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2019

Vortrag anlässlich der 59. Jahrestagung der GEWISOLA
(Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V.)
„Landwirtschaft und ländliche Räume im gesellschaftlichen Wandel"
Braunschweig, 25. bis 27. September 2019

Price dispersion in thin farmland markets: What is the role of asymmetric information?

Christoph Kahle[*], *Stefan Seifert*[‡], *and Silke Hüttel*[▷]

Abstract

This paper investigates the role of information and search cost in the price formation in farmland markets. Using a comprehensive data set with more than 10,000 transactions between 2014–2017 in one of the eastern German Federal States, we estimate a two-tier model to capture price effects induced by asymmetrically distributed search cost between buyers and sellers. By relating these costs to the degree of professionalism, we can identify realtive price effects and institutional sellers to sell at the lowest cost of being information deficient. No price differences can be indentified by contrasting farmers and non-farmers.

Keywords

thin farmland markets, hedonic price, two-tier model

JEL Codes: D82, D83, Q15, Q24

1 Introduction

A small number of buyers and/or sellers, low liquidity, and few transactions characterize thin markets. Farmland markets share these characteristics: land is generally limited and its immobility causes markets to be local and, thus, narrow in supply. Farms, as main users, typically operate at a local scale contributing to thinness. Capital, however, is in fact mobile, but despite a recently observed increasing demand for land by investors with the intention to store wealth or hedge against inflation (cf. Magnan and Sunley, 2017), the trading volume remains low. For instance, in Germany, since the 1990s, the annual market volume was less than 1 percent of the total available farmland (Destatis, 2017). Besides the overall limited or even decreasing potential supply of land, this lack of liquidity can be related to asymmetric information acquisition, search and transaction costs in farmland markets. Under such asymmetries, the maximum willingness to pay may exceed the minimum willingness to accept and expectations on surpluses emerge over which agents can bargain (Harding et al., 2003). As a result, a single agent may influence the farmland price and, besides market power such bargaining frictions may add to illiquid markets. Prices for observed transactions may thus vary for the same fundamental value and neither send appropriate market information nor help efficient price discovery.

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[0]We gratefully acknowledge financial support from the German Research Foundation (DFG) through Research Unit 2596 'Agricultural Land Markets - Efficiency and Regulation' 2017–2020. We thank the Committee of Land Valuation Experts of Saxony-Anhalt and the State Office for Survey and Geoinformation (LVermGeo) for the collaboration, and providing the data. We further thank the participants of the FORLand workshops and the two anonymous reviewers for their helpful comments.

Sellers' and buyers' price impacts are often traced back to different expectations on potential future returns of the farmland by new owners (e.g., Brorsen et al., 2015; Croonenbroeck et al., 2019). Labelled as locational value, urban land prices have been shown to vary systematically with proximity to attractive surroundings and infrastructure including cultural offers (e.g., Kolbe et al., 2015). In this regard, an optional value induced by expected future land development, in particular in urban proximity, has been discussed (e.g., Capozza and Helsley, 1989; Plantinga and Miller, 2001). Likewise, for rural land markets, expectation on future zoning regulation may impact prices in the peri-urban market (e.g., Eagle et al., 2014; Livanis et al., 2006; Turner et al., 2014).[1] Further attempts to explain price variation for the same fundamental value comprise the locally differing relevance of policy-induced impacts (e.g., Breustedt and Habermann, 2011; Graubner, 2017), highly subsidized renewable energy production such as locally different agglomeration of biomass (e.g., Hennig and Latacz-Lohmann, 2016) or wind power stations (e.g., Ritter et al., 2015). Also local farming conditions such as regional farm and ownership concentration have been discussed (e.g., Back et al., 2018; Margarian, 2010). These authors, however, conclude that the local farming conditions as well as the market micro structure in terms of supply, demand and ownership remain hard to measure, which challenges identification of price impacts. The majority of farmland price studies acknowledges such effects by means of implicit spatial effects, where spatio-temporal dependencies of prices have been suggested at the local scale (e.g., Maddison, 2009) and also at a greater scale (e.g., Grau et al., 2018).

Thus far, to our knowledge, only few studies exploit the impact of farmland market thinness explicitly; for instance, prices are shown to be sensitive to seller and buyer types (e.g., Cotteleer et al., 2008; Hüttel et al., 2016), and to bargaining power (Kuethe and Bigelow, 2018). While studies for the real estate market highlight the role of information costs along with market power in the price schedule (Kumbhakar and Parmeter, 2010), to our knowledge, the impact of search and information costs in farmland price formation are thus far rarely analysed. One notable exception is the paper by Curtiss et al. (2013) who consider differences in bargaining positions as a price determinant in the Czech farmland markets. These results, however, lack external validity with respect to farmland markets with higher degrees of professionalism, stronger institutions, monitoring and regulation experience. Moreover, the authors concentrate on average effects of buyer and seller types, while the opportunity to retrieve evidence on the asymmetry of the information in the market remains unexploited.

In this paper, we aim at closing this gap and investigate how information on buyer and seller types regarding professionalism can be related to informational asymmetries and search cost. Taking the sellers and buyers identity, we target at identifying their relative price imapcts. We base our analysis on a hedonic pricing model under incomplete information (Polachek and Yoon, 1987). In this framework, asymmetric information and search cost induce either losses to the sellers or additional cost to the buyers captured by two additional error terms within the hedonic price function. Observed prices will thus vary with agents' levels of information and search cost as well as their market positions. Following the idea that these costs are related to the degree of professionalism of sellers and buyers, we proxy search costs by categorizing agents, for example, professional real estate agents on the seller side, or tenants and farmers on the buyer side.

Our empirical analysis uses a comprehensive data set with more than 10,000 farmland transactions between 2014–2017 in one of the eastern Federal States in Germany, Saxony-Anhalt. Due to the history of economic transition, this region offers an ideal setting to

[1] We refer to Nickerson and Zhang (2014) for an excellent overview on farmland price determinants.

contrast different degrees of professionalism and hence search cost in particular on the seller side. We can identify sales by the major land privatizing agency in eastern Germany (*Bodenverwertungs- und -verwaltungs GmbH*, BVVG) as well as other public sellers, and professional sellers such as real estate agents. We hypothesise that professional sellers benefit from lower search cost. Regarding the buyer side, we differentiate whether the former tenant buys with or without remaining rental term, or whether a farmer or a non-farmer buys. We hypothesise that farmers and former tenants have lower informational costs and better information about the plot and the local market.
We specify a two-tier model in the spirit of Kumbhakar and Parmeter (2010) consisting of a hedonic part with main lot characteristic and enhanced by local peculiarities such as renewable energy production with wind and biomass. Modelling the hedonic price function within a stochastic frontier framework combined with spatial effects will further help to mitigate the omitted variable bias usually prevalent in such models, typically due to data limitations (Carriazo et al., 2013). For validation purposes, we contrast the findings of a two-tier model based on the theory of thin markets to a simplified reduced from model, where seller and buyer characteristics linearly add to the price schedule. Our results give evidence on price mark-ups achieved by professional sellers. The categorization by farmer versus non-farmers and by tenancy status, however, cannot contribute to identify systematic price differences on the buyer side. The contribution of our paper aims at informing the discussion about policy measures to improve market efficiency and design effective regulation.
The remainder of the paper is organized as follows: section 2 presents the theoretical and econometric framework. Section 3 outlines the empirical strategy, the data, and the hypotheses. Results are presented and discussed in section 4, and section 5 concludes.

2 Modeling and estimation

2.1 A hedonic pricing model with incomplete information

To identify the effects of differential search costs on prices, we employ a search model with bargaining. We assume that buyers and sellers enter the market with a set of beliefs about the price distribution given the heterogeneity of the land, where both parties employ different sets of information. Finding a lot offer or a buyer is costly, and gathering information will improve an agents' bargaining position. Therefore, both agents are assumed to search optimally but the buyer faces a trade-off between incurring additional search costs for continued information gathering and finding a seller with a lower willingness to accept (WTA). Likewise, sellers may search for the highest paying buyer until costs outweigh the benefits of identifying a buyer with a higher willingness to pay (WTP). Search costs may differ between different buyer and seller groups. For instance, a local farmer may gather information more easily than a non-local buyer. Similarly, an experienced professional seller may have lower search costs than a private vendor. Hence, agents with higher search costs may stop information gathering earlier resulting in higher prices for buyers with high search costs, and lower prices for sellers with high search costs.
To model information asymmetries and search costs, we use a hedonic pricing model with incomplete information following Kumbhakar and Parmeter (2010). A two-tier frontier framework as proposed by Polachek and Yoon (1987) is used to model incomplete information. Further, heterogeneity among buyers and sellers is incorporated by expanding the hedonic function by two one-sided error terms that acknowledge buyer and seller characteristics. Starting at the standard hedonic pricing model in the spirit of

Rosen (1974) under full information we model the price as:

$$(1) \quad P_h = h(x) + v$$

where P_h is the hedonic price, x denotes a vector of lot characteristics (e.g., lot size and soil quality), $h(.)$ the hedonic price function, and v denotes measurement errors and noise. Following Polachek and Yoon (1987), the market price is modelled using an upper and a lower bound given by the maximum WTP and the minimum WTA, respectively. A seller receives:

$$(2) \quad P_m^s = P_b - u$$

where P_b refers to the highest WTP by a potential buyer in the market. Symbol $u, u > 0$ denotes the costs to a seller from being information deficient, i.e., a loss due to not identifying the buyer with the highest WTP. Likewise, from a buyer's perspective, the price paid, P_m^b, is given by

$$(3) \quad P_m^b = P_s + \omega$$

where P_s is the lowest WTA in the market, and $\omega, \omega > 0$ denotes the costs of being information deficient, i.e., cost due to not identifying the lowest WTA.
For any transaction to take place, the price paid by the buyer equals the price received by the seller, forming the market price $P_m = P_b - u = P_s + \omega$. Rearranging gives:

$$(4) \quad P_m + u - \omega = P_b - \omega = P_s + u,$$

where $P_s + u$ and $P_b - \omega$ are the hedonic prices for sellers and buyers but adjusted for their information. However, P_s, P_b, u, and ω remain unobserved and identification of effects requires further assumptions (see Kumbhakar and Parmeter, 2010). Following Kumbhakar and Parmeter (2010), who argue that $P_m + u - \omega$ corresponds to the price under full information, i.e., the hedonic price of the good, taking equations (4) and (1) gives the base for estimation as

$$(5) \quad P_m = h(x) + v + w - u = h(x) + \varepsilon.$$

Equation (5) states that the observed market price of a lot consists of the implied characteristics of the lot $h(x)$, unobserved noise v, and the costs of information deficiency of buyers (ω) and sellers (u). ε is a composite error term that collects noise and costs of information deficiency.
Two aspects should be noted: First, this model collapses to the standard hedonic pricing model if either no information deficiencies exists ($u = \omega = 0$) or deficiencies on buyer and seller side are identical ($u = \omega$). Second, in the current setting, cost of informational deficiency u and ω are identical for all buyers and sellers, respectively. Given buyers' and sellers' heterogeneity, we model costs of being information deficient for the buyer, ω, as a function of buyer characteristics z_ω, and the respective costs for a seller are expressed as a function of seller characteristics z_u. The resulting hedonic pricing model with incomplete information and buyer- and seller-specific costs of information deficiency is given by

$$(6) \quad P_m = h(x) + v + w(z_\omega) - u(z_u) = h(x) + \varepsilon.$$

2.2 Estimation

To estimate equation (6), we employ a two-tier stochastic frontier approach with scaling property as proposed by PARMETER (2018). For this purpose, we define the respective costs of being information deficient in land transaction i ($i = 1, ..., N$) as $u_i = u(z_{u,i}, \delta_u)$ and $\omega_i = \omega(z_{\omega,i}, \delta_\omega)$. The two random variables u_i and ω_i possess the scaling property if $u_i = u(z_{u,i}, \delta_u) = g_u(z_{u,i}, \delta_u)u_i^*$ and $\omega_i = \omega(z_{\omega,i}, \delta_\omega) = g_\omega(z_{\omega,i}, \delta_\omega)\omega_i^*$, where $g_u(.) \geq 0$, $g_\omega(.) \geq 0$, and both u_i^* and ω_i^* are independent from z. The functions $g_u(.)$ and $g_\omega(.)$ are the scaling functions, and the distributions of u_i^* and ω_i^* are the basic distributions (cf. WANG and SCHMIDT, 2002). To impose the scaling property, we specify $\mu_u^* = E[u_i]$ and $\mu_\omega^* = E[\omega_i]$. To account for the non-negativity restrictions from the theoretical model with respect to u and ω, we use exponential functions, such that $g_u(z_{u,i}, \delta_u) = e^{z'_{u,i}\delta_u}$ and $g_\omega(z_{\omega,i}, \delta_\omega) = e^{z'_{\omega,i}\delta_\omega}$. Imposing the scaling property implies that characteristics z_u and z_ω affect the scale of the functions $u(z_{u,i}, \delta_u)$ and $\omega(z_{\omega,i}, \delta_\omega)$, respectively, but not their shape. That is in economic terms, u_i^* and ω_i^* define the baseline costs of information deficiency. The actual costs of information deficiency then depend on buyer and seller characteristics that proxy their level of professionalism. The function $g_u(.)$ and $g_\omega(.)$ scale these base costs relatively. Thus, our econometric model incorporates hedonic pricing as well as the features of a two-tier stochastic frontier that account for heterogeneity among agents based on the scaling property. Estimation uses non-linear least squares as

$$(7) \quad (\hat{\beta}, \hat{\delta_u}, \hat{\delta_\omega}, \hat{\mu_u^*}, \hat{\mu_\omega^*}) = \min_{(\beta, \delta_u, \delta_\omega, \mu_u^*, \mu_\omega^*)} \frac{1}{n} \sum_{i=1}^{N} \left[y_i - h(x_i, \beta) + \mu_u^* e^{z'_{u,i}\delta_u} - \mu_\omega^* e^{z'_{\omega,i}\delta_\omega} \right]^2$$

Solving this minimization gives the parameters of interest: the β coefficients represent the implicit values of lot characteristics x, the base costs of information deficiency μ_u^* and μ_ω^*, and scale parameters δ_u and δ_ω, that capture therelative impact of buyer and seller characteristics z_u and z_ω compared to a base category. An equivalent model specification can incorporate the base cost parameters into the exponential functions as intercepts to be estimated. Identification of the parameters for δ_u and δ_ω requires $\mu_\omega^* e^{z'_{\omega,i}\delta_\omega}$ to be different from $\mu_u^* e^{z'_{u,i}\delta_u}$. Valid inference for the parameter estimates needs to account for heteroscedasticity in the composite error term, where procedures for robust standard errors in NLS frameworks will be used (PARMETER, 2018).

Applying an estimation procedure based on the scaling properties offers advantages. First, although further assumptions on $w(z_\omega)$ and $u(z_u)$ are required, no distributional assumptions for those terms are necessary, which allows using NLS. On the contrary, a more efficient Maximum Likelihood procedure would require precise distributional assumptions for both inefficiency terms, but no closed form solution for the likelihood function may exist. Second, contrary to estimation of u and ω by deconvolution of a composite error term based on unobservables as proposed by KUMBHAKAR and PARMETER (2009, 2010), the approach allows recovering estimates of u and ω from observables z_w and z_u.

3 Empirical strategy

3.1 Background and hypotheses

In our empirical application, we analyse informational asymmetries in farmland transactions in the eastern German Federal State Saxony-Anhalt. Saxony-Anhalt's agricultural structure and land market has been influenced by the the eastern German history of expropriation, land collectivization and socialistic policy between 1945 and 1989. Farms operate at 280 hectares on average, are, thus, larger than western German farms, rely less on the family workforce and operate at a high land lease share of around 72 percent (State Office of Statistics, 2018b). As a side effect of the economic transition, land ownership is fragmented (Hartvigsen, 2014) and in 2018, around 40 percent of the total agricultural area is operated by 280, that is, 7 percent of all farms, with more than 1,000 ha, in particular cooperatives.

The land market in Saxony-Anhalt experienced a strong price increase starting in 2007, and average prices more than tripled from 5,055 €/ha in 2007 to 17,903 €/ha in 2017, which is highest among all eastern states, but below the German average of about 24,064 €/ha (Destatis, 2017). In 2017, farmland transactions of around 8,400 ha took place, i.e., less than 1 percent of the total agricultural area, and considerable price dispersion can be observed as indicated by the price per soil quality index point[2] in the left part of Figure 1. In the right part, we present the number of transactions at municipal level in 2017: although in total more than 3,000 transactions are registered, at a local level the number of transactions is rather low and for half of the municipalities less than 10 transactions are observed pointing to market thinness.

Today's land ownership fragmentation in Saxony-Anhalt results in heterogeneous buyers and sellers. These different agents face individual search and informational costs in the market with asymmetric distributions depending on the level of professionalism and experience. To identify how such asymmetric cost affect the price schedule, we assume that the level of search and information costs is directly related to a buyer or seller type. Therefore, we group sellers and buyers depending on their level of professionalism (search costs) relative to the other. This in turn will be the base to derive hypotheses regarding the effect of buyer/seller identity on the market outcome to be tested.

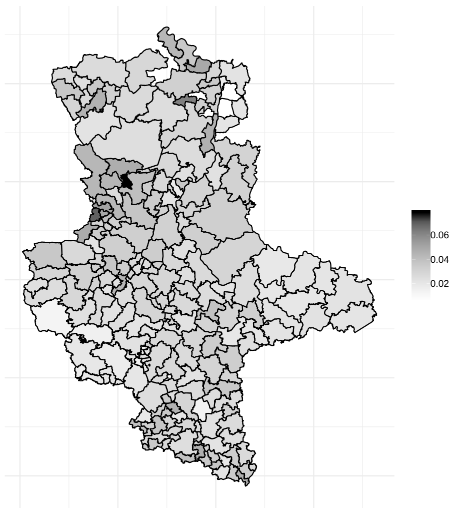
On the seller side, a major player is state agency *Bodenverwertungs- und - Verwaltungs GmbH*, BVVG in the following. BVVG was founded in 1992 as a direct successor of the German privatization agency (*Treuhandanstalt*) with the mandate to privatize the former state-owned agricultural and forest land in eastern Germany on behalf of the Federal Ministry of Finance until 2030. In eastern German land markets, BVVG is the largest single agent with a share around 20 percent of the total market volume, regionally even up to 60 percent. While in the early years BVVG leased out at long term contracts, since 2007 BVVG uses public tendering procedures according to the Privatization Principles in Germany in line with European Law. These tenders are always published not only on the website, but also in local newspapers and farmers' magazines in a professional layout including information about the tendered lot. Moreover, auction rules and bidder requirements are clearly communicated. This can ease access for potential buyers to information and facilitates at the same time the search process of BVVG. As a notable seller, this agency may not only signal professionalism but also reliability. This in turn may reduce risks of transaction failure for potential buyers and contribute to finding potential buyers. We therefore hypothesize that the BVVG incurs lower search cost than other market participants resulting in lower cost of being information deficient.

A second seller category are professional private sellers, such as real estate agencies, as they may exhibit a level of professionalism that impacts search costs. They often use procedures comparable to public tenders, and they advertise and target potential buyers efficiently. As a result, we expect lower search cost for professional sellers, in particularly compared to private persons facing a transaction once in the lifetime. As third, we consider public sellers such as municipal or state administration. While they usually exhibit a high

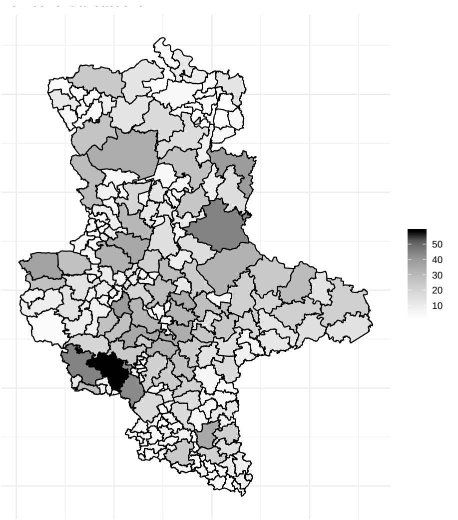
[2]The soil quality index is an official index for Germany to unify pedologic, scientific, and (agro-) economic considerations including water availability within one measure for arable land ('Ackerzahl') and grassland ('Grünlandzahl'). Low (high) numbers indicate low (high) productivity (BMJV, 2007).

Figure 1: Saxony-Anhalt farmland market 2017 at municipal level

(a) Median price €/m^2 per soil quality index point



(b) Number of land transactions



degree of experience and professionalism, and refer to public tenders, this advantage may be off-set by costs caused by a potential principal agent problem: public sellers' goal may not primarily be selling at profit maximizing prices, and lower prices might be accepted due to time limitations and missing incentives to invest in search. We hypothesize costs of information deficiency for public sellers to be higher relative to professional private sellers, but lower compared to private sellers.

On the buyer side, we can differentiate farmer and non-farmer buyers, and (former) tenants. We hypothesize that (local) farmers and tenants are better informed about potential returns from the land-use, and about local market conditions including potential alternative and future offers. Thus, for these buyer groups we expect lower informational cost such that these groups pay lower mark-ups due to search compared to other buyers. We can, however, not identify whether the farmer buyer is a local farmer or buys for pure investment reasons with the intention to immediately rent out.

Another specificity arises from leased land and we can distinguish whether a tenant buys within the current lease rate, or after the lease term is finished. If the land is sold at the end of the rental term, the tenant should be prepared without time cost to make an offer as potential buyer. This would result in lower informational costs for tenants. If the land is sold within the current lease term, the tenant may face additional cost for instance to finance the purchase and may not be prepared. Moreover, finding alternative land may not be possible in a short time to secure production capacity. This implies higher costs of information deficiency on the tenants side compared to non-tenants. A transaction within the lease term, however, indicates that the seller preferred the purchasing price over a constant revenue stream from the lease. This discounting could indicate that the seller was not willing or able to wait, that is, accepting at lower prices. This might offset the informational costs of the tenant and the overall effect is unclear.

Lastly, we acknowledge that BVVG regularly publishes auction results on their website making prices, location, time and core plot characteristics accessible for all potential market players. Such transparency may thus decrease information costs in regions with many BVVG transactions but for buyers and sellers. We will test for such effects by adding BVVG's share on the total number of transactions in the respective municipality.

3.2 Data

For the empirical analysis, we dispose of a unique and rich data set provided by the Committee of Land Valuation Experts (*Gutachterausschuss für Grundstückswerte in Sachsen-Anhalt*, LVermGeo, 2018a). The data contains all land market transactions in this state in the period 2014–2017 with comprehensive information on each transaction, including transaction details (e.g., contract date and price), lot characteristics (e.g., location, size, and soil quality), as well as anonymous buyer and seller information. The initial data set contains 12,134 transactions. A first data treatment selects only arm's-length transactions and removes observations with missing or inconsistent values. We consider transactions of arable land and additional outlier detection based on the minimum covariance determinant estimator (Rousseeuw and Driessen, 1999) leads to the final sample with 10,778 observations.

To grasp price variation for the same fundamental value, we consider lot characteristics as factors in the hedonic function, and variables explaining the environment in which a transaction takes place. Since many studies have shown the price impact of subsidized renewable energy sources on land market prices (e.g., Haan and Simmler, 2018; Kostov, 2009; Patton and McErlean, 2003), we add the density of wind power and biomass capacity in a municipality, measured as the number of turbines and the electric capacity per hectare, respectively. We use information provided by the State Office for Survey and Geoinformation (LVermGeo, 2018b), the State Office of Statistics (State Office of Statistics, 2018a) and the Federal Network Agency (Bundesnetzagentur, 2018). Further, we indicate if a lot is in a wind energy area, which allows building a wind engine and thus captures high potential future earnings from this alternative land use.

Table 1 shows the descriptive statistics: the average price over all transactions is about 1.63 €/m^2 and varies between less than 0.35 and more than 4.08 €/m^2 with lot size ranging from less than 0.03 ha to more than 100 ha at a mean of about 3 ha. A lot can be operated independently (e.g., no further right of way is necessary) in 86 percent of the transactions, is leased out in 73 percent of the cases and 1 percent of the transactions lie in a region eligible for wind energy use. BVVG carries out about 8 percent of the transactions, a public seller in 2 percent, and a private professional seller is in 2 percent of the transactions responsible on the seller side. On the buyer side, tenants and farmers as buyers accounting for 49 and 74 percent of the transactions, respectively. If the land is sold during term, on average 5.11 years remain.

3.3 Model specification

To specify the functional form of the hedonic part of the regression equation, we refer to a Box-Cox transformation for the continuous variables lot size, soil quality and the price. To stabilize the variance estimate, we regress the log per hectare price on the square root of size and soil quality, and their interaction. To control for spatial and temporal effects, we first add dummies LC_k for location classes based on information provided by the Committee of Land Valuation Experts (LVermGeo, 2018a). Each of the twelve classes represents a geographically compact area with similar characteristics and captures other unobserved factors, such as, e.g., connection to infrastructure.[3] Second, to control for intertemporal effects, we use a linear-quadratic trend, τ and τ^2, where τ equals one in 2014, two in 2015, and so on. To account for spatio-temporal particularities, we interact

[3] A map of the location classes is provided in Figure A1 in the appendix.

Table 1: Descriptive statistics for dataset, 2014–2017

N = 10,778		Mean	Median	SD	1% Quant.	99% Quant.
Dependent variable						
Price (€/m^2)	P	1.63	1.50	0.86	0.35	4.08
Lot characteristics						
Lot size (ha)	x_S	3.08	1.02	6.40	0.03	26.93
Soil quality (Index)	x_Q	64.11	66.00	22.65	21.00	100.00
Lot independence (1/0)	x_I	0.86	1	0.35	0	1
Lot is leased (1/0)	x_L	0.73	1	0.45	0	1
Wind energy area (1/0)	x_W	0.01	0	0.08	0	1
Lease term if leased (years)	x_{LT}	5.11	4.00	5.47	0.00	24.00
Controls at municipal level						
Wind power stations per ha	m_W	0.002	0.001	0.003	0	0.02
Biomass capacity kW per ha	m_B	0.33	0.1	2.44	0	2.58
Transaction share of BVVG	m_{BVVG}	0.12	0.09	0.10	0.00	0.48
Seller/buyer characteristics						
BVVG (1/0)	$sBVVG$	0.08	0	0.28	0	1
Professional seller (1/0)	$sProf$	0.02	0	0.13	0	1
Public seller (1/0)	$sPub$	0.02	0	0.15	0	1
Buyer: Farmer (1/0)	bF	0.74	1	0.44	0	1
Buyer: Tenant (1/0)	bT	0.49	0	0.50	0	1

Note: Due to data privacy reasons, we cannot report minima and maxima.

the time trend with the location classes ($LC_k \cdot \tau$). The final regression equation is

$$\begin{aligned} log(P) =&\beta_S\sqrt{x}_S + \beta_Q\sqrt{x}_Q + \beta_{SQ}(x_S x_Q) + \beta_I x_I + \beta_L x_L + \beta_W x_W \\ &+ \gamma_W m_W + \gamma_B m_B + \gamma_{BVVG} m_{BVVG} + \gamma_\tau \tau + \gamma_{\tau^2}\tau^2 \\ &+ \sum_{k=1}^{12}\gamma_{LC,k} LC_k + \sum_{k=1}^{12}\gamma_{LC,\tau,k}(LC_k \cdot \tau) \\ &- exp(\mu_S + \delta_{sBVVG} sBVVG + \delta_{sPub} sPub + \delta_{sProf} sProf) \\ &+ exp(\mu_B + \delta_{bT|x_{LT}=0}(bT \cdot \mathbb{1}_{x_{LT}=0}) + \delta_{bT|x_{LT}>0}(bT \cdot x_{LT}) + \delta_{bF} bF) + v \end{aligned} \tag{8}$$

where the β's are hedonic parameters to be estimated, the γ's are parameters for control variables at municipal level as well as time- and spatial effects, δ's are parameters for the impact of buyer and seller characteristics, μ_B and μ_S denote the base costs of being information deficient for buyers and sellers, and v a noise term. Symbol $\mathbb{1}$ denotes the indicator function equal to one if the corresponding condition is fulfilled, and zero otherwise. μ_B and μ_S are specified as intercepts of the exponential functions. For identification reasons no other intercept is included in the regression.

Estimation uses non-linear least squares and to account for heteroskedasticity induced by the composed error term, we refer to clustered standard errors. These clusters use combinations of thirty quantiles of the lot size and the squared soil quality. The reduced from model used for comparison reasons, encompasses equation 8 but adjusted such that the buyer and seller terms enter the regression equation linearly additive.

4 Results

In Table 2 we present the estimates of the two-tier model (equation 8) and the reduced form OLS model. The adjusted R^2 of the OLS model is 0.675 and within a satisfying range. For the two-tier model, the squared correlation coefficient for observed and fitted values of the dependent variable is 0.676, which indicates a similar goodness of fit as the OLS estimation. From a technical perspective, it should be noted that the OLS intercept corresponds to the sum of the base costs of information deficiency from the two-tier framework ($-2.155 \approx e^{-3.034} - e^{0.789}$). Kumbhakar and Parmeter (2010) argue that an OLS intercept might be biased if $E(\omega - u) \neq 0$ which does not seem to be the case in our application.

Comparing magnitude and significance of the parameters of the two approaches reveals striking similarities: in both models, the core hedonic variables soil quality and lot size show the expected positive significant effects, which is in line with many studies (e.g., Lehn and Bahrs, 2018), though in a non-linear manner (e.g., Maddison, 2000). Interacting lot size and soil quality reveals a negative coefficient indicating that prices decrease for the larger plots at high soil qualities. As discussed by Brorsen et al. (2015), this may point to capital and borrowing constraints resulting in a lower number of competitors on the buyer side for such lots. Interestingly, whether a lot can be independently used or not, is not relevant for the price vector. Likewise, the tenancy status of a lot does not influence the price significantly.

Among the control variables, the positive and significant estimate of the average share of BVVG-sales within a region is noteworthy: while the magnitude of the effect is small in monetary terms, the estimate points towards the considerable role of this institution in these land markets and its contribution to overall market transparency. In this regard, the supply management of this agency over space and time may also be relevant in terms of market power.

Regarding the effect of renewable energy sources we do not find significant effects with respect to wind, both the number of wind turbines within a region and the location of a lot in a wind energy area. These results are not in line with Haan and Simmler (2018) and Ritter et al. (2015); these authors, however, analysed data from the boom-phase of wind power under fixed feed-in tariffs, whereas our study already includes transactions under variable tariffs starting in 2017. Likewise, the installed regional capacity in biomass for energy production reveals a small and statistically insignificant price-increasing effect, although with p-values close to 10 percent. Previous studies rather report significant effects of biomass on rental prices in the boom years (Hennig and Latacz-Lohmann, 2016), but not on purchase prices (Habermann and Breustedt, 2011). Our results indicating minor effects might be due to a lagged effect on purchase prices in a sense of a long-term effect of land-intense biomass-based production. Further, the actual effect of biomass might be stronger but could be absorbed by the spatial control variables.

In both models, the trend variables indicate a positive price development for the observation period 2014–17, but the negative sign for the squared trends suggest a slowdown. The spatial effects are positive and statistically significant in reference to the base category Wittenberg.[4] Regional time trends, modelled as interactions of the regional dummies with the trend variable point in some cases to local particularities, which might include economic and infrastructure effects not captured by the controls.

[4] Parameter estimates for the spatial effects are provided in Table A2 in the appendix.

Table 2: Regression results: Parameter estimates and standard errors in parentheses

	Dependent variable: Log price			
	Two-tier		*OLS*	
Lot characteristics				
Intercept			-2.155^{***}	(0.053)
$\sqrt{}$Lot size	0.117^{***}	(0.010)	0.118^{***}	(0.010)
$\sqrt{}$Soil quality	0.203^{***}	(0.006)	0.203^{***}	(0.006)
Soil quality × lot size	-0.0001^{***}	(0.00002)	-0.0001^{***}	(0.00002)
Lot independence	−0.003	(0.011)	−0.003	(0.011)
Wind energy area	−0.005	(0.047)	−0.004	(0.046)
Lot is leased	0.013	(0.011)	0.011	(0.011)
Wind power stations	−0.600	(0.953)	−0.556	(0.965)
Biomass capacity	0.002	(0.001)	0.002	(0.001)
BVVG share	0.156^{***}	(0.057)	0.158^{***}	(0.056)
Seller characteristics				
Base cost	0.789^{***}	(0.026)		
BVVG	-0.193^{***}	(0.012)	0.388^{***}	(0.016)
Professional seller	-0.089^{***}	(0.012)	0.189^{***}	(0.024)
Public seller	-0.030^{*}	(0.017)	0.066^{*}	(0.036)
Buyer characteristics				
Base cost	-3.034^{***}	(0.654)		
Farmer	0.416	(0.298)	0.021^{***}	(0.008)
Tenant (no lease term)	−1.467	(1.564)	-0.052^{***}	(0.008)
Tenant × lease term	−0.154	(0.155)	-0.004^{***}	(0.001)
Time controls				
Trend	0.158^{***}	(0.020)	0.158^{***}	(0.020)
Trend^2	-0.012^{***}	(0.003)	-0.012^{***}	(0.003)
Location classes	yes		yes	
Observations	10,778		10,778	
$\text{Cor}_{\text{P}, \hat{\text{P}}}$	0.676		0.676	
Residual Std. Error	0.326 (df = 10,737)		0.326 (df = 10,738)	

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Next, we turn to the variables of interest relating cost of being information deficient to different buyer and seller types. While the buyer base cost term is found to be low and close to zero ($e^{-3.034}$), on the seller side, we find a considerable baseline effect ($e^{0.789}$). However, of interest are relative effects by categories representing different degrees of professionalism. To ease interpretation, we refer to marginal effects of seller and buyer charactristics evaluated at the sample mean (c.f. Table 3).

Table 3: Marginal effects of seller and buyer characteristics

	€/m^2	Percent
Seller		
BVVG [y/n]	0.699	47.10
Professional seller [y/n]	0.308	20.73
Public seller [y/n]	0.101	6.79
Buyer		
Farmer [y/n]	0.026	1.68
Tenant (no lease term) [y/n]	-0.080	-4.99
Interaction tenant-lease term [years]	-0.005	-0.34

On the seller side, we find considerable positive effects for the BVVG and other professional sellers that are able to obtain mark-ups of about 47 and 20 percent, respectively. Also public sellers achieve a price mark-up attributed to lower cost of being information deficient, although this effect is at a moderate level. These estimates support our argumentation: we find experienced, professional sellers to be able to obtain a mark-up compared to private and other non-specialized sellers. These sellers are able to reduce search costs by, e.g., advertising and efficient targeting of potential buyers. Further, these results can be traced back to the use of auctions with public tenders, where prices compared to those from negotiated sales have be shown to be higher (e.g., Bulow and Klemperer, 1996; Chow et al., 2015).

On the buyer side, we do not find significant effects for the different buyer types in the two-tier framework. From these findings we conclude that buyers may be differently informed and have different search costs, but these cannot be identified, neither by distinguishing farmers and non-farmers (cf. Hüttel et al., 2016), nor by tenant or non-tenants (cf. Croonenbroeck et al., 2019). This result can in parts be explained by the heterogeneous group of farmers including locals and investors from other regions or start-ups. The latter group challenges the indication farmer versus non-farmer: depending on start-up's progress at the time of sale, these can be assigned to either group but neither group being informative regarding search costs. Likewise challenging, an observed transaction within an existing lease term may not only represent different informational and search costs levels, but also a change in the landowners preference towards a purchase price over a constant revenue stream from the lease. This may for example be caused by a change in the land ownership by inheritance.

Results obtained in the simpler OLS model (compare Table 2, right column) are mostly in line with the results from the two-tier framework, however, not for the buyer side: the estimates from the reduced form OLS suggest significant effects of the different buyer characteristics, though at a low level.This model would indicate weak effects that farmers pay slightly higher prices and tenants slightly lower.

5 Concluding remarks

This paper investigates the role of information and search cost related to sellers' and buyers' characteristics in the price formation in thin farmland markets. Based on a two-tier framework with scaling property, we find relevance of hedonic price characteristics such as size and soil quality and mark-ups for professional sellers likely related to lower search cost. Institutional sellers relying on public tenders achieve the lowest losses from being information deficient. Similar findings are retrieved if other professionals sold the lot. We do, however, find no considerable differences between farmer and non-farmer buyers. From these findings we conclude that buyers may be differently informed and have different search costs, but these can neither be identified by distinguishing farmers and non-farmers, nor by tenant or non-tenants. This supports the hypothesis of the complexity of farmland markets given the thinness. Binary distinctions in farmers and non-farmers in reduced form models may even lead to wrong conclusions. Based upon these findings, we consider information deficiency and market mechanisms as relevant in explaining price dispersion over space and time for the same fundamental value. Thus, our results underline the relevance of the market micro-structure. Potential directions towards policy implications include the role of fostering market transparency for efficient price discovery in farmland markets, whereas for future research the role of local market power, speculation effects and bargaining power should be explored in greater detail. Nonetheless, our study has some linitations. It must be acknowledged that a low variation in buyer and seller characteristics can impair identification. Further, we cannot rule out correlation of search cost and hedonic variables. Estimates of the slope coefficients can then be biased and inefficient. This is left for future research.

6 Appendix

Table A1: Main descriptive statistics by seller and buyer types

	Mean	Median	St. Dev.	Q1	Q99
Seller: BVVG					
Price (€/m^2)	2.43	2.42	1.00	0.60	4.77
Lot Size (ha)	8.17	3.38	14.73	0.03	90.66
Soil Quality (Index)	63.91	65.00	21.99	21.00	99.00
Lot Independence (1/0)	0.86	1.00	0.35	0.00	1.00
Wind energy area (1/0)	0.00	0.00	0.07	0.00	0.00
Lot is leased (1/0)	0.67	1.00	0.47	0.00	1.00
Seller: Professional Seller					
Price (€/m^2)	2.37	2.42	1.06	0.57	4.61
Lot Size (ha)	5.65	4.58	7.61	0.06	23.00
Soil Quality (Index)	70.71	75.00	22.29	22.00	99.00
Lot Independence (1/0)	0.94	1.00	0.23	0.00	1.00
Wind energy area (1/0)	0.01	0.00	0.07	0.00	0.00
Lot is leased (1/0)	0.69	1.00	0.46	0.00	1.00
Seller: Public Seller					
Price (€/m^2)	1.58	1.40	0.89	0.41	4.13
Lot Size (ha)	4.39	0.82	10.94	0.02	68.37
Soil Quality (Index)	59.18	58.50	23.13	20.10	100.00
Lot Independence (1/0)	0.72	1.00	0.45	0.00	1.00
Wind energy area (1/0)	0.00	0.00	0.00	0.00	0.00
Lot is leased (1/0)	0.48	0.00	0.50	0.00	1.00
Buyer: Farmer					
Price (€/m^2)	1.65	1.52	0.86	0.35	4.18
Lot Size (ha)	3.36	1.18	6.68	0.06	29.06
Soil Quality (Index)	64.93	67.00	22.42	21.00	100.00
Lot Independence (1/0)	0.89	1.00	0.31	0.00	1.00
Wind energy area (1/0)	0.01	0.00	0.09	0.00	0.00
Lot is leased (1/0)	0.78	1.00	0.41	0.00	1.00
Buyer: Tenant					
Price (€/m^2)	1.59	1.50	0.81	0.35	3.96
Lot Size (ha)	3.02	1.00	6.43	0.06	28.21
Soil Quality (Index)	65.50	68.00	22.32	21.00	100.00
Lot Independence (1/0)	0.89	1.00	0.31	0.00	1.00
Wind energy area (1/0)	0.01	0.00	0.09	0.00	0.00
Lot is leased (1/0)	0.88	1.00	0.33	0.00	1.00

Table A2: Regression results: Spatial (Location classes) and spatio-temporal effects (Location class - time - interaction) - Reference class: Wittenberg

	Dependent variable: Log price			
	Two-tier		*OLS*	
Altmark-Mitte	0.340***	(0.075)	0.343***	(0.075)
Altmark-Ost	0.103	(0.094)	0.104	(0.094)
Altmark-West	0.286***	(0.069)	0.287***	(0.068)
Boerde	0.670***	(0.044)	0.671***	(0.045)
HAL-Sued	0.475***	(0.044)	0.481***	(0.045)
Harz	0.075**	(0.038)	0.077**	(0.038)
MD-HAL	0.515***	(0.032)	0.515***	(0.032)
MD-Nord	0.187***	(0.037)	0.189***	(0.038)
MD-Ost	0.459***	(0.048)	0.461***	(0.048)
ST-Sued	0.562***	(0.045)	0.565***	(0.045)
Vorharz	0.427***	(0.044)	0.428***	(0.044)
Altmark-Mitte × trend	0.012	(0.023)	0.012	(0.022)
Altmark-Ost × trend	0.040	(0.031)	0.040	(0.030)
Altmark-West × trend	0.010	(0.025)	0.010	(0.025)
Boerde × trend	−0.020**	(0.008)	−0.020**	(0.008)
HAL-Sued × trend	−0.023*	(0.012)	−0.024*	(0.012)
Harz × trend	0.011	(0.011)	0.011	(0.011)
MD-HAL × trend	−0.020***	(0.007)	−0.020***	(0.007)
MD-Nord × trend	0.007	(0.014)	0.007	(0.013)
MD-Ost × trend	−0.022*	(0.012)	−0.021*	(0.013)
ST-Sued × trend	−0.015	(0.012)	−0.015	(0.012)
Vorharz ×trend	−0.005	(0.012)	−0.006	(0.012)
Observations	10,778		10,778	
$\text{Cor}_{\text{P}, \hat{\text{P}}}$	0.676		0.676	
Residual Std. Error	0.326 (df = 10,737)		0.326 (df = 10,738)	

Note: *$p<0.1$; **$p<0.05$; ***$p<0.01$

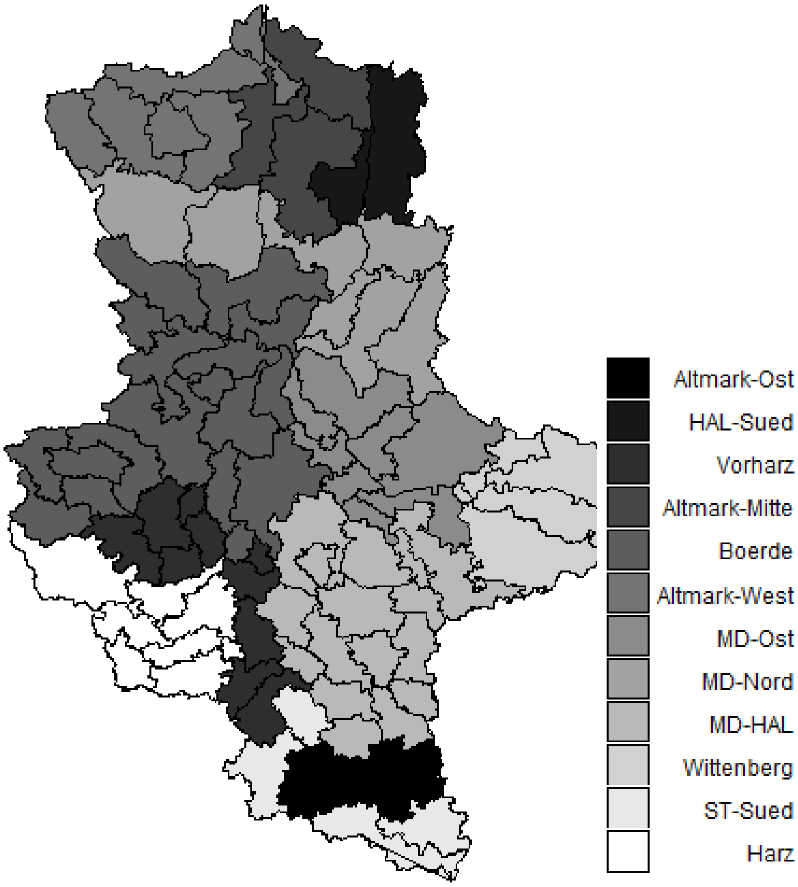


Figure A1: Map of location classes

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