.001	-0.005	-0.003	-0.003	-0.005
SC										
SC_2	0.047***	0.024**	0.038***	0.038***	0.024*	0.066***	0.041***	0.047***	0.047***	0.041*
SC_3	0.049***	-0.007	0.037***	0.037***	-0.007	0.078***	0.008	0.050***	0.050***	0.008
SC_4	0.027***	-0.047***	0.025***	0.025***	-0.047**	0.067***	-0.021	0.044***	0.044***	-0.021
FD	0.035*	0.343***	0.366***	0.366***	0.343***	0.108***	0.453***	0.495***	0.495***	0.453***
$HA\|FD$	-0.261***	-0.259***	-0.218***	-0.218***	-0.259**	-0.400***	-0.345***	-0.344***	-0.344***	-0.345**
HD										
HD_2	0.031***	0.010	0.012*	0.012**	0.010*	0.020***	0.006	0.007	0.007	0.006
HD_3	0.029***	0.012	0.013	0.013	0.012	0.014*	0.002	0.005	0.005	0.002
HD_4	0.139***	0.135***	0.143***	0.143***	0.135***	0.116***	0.135***	0.139***	0.139	0.135***
$const$	-0.010	-0.033	-0.160***	-0.160***	-0.033	-0.087***	-0.088***	-0.239***	-0.239***	-0.088*
N (Tsd.)	42.489	42.489	42.489	42.489	42.489	22.593	22.593	22.593	22.593	22.593
Wald χ^2	81223.460		84404.330	24250.400		52651.330		54677.650	15532.840	
Prob $> \chi^2$	0.000		0.000	0.000		0.000		0.000	0.000	
R^2_w	0.686	0.688	0.688	0.688	0.688	0.725	0.727	0.727	0.727	0.727
R^2_b	0.407	0.365	0.499	0.499	0.365	0.231	0.130	0.429	0.429	0.130
R^2_o	0.577	0.554	0.621	0.621	0.554	0.624	0.591	0.667	0.667	0.591
u	0.255		0.228	0.228		0.193		0.163	0.163	
e	0.272		0.272	0.272		0.268		0.268	0.268	
ρ	0.468		0.413	0.413		0.342		0.269	0.269	
F		3048.010			786.640		2102.280			560.160
Prob $> F$		0.000			0.000		0.000			0.000
corr(u_i, Xb)		-0.073			-0.073		-0.083			-0.083

Source: Own calculation. [a] With regional effects, [b] Robust standard errors, * $p < 0.1$, ** $p < 0.5$, *** $p < 0.01$. Time- and regional-specific effects are compressed.

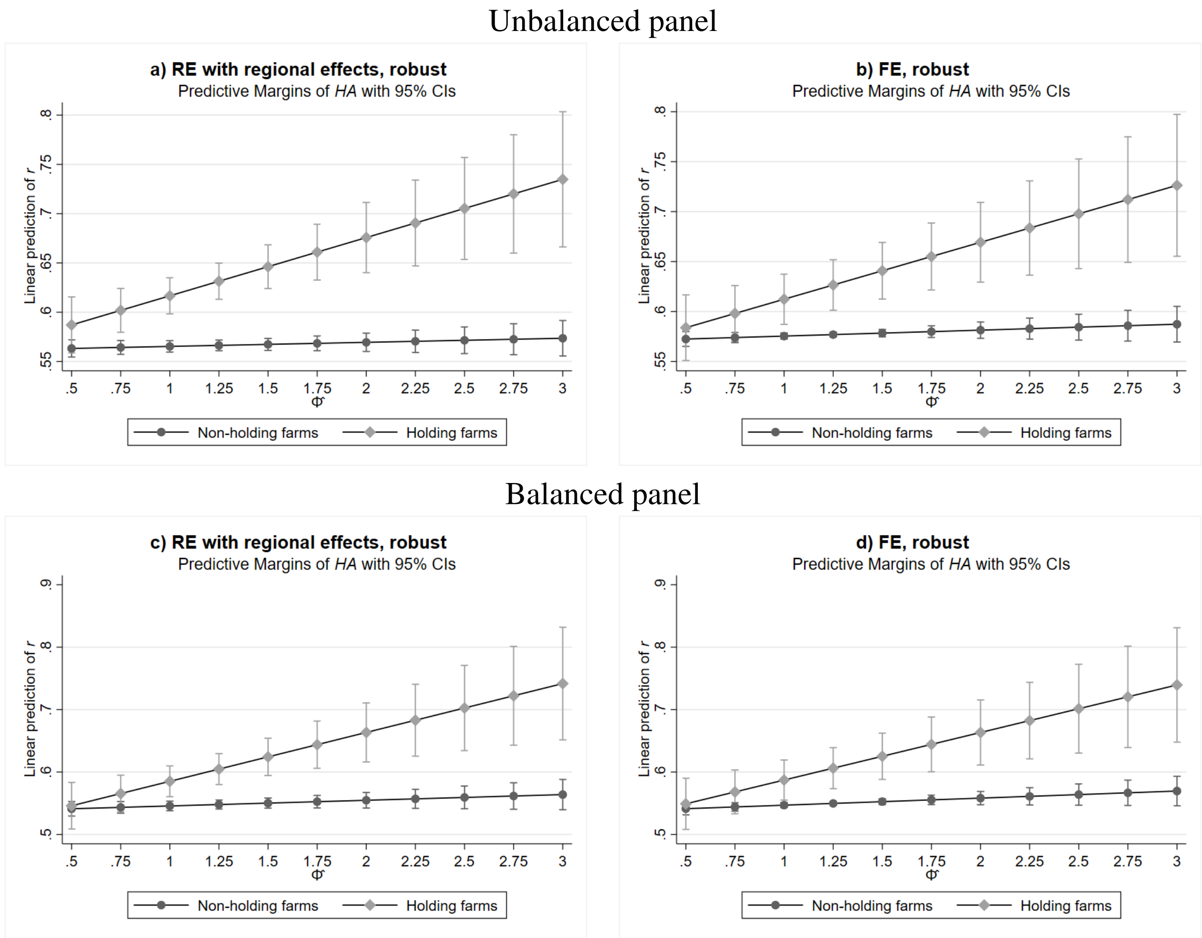

Figure 4. Prediction of the land rental price, based on holding affiliation and output price index.

Using a unique dataset of farm-level accounting data from Ukraine, we find empirical support for the theoretical expectations, i.e., independent farms are smaller and pay lower rental prices than agroholdings, and also that agroholding farms may act as price leader in local land markets. With these results we provide an additional explanation for observable differences between agroholdings and independent farms based on strategic behavior (under spatial competition) and beyond potential differences due to economies of scale and size or better/worse access to input or output markets, which is commonly stressed in the literature (cf. Hermans et al., 2017; Petrick et al., 2013; Walther, 2014).

The present paper can be considered a first explorative approach to the competitive role of agroholdings in land markets. On the one hand, the results need to be interpreted with caution as the link between the theoretical framework and empirical application is certainly incomplete. On the other hand, the welfare implications, e.g., of agroholdings acting as price leader were not the scope of this paper. Accordingly, we cannot conclude if the presence of agroholdings in land markets increases (e.g., due to higher rental prices) or decreases (e.g., because of potential entry deterrence/competitive distortion) the welfare of landowners or society. These questions seem to be interesting for further research.

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Appendix

Table A1. Descriptive statistics, balanced panel

Variable		Mean	St. Dev.	Min	Max
Rental price (UAH/ha)	r	0.559	0.535	0.010	4.937
Output price index	$\hat{\phi}$	1.224	0.357	0.500	3.921
Material and capital costs (UAH/ha)	$\hat{c}$	3.023	2.758	0.101	19.928
Share of crop production in total production	s_{cp}	0.808	0.246	0.000	1.000
Share of cash crops in crop production	s_{cc}	0.762	0.223	0.003	1.000
Subsidy recipient (0/1)	ρ_s	0.240	0.427	0.000	1.000
VAT recipient (0/1)	ρ_v	0.223	0.416	0.000	1.000
Holding affiliation (0/1)	HA	0.080	0.271	0.000	1.000
Farm size (1000 ha)	FS	3.073	4.802	0.020	126.912
Size class (1,2,3,4)	SC	3.000	0.973	1.000	4.000
Farm density (# of farms per 1000 ha)	FD	0.508	0.130	0.236	2.376
Holding density (1,2,3,4)	HD	2.555	1.109	1.000	4.000

Source: State Statistics Service of Ukraine (SSSU). Balanced panel with 22,593 observations for the years 2007-2016.

Table A2. Correlation matrix (balanced panel)

	HA	$\hat{c}$	$\hat{\phi}$	s_{cp}	ρ_s	ρ_v	SC	FD	HD
HA	1.000								
$\hat{c}$	0.204	1.000							
$\hat{\phi}$	0.010	0.220	1.000						
s_{cp}	0.032	0.155	0.072	1.000					
ρ_s	-0.079	-0.331	0.008	-0.112	1.000				
ρ_v	-0.009	-0.098	-0.095	0.135	-0.113	1.000			
SC	0.146	0.023	0.087	0.073	0.068	0.050	1.000		
FD	-0.029	0.065	0.083	-0.188	-0.016	-0.089	-0.243	1.000	
HD	0.147	0.368	0.029	-0.114	-0.344	0.032	-0.161	-0.092	1.000

Source: Own calculation