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Agricultural Land Markets – Efficiency and Regulation

The Spatial and Temporal Diffusion of Agricultural Land Prices

Xinyue Yang[*], Martin Odening[**], Matthias Ritter[***]

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Abstract

In the last decade, many parts of the world experienced severe increases in agricultural land prices. This price surge, however, did not take place evenly in space and time. To better understand the spatial and temporal behavior of land prices, we employ a price diffusion model that combines features of market integration models and spatial econometric models. An application of this model to farmland prices in Germany shows that prices on a county-level are cointegrated. Apart from convergence towards a long-run equilibrium, we find that price transmission also proceeds through short-term adjustments caused by neighboring regions.

Keywords: Agricultural land markets; price diffusion; spatial dependence; ripple effect

JEL codes: Q 24, C 23

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1 Introduction

In the last decade, many parts of the world experienced drastic increases in agricultural land prices. In the European Union (EU), agricultural land prices in Germany surged by almost 150% from an average of 8,909 €/ha in 2006 to 22,310 €/ha in 2016 (Federal Statistical Office of Germany 2017). In France, average farmland prices increased by 33% in the last decade to reach 5,940 €/ha in 2014, while land prices in the United Kingdom (UK) more than doubled during that time (European Commission 2016). Likewise, in the United States the average value of cropland increased from 6,252 $/ha to 10,107 $/ha between 2007 and 2017 (U.S. Department of Agriculture 2017). Drivers of this price surge are claimed to be higher land rents due to increased productivity and food prices, the conversion of agricultural land to non-agricultural uses, and speculative activities of financial investors (e.g., Deininger and Byerlee 2011). Farmers and politicians are concerned about this development since high land prices are an obstacle for the expansion of family-operated farms. In addition, the concentration of farmland in the ownership of large holdings or non-agricultural investors is suspiciously monitored. Indeed, many governments take actions or contemplate measures that target the capping of land prices. For example, in 2014, Belgium laid the foundation for new land market instruments, such as the land observatory, land bank, and updated preemption rights. Belgium also tightened land market regulations, which had previously been liberal. In the same year, new land market regulations aiming to restrict the purchase of agricultural land by foreigners and non-farmers were released in Slovakia. Likewise, in Germany, the Federal Ministry and the State Ministries of Agriculture are currently discussing bills that target the broad distribution of land ownership, the prevention of dominant land market positions on the supply and demand side, the capping of land rental and sales prices, and the special treatment of farmers compared with non-agricultural investors.

It should be noted, however, that the surge of agricultural prices, which triggered the aforementioned policy debate, did not take place evenly in space and time. For example, land prices in Western and Eastern Germany differ significantly even 20 years after reunification. Not only do price levels vary, but growth rates of land prices also vary between and within countries. In France, for example, significant double-digit increases took place from 2011 to 2014 in northern parts (+38%) and western parts (+11%), whereas land prices declined in other regions, notably in the Mediterranean area (–8%) (European Commission 2016). Italy also witnessed an uneven price development in the farmland market: Land values almost doubled from 1992 to 2010 in Northern Italy, while in Central and Southern regions land values increased by only 15–30% (Mela et al. 2012).

Yang et al. (2017) show that even on a regional scale, agricultural land markets may exhibit different dynamics. Potential causes of diverging land prices are different agricultural production systems and disparities in regional growth in conjunction with the limited mobility of agricultural production. On the other hand, it is widely acknowledged that land prices are sticky across space. This is not only due to the spatial correlation of land price characteristics, such as soil quality, but also an implication of adjustments to shocks in demand and supply of land markets. For example, if land prices in the urban fringe increase because agricultural land is converted to commercial land, liquid farmers will likely acquire agricultural land in the neighboring area as a substitute and thus increase land prices. Likewise, if a windfarm is built, this not only creates significant rents in that area, but also generates regional spill-over effects since ecological compensation areas have to be established elsewhere. Ritter et al. (2015) provide empirical evidence for this “ripple effect” in Brandenburg, Germany. However, so far it is not well understood how fast this kind of spatial price transmission works and whether it describes a local or regional phenomenon. From a policy perspective as well as for the optimal timing of land sales, it is of great interest to know whether regional land price differentials diminish or not and how price shocks diffuse in space.

At least three types of statistical models can be distinguished that aim to explain the behavior of land prices: spatial econometric models, time series models, and spatio-temporal models. Spatial econometric models, which encompass spatial lag and spatial error models, are nowadays more or less standard in hedonic models of land prices (e.g., Huang et al. 2006, Patton and McErlean 2003, Hüttel et al. 2013). These models are static in nature and they focus on measuring the unbiased impact of land attributes on land prices while accounting for their spatial relationships. Time series models are used to estimate trends and structural breaks in land price developments (Gutierrez et al. 2007), test the present value model of prices, and detect price bubbles (Falk 1991). The third modelling approach, spatial-temporal models, seems to be the most suitable approach for our analysis because it captures both dimensions of interest, i.e., space and time.

There are only few applications of spatio-temporal models to farmland prices. Carmona and Roses (2012) apply panel unit root tests to explore the convergence of farmland prices in Spanish provinces at the beginning of the last century. They find that the Spanish land market is spatially integrated and interpret this finding as an indicator of land market efficiency. More recently, Yang et al. (2017) apply second-generation panel unit root tests in an iterative procedure to identify “convergence clubs” of regional land markets that share the same price development. Though panel unit root tests give a first impression of the similarity of price trends in different regional land markets, they do not allow for a complete description of price diffusion processes. More specifically, it is not possible to distinguish between convergence, co-integration, and spatial diffusion. Pesaran and Tosetti (2011) suggest a price diffusion model that is able to disentangle these effects and Holly et al. (2011) use this model to analyze the spatial and temporal diffusion of house prices in the UK. A nice feature of this model is that it enables the testing of whether a specific region is dominant in a sense that it is typically the source of price shocks that are then transmitted to neighboring regions with a time delay, while there are no feedback effects. Such a phenomenon is often observed for big cities in the context of house prices (Meen 1999, Lee and Chien 2011).

In this paper, we apply the price diffusion model of Pesaran and Tosetti (2011) to study the behavior of farmland prices in the state of Lower Saxony, Germany. Within this modelling framework, we are able to answer a set of interesting research questions: Are regional land markets separated or are they integrated such that prices converge in the long-run? If low price regions catch up with high price regions, how long does this adjustment take? Can we find ripple effects in farmland markets? Is it possible to identify dominant regions in farmland markets, such as in areas with high land rents or in close proximity to urban land markets? Though we target at a description of land price dynamics rather than a full economic explanation of these dynamics, it is an important step towards a more comprehensive understanding of farmland markets.

2 Methodology

Beenstock and Felsenstein (2007) develop a spatial vector autoregression (SpVAR) model, which is motivated by the ability to explicitly consider the potential impacts of economic events in space. In the SpVAR model, which consists of temporally lagged terms and spatially lagged terms, the land prices in region *i* at time *t* are given by:

$$p_{it} = c_i + \sum_{l=1}^{L_{\alpha i}} \alpha_{il} p_{i,t-l} + \sum_{l=0}^{L_{\rho i}} \rho_{il} \bar{p}_{i,t-l} + u_{it}, \tag{1}$$

where p_{it} denotes the land price in region *i* at time *t*, $i = 1, \dots, N$ and $t = 1, \dots, T$; c_i is a region-specific fixed effect; $p_{i,t-l}$ is the time-lag of the dependent variable with weights α_{il}; $\bar{p}_{it}$ is the spatially lagged price with its temporal lags $\bar{p}_{i,t-l}$ and weights ρ_{il}. $L_{\alpha i}$ and $L_{\rho i}$ denote the region-specific maximal number of temporal lags for the dependent variable and its spatially lagged prices; and u_{it} is an error term, which can consider spatial correlation.

There are several weighting schemes for spatial structures in the spatial econometric literature based on contiguity or distance. Since average land prices per county do not have a distinct spatial core, we employ the queen contiguity scheme, namely that two counties are considered neighbors if they share a common border. The average neighbor price is then calculated as the weighted average of the neighbors' prices according to $\bar{p}_{it} = \sum_{j=1}^{N} w_{ij} p_{jt}$ with weights w_{ij} defined as follows:

$$w_{ij} = \begin{cases} \frac{1}{N_i} & \text{if } i \text{ and } j \text{ share a border, } i \neq j, \\ 0 & \text{otherwise,} \end{cases} \tag{2}$$

where N_i denotes the number of neighbors in region i and it follows that $\sum_{j=1}^{N} w_{ij} = 1$.

Since asset prices are typically nonstationary, it is useful to employ spatial cointegration methods. The relationship between cointegrated variables is captured by vector error correction models (VECMs). Whereas conventional VECMs only consider temporal dynamics, spatial vector error correction models (SpVECMs) incorporate spatial as well as temporal dynamics (Beenstock and Felsenstein 2010). In this framework, the long-run relationship between prices in a region and the average prices in neighboring areas can be modeled through the following spatial autoregressive (SAR) equation:

$$p_{it} = \delta_i + \beta_i \bar{p}_{it} + \mu_{it}, \tag{3}$$

where $\bar{p}_{it}$ denotes the spatially lagged price as defined above. If β_i is significant and μ_{it} is stationary, there exists a long-run equilibrium between land prices in region *i* and the average prices in the neighboring area. Temporary deviations from the long-run equilibrium in the previous period, $\mu_{it} = p_{i,t-1} - \delta_i - \beta_i \bar{p}_{i,t-1}$ are corrected towards the equilibrium relation through the adjustment speed ϕ_i:

$$\Delta p_{it} = \gamma_i + \phi_i\left(p_{i,t-1} - \delta_i - \beta_i \bar{p}_{i,t-1}\right) + \sum\nolimits_{l=1}^{L_{ia}} a_{il}\Delta p_{i,t-l} + \sum\nolimits_{l=0}^{L_{ib}} b_{il}\Delta \bar{p}_{i,t-l} + \epsilon_{it}, \qquad (4)$$

where $\Delta p_{it} = p_{it} - p_{i,t-1}$, $i = 1, \dots, N$, and $t = 1, \dots, T$. γ_i denotes region-specific fixed effects. $\sum_{l=1}^{L_{ia}} a_{il}\Delta p_{i,t-l}$ describes short-run dependencies of prices in region i and $\sum_{l=1}^{L_{ib}} b_{il}\Delta \bar{p}_{i,t-l}$ describes short-run dependencies of prices in the neighboring area; $b_{i0}\Delta \bar{p}_{it}$ captures the contemporaneous effect on the price change in the neighboring area; and ϵ_{it} is an error term. If cointegration is present, we further analyze whether the average price in the neighboring area converges to the price in region i. In the case of convergence, land prices are cotrending and the cointegrating vector $(1, -\beta_i)$ equals $(1, -1)$. Although this provides evidence on a possible clustering of cointegration outcomes, price convergence is not necessary for spatiotemporal price diffusion.

So far, the diffusion was restricted to adjacent regions. However, the price changes in one region may also affect its higher-order neighbors or even the whole area. The phenomenon of a spill-over of shocks from one location to other places leading to a global effect on prices in all other regions is referred to as spatial ‘ripple effect’ (Meen, 1999). This effect can be regarded as a special case of price diffusion since: 1) The diffusion area not only includes nearby regions, but also further areas; and 2) The diffusion direction is one-way, which means that a shock starting in one center spreads to other regions and there are no feedback effects. In empirical applications on house markets (e.g., Holly et al. 2011, Helgers and Buyst 2016), a large city and major financial center, usually with the highest prices, is considered the dominant region to drive price development in all other regions. To confirm that a county is a dominant region, the following pairs of equations are estimated for all other $N - 1$ counties:

$$\Delta p_{0t} = d_{0i} + \phi_{0i}\left(p_{0,t-1} - \omega_{0i} - \beta_{0i} p_{i,t-1}\right) + \sum\nolimits_{l=1}^{L} a_{0il}\Delta p_{i,t-l} + \sum\nolimits_{l=1}^{L} c_{0il}\Delta p_{0,t-l} + \varepsilon_{0it} \qquad (5)$$

$$\Delta p_{it} = d_{i0} + \phi_{i0}\left(p_{i,t-1} - \omega_{i0} - \beta_{i0} p_{0,t-1}\right) + \sum\nolimits_{l=1}^{L} a_{i0l}\Delta p_{i,t-l} + \sum\nolimits_{l=1}^{L} c_{i0l}\Delta p_{0,t-l} + \varepsilon_{i0t} \qquad (6)$$

with $\sum_{l=1}^{L} a_{il}\Delta p_{i,t-l}$ and $\sum_{l=1}^{L} c_{il}\Delta p_{0,t-l}$ denoting the short-run dependencies from the price changes in region i and in the dominant region 0, respectively. The adjustment speed ϕ_{0i} in Equation (5) describes how fast the price change in a potential dominant region 0, Δp_{0t}, is corrected towards a long-run equilibrium with county i (if existent). In contrast, in Equation (6) the adjustment speed ϕ_{i0} depicts how fast the price change in county i, Δp_{it}, is corrected towards a long-run equilibrium with the potential dominant region 0. This estimation is repeated for all candidates for a dominant region. According to the definition of a dominant region, its price should affect the prices in the other counties in the long-run, i.e., ϕ_{i0} should be significant for all i, whereas the price in the dominant region should not be affected by prices in other counties in the long-run, i.e., ϕ_{0i} should be insignificant for all i.

In case a dominant region 0 exists, the long-run equilibrium relationship in Equation (3) is extended in the following way to account for the special role of the price in the dominant region, p_{0t}:

$$p_{it} = \omega_i + \beta_i \bar{p}_{it} + \beta_{i0} p_{0t} + \mu_{i0t} \tag{7}$$

with $i = 1, \ldots, N-1$ indicating the non-dominant regions. Note that for direct neighbors, the dominant region is excluded in the calculation of the average price in the neighboring area $\bar{p}_{it}$.

With the long-run equilibrium (7), the diffusion model from Equation (4) can be adapted by adding the prices of the dominant region:

$$\begin{aligned}\Delta p_{it} = {} & \tau_i + \phi_i (p_{i,t-1} - \omega_i - \beta_i \bar{p}_{i,t-1} - \beta_{i0} p_{0,t-1}) \\ & + \sum\nolimits_{l=1}^{L_{ia}} a_{il} \Delta p_{i,t-l} + \sum\nolimits_{l=0}^{L_{ib}} b_{il} \Delta \bar{p}_{i,t-l} + \sum\nolimits_{l=0}^{L_{ic}} c_{il} \Delta p_{0,t-l} + \epsilon_{it}\end{aligned} \tag{8}$$

with $i = 1, \ldots, N-1$. The coefficient ϕ_i denotes the adjustment speed of region i to the new long-run equilibrium. $\sum_{l=0}^{L_{ic}} c_{il} \Delta p_{0,t-l}$ captures the short-run dependencies of the price change in the dominant region including a contemporaneous effect for $l = 0$.

With the two abovementioned models, Equations (4) and (8), the procedure for analyzing the diffusion of prices involves several steps. First, we carry out Augmented-Dicky-Fuller (ADF) tests on the individual price series to discern the long-run price development in each county. The next step consists of Johansen tests for the pair-wise cointegration between prices of each county and its neighbors' average price, and the estimation of the long-run equilibrium vectors in the cointegrating equations to confirm that a long-run equilibrium relationship exists. In this case, we can use the error correction term from prices of neighbors to control for price changes. For the model with the neighbors' average price and the dominant region, we also test for pairwise cointegration between prices in each county and long-run equilibrium and estimate their long-run equilibrium vectors. If the cointegrating relationships are confirmed, we can estimate the two diffusion models (4) and (8). Due to the inclusion of contemporaneous effects $\Delta \bar{p}_{it}$ and Δp_{0t} in the two models, an endogeneity problem might appear. Hence, we conduct the Wu-Hausman test: If the Wu-Hausman test rejects exogeneity, we use instrumental variables for the contemporaneous terms. For counties with exogenous contemporaneous terms, we take seemingly unrelated regressions (SUR) to estimate the system of price change equations to account for correlation in the error terms.

3 Study area and data

In our empirical analysis, we study the diffusion of land prices in Lower Saxony, Germany. Lower Saxony is located in northwest Germany and consists of 37 counties. It is the second largest state in Germany, covering an area of 47,600 square kilometers. About 60 percent of this area is used for agricultural production. In terms of production value, Lower Saxony is one of the leading states, contributing more than 20 percent to Germany's revenues from agriculture. However, natural conditions, production structures, and farm size structures differ largely across regions within Lower Saxony. This heterogeneity of agricultural production renders Lower Saxony an interesting study region. Differences in land use intensity translate into differences in land rental and sales prices, making the analysis of price diffusion processes nontrivial.

Figure 1. Regional distribution of land prices (€/ha) and livestock density in Lower Saxony in 2015

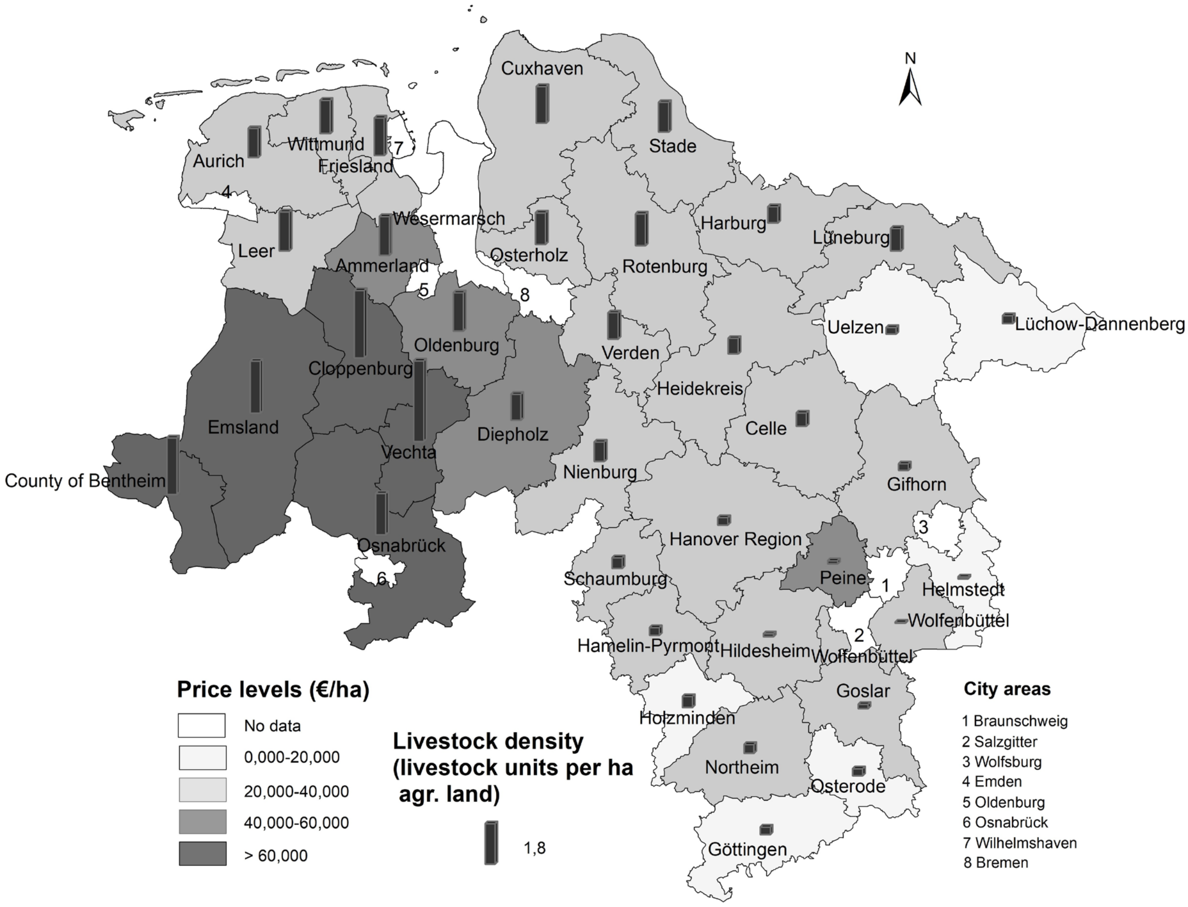


Figure 1 depicts the spatial differences of the price levels and livestock density in Lower Saxony in 2015. Table 1 summarizes key variables on agricultural production on a county level. Three different regions can be distinguished. The eastern and southeastern part of Lower Saxony is characterized by fertile soils. In this region, farms are rather large (often more than 100 ha on average) and specialized in cash crops. The livestock density for most of the counties in this region is less than 0.5 livestock units (LSU) per hectare and the sale prices for agricultural land are rather low (around 20,000 €/ha) with moderate price growth between 1990 and 2015 compared to the rest of Lower Saxony. The northern part of Lower Saxony, which is close to the coast, is characterized by a low share of arable land (less than 50%). This region is dominated by dairy production, but also has a large pomiculture area.

The western part of Lower Saxony is famous for its intensive livestock production. In view of rather poor soil quality (mostly around 30 soil quality points) and relatively small farm sizes (50–60 ha on average), livestock production shows comparative advantages and its intensity has steadily increased over the last few decades. Actually, 70 percent of Lower Saxony’s hog production and more than 80 percent of its poultry production are concentrated in this region. More recently, biogas production became an important alternative business in this region. The fact that 50 percent of Lower Saxony’s total agricultural revenues are generated in this part demonstrates its particular role.

Table 1. Descriptive statistics of agriculture in Lower Saxony

County	Number of farms	Average farm size (ha)	Share of arable land	Average soil quality (index points)	Livestock density (livestock units/ha agr. land)	Land sale price 2015 (€/ha)	Price growth rate 1990–2015	Ratio of rental and sales price
Ammerland	841	50.72	48%	31	1.74	41,862	228%	1.73%
Aurich	1,315	62.85	48%	42	1.31	28,716	128%	1.61%
Bentheim	1,140	51.14	86%	30	2.55	60,882	214%	1.52%
Celle	632	82.64	79%	35	0.60	20,368	95%	1.88%
Cloppenburg	1,758	54.33	87%	32	3.05	78,441	264%	1.56%
Cuxhaven	1,857	73.38	45%	42	1.65	26,631	134%	2.07%
Diepholz	1,693	76.51	82%	36	1.17	47,312	240%	1.80%
Emsland	2,812	57.80	90%	30	2.35	61,723	304%	1.53%
Friesland	576	76.19	34%	41	1.70	35,670	109%	2.16%
Gifhorn	817	94.94	83%	38	0.30	25,090	209%	2.14%
Goslar	289	95.19	87%	61	0.20	24,348	62%	2.40%
Göttingen	726	79.15	86%	57	0.34	19,707	52%	1.91%
Hamelin-Pyrmont	482	81.39	89%	59	0.35	29,186	41%	2.01%
Hanover Region	1,481	78.23	84%	50	0.34	36,419	69%	1.44%
Harburg	860	63.86	66%	35	0.74	24,984	126%	1.40%
Heidekreis	900	77.17	69%	32	0.71	26,226	148%	1.84%
Helmstedt	359	115.16	91%	51	0.09	18,446	8%	2.44%
Hildesheim	811	83.73	94%	71	0.14	34,539	36%	1.54%
Holzminden	321	79.65	74%	57	0.49	17,829	38%	1.92%
Leer	1,138	59.05	26%	32	1.76	35,941	179%	1.97%
Lüchow-Dannenberg	587	103.32	80%	36	0.37	17,760	118%	2.25%
Lüneburg	10,480	76.55	65%	39	1.02	20,774	176%	2.62%
Nienburg	1,169	69.98	84%	35	0.88	31,244	160%	2.23%
Northeim	815	69.47	84%	66	0.39	22,104	61%	1.72%
Oldenburg	955	66.87	76%	31	1.73	55,414	259%	1.34%
Osnabrück	2,418	48.44	84%	38	1.87	62,253	231%	1.46%
Osterholz	737	53.75	37%	30	1.42	21,528	46%	1.59%
Osterode	242	64.11	70%	55	0.32	14,553	155%	2.31%
Peine	401	89.19	91%	60	0.15	41,094	84%	1.85%
Rotenburg	1,642	76.76	68%	27	1.44	31,650	241%	1.93%
Schaumburg	440	76.32	86%	64	0.48	31,898	42%	1.59%
Stade	1,276	62.87	52%	40	1.34	34,521	211%	1.89%
Uelzen	693	107.51	90%	34	0.29	19,474	68%	2.41%
Vechta	1,140	56.60	89%	39	3.64	90,457	235%	1.34%
Verden	698	66.09	70%	37	1.18	31,318	197%	1.49%
Wittmund	657	64.30	43%	39	1.50	30,323	238%	1.84%
Wolfenbüttel	403	126.35	96%	73	0.05	34,194	82%	1.50%

Data regarding the number of farms, farm size, share of arable land, average soil quality, livestock density, and land sale price for arable land (1990, 2010, and 2015) are courtesy of the Statistical Office of Lower Saxony (2016). The rental/sale price ratio (2010) is calculated based on rental price data from the LSKN (Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen) (2010). The index points for the average soil quality refer to an official index in Germany. The lowest measured value is 7, the highest 104 points.

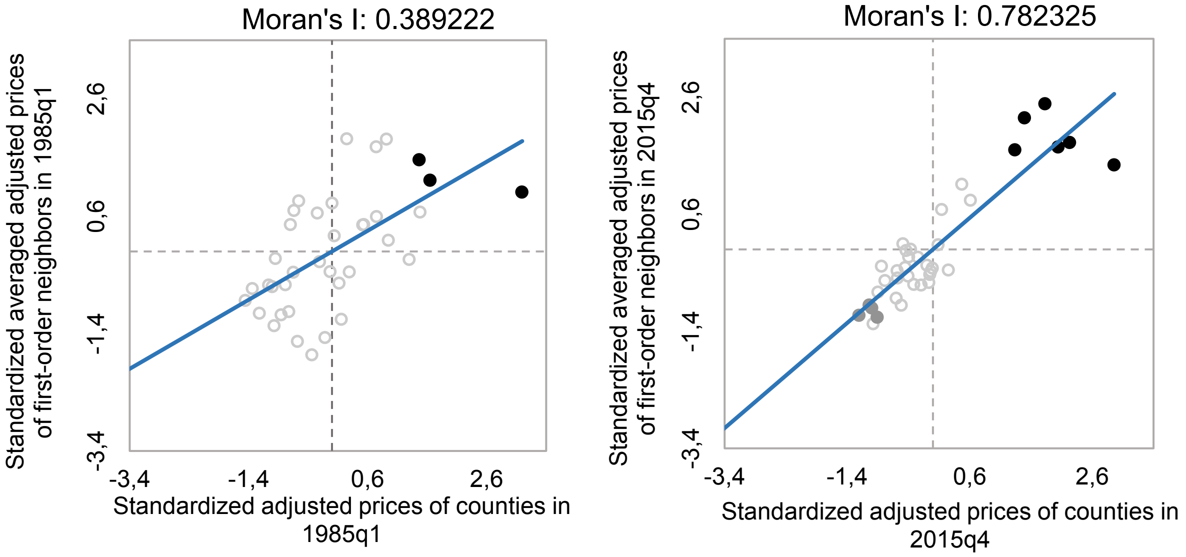
This area has also experienced the highest price growth rates between 1990 and 2015 (Emsland +304%, Cloppenburg +264%, and Oldenburg 259%) and the highest absolute prices in 2015 (Vechta 90,457 €/ha, Cloppenburg 78,441 €/ha, and Emsland 61,723 €/ha). The counties Emsland, Cloppenburg, Vechta, and Oldenburg are candidates for the choice of a dominant county in our model since these counties have the highest absolute prices and price growth rates. The final decision of Cloppenburg as the dominant region in our model will be justified later.

The data applied for the estimation of price diffusion models are based on records of individual land sales transactions for arable land from January 1985 to December 2015. The raw data are provided by the committee of evaluation experts in Lower Saxony (*Oberer Gutachterauschuss für Grundstückswerte in Niedersachsen*), which records all land transactions that take place in Lower Saxony. Besides the price of each sold lot, the data set contains its soil quality as a yield index (*Ertragsmesszahl*) and the size in square meters. We use these transaction data to build a balanced panel of quarterly average county prices. For this purpose, we first perform a hedonic regression and model the logarithm of the price per hectare as a linear function of the soil quality, the size, a county-specific fixed effect, and a county-specific linear time trend. The latter two are included to reduce the risk of omitted variable bias. After estimating the regression with all observations, we exclude transactions in which the residuals exceed four standard deviations of the empirical distribution of all residuals. These observations are considered outliers since their prices cannot be explained by their soil quality, size, or location. Then, we re-estimate the model for the new dataset. If the estimated coefficients of soil quality and size are found to be statistically significant, we use them to adjust prices to the overall averages of soil quality and size. Afterwards, the adjusted transactions are averaged for each quarter and each county. In case of missing values for some counties in some quarters, we linearly interpolate and fill longer gaps with annual data from the statistical office of Lower Saxony. This results in a balanced panel dataset of 4,588 quarterly observations, which form the basis of our analysis.

To give a first impression of the spatial relationship of land prices, we apply Moran's I on the adjusted log prices in the first and the last quarter of the observation period. The p-values significantly reject the null hypothesis that prices are randomly distributed in the study area, depicting spatial autocorrelation of land prices in Lower Saxony in the two quarters.

As Figure 2 shows, Moran's I is positive for both quarters, indicating that a higher (lower) price in a county is usually linked to higher (lower) prices in the neighboring area. Since the value for the last quarter is larger than that for the first quarter, this relationship has increased over time. Moreover, the local Moran's I (calculated according to Anselin (1995)) depicts that Cloppenburg, Vechta, and Osnabrück form a high-high cluster in 1985q1, as well as in 2015q4 together with Emsland, Oldenburg, and Bentheim. This once again demonstrates the particular role of the four candidates for the dominant region.

Figure 2. Moran's I indices and scatter plots of adjusted prices in 1985q1 and 2015q4



Note: The black (gray) filled dots indicate counties in a high-high (low-low) cluster according to the local Moran's I.

4 Results

Before we turn to the results of the cointegration analysis and the price diffusion models, we inspect the long-run behavior of the adjusted log prices of arable land. Most counties of Lower Saxony show a clear upward trend over the observed period and ADF tests on the individual quarterly price series confirm the non-stationary price development for 33 out of 37 counties at the 5% significance level. Due to the rather low power of the univariate ADF tests, counties that exhibit a stationary price development (Goslar, Leer, Osterholz, and Wolfenbüttel) are not excluded from the subsequent cointegration analysis.

To confirm that the county prices are cointegrated with their neighbors' average price, which is a precondition for the error correction term in the price diffusion model (4), we test their pairwise cointegration. Table 2 presents the results of the Johansen tests. The trace statistics clearly reject the null hypothesis of no cointegrating relationships for all counties. It is not surprising that there is a long-run connection between land prices in neighboring counties since neighbors often share similar natural conditions and production structures. Thus, economic factors causing a change of land values in one county, such as new technologies, subsidies or increased land demand by financial investors, will likely affect neighboring counties as well.

Cointegration is necessary, but not sufficient to establish the convergence of land prices among neighboring counties. To verify that county prices and average prices in the neighboring area actually converge, we need to further prove that prices are cotrending and that the cointegrating vectors $(1, -\beta_i)$ are equal to $(1, -1)$ (Abbott and De Vita 2013). According to Table 2, there are 14 counties in which land prices converge with their average neighbors' prices. However, this does not imply that prices approach the same level in the long-run, which would be in contrast to the rather heterogeneous price paths reported in Table 1. First, one has to recall that we are analyzing adjusted (homogenized) prices, while Table 1 displays actual prices. Second, for 7 of the 14 counties, we find a significant coefficient δ_i in Table 2. This indicates that adjusted land prices among neighbors are equal up to a constant in the long-run, i.e., the relative “law of one price” holds. Since we analyze log prices, this means that absolute prices have a constant ratio, i.e., they change with the same rate.

Table 2. Pairwise cointegration tests with neighbors

County	Trace statistic	Cointegrating vector $\hat{\boldsymbol{\beta}}_i$	Constant $\hat{\boldsymbol{\delta}}_i$
Ammerland	34.67***	0.901***+	0.962*
Aurich	54.19***	0.686***	2.802***
Bentheim	43.26***	0.757***	2.603***
Celle	41.78***	0.750***	2.282***
Cloppenburg	31.22***	1.121***	-0.956**
Cuxhaven	41.84***	0.771***	2.042***
Diepholz	45.47***	1.151***	-1.654***
Emsland	52.70***	1.035***+	-0.254
Friesland	50.30***	0.768***	2.071***
Gifhorn	45.25***	1.344***	-3.519***
Goslar	35.64***	0.443***	5.353***
Göttingen	38.73***	0.506***	4.712***
Hamelin-Pyrmont	53.74***	0.616***	3.721***
Hanover Region	38.78***	0.831***+	1.929***
Harburg	45.13***	0.739***	2.558***
Heidekreis	57.45***	1.104***+	-1.162***
Helmstedt	49.67***	0.656***	3.095***
Hildesheim	38.98***	0.795***+	2.076***
Holzminden	65.43***	0.762***+	2.003*
Leer	42.74***	0.896***+	0.881
Lüchow-Dannenberg	35.52***	0.857***+	1.033*
Lüneburg	36.99***	0.792***	1.876***
Nienburg	38.89***	1.174***	-1.767***
Northeim	40.85***	0.857***+	1.284
Oldenburg	35.66***	1.026***+	-0.355
Osnabrück	50.43***	0.830***	1.704***
Osterholz	48.54***	0.634***	3.618***
Osterode	40.60***	0.990***+	-0.413
Peine	39.55***	0.591***	4.129***
Rotenburg	46.13***	1.247***	-2.335***
Schaumburg	32.41***	0.522***	4.581***
Stade	46.55***	1.067***+	-0.547
Uelzen	78.55***	0.878***+	1.267*
Vechta	60.88***	0.866***	1.761***
Verden	38.64***	0.862***	1.258***
Wittmund	43.76***	1.075***+	-0.815
Wolfenbüttel	67.25***	0.658***	3.292***

The trace statistic for testing $H_0: r = 0$ vs. $H_1: r \geq 1$was estimated with unrestricted intercepts and restricted trend coefficients; r denotes the number of cointegrating vectors. *, **, and *** denote significance at the 90%, 95%, and 99% level, respectively. + indicates that $\hat{\beta}_{is}$ is not significantly different from 1 at the 99% significance level.

We now proceed to the results of the price diffusion model (4). Since contemporaneous terms $\Delta\bar{p}_{it}$ are included in the model, we test whether this term is weakly exogenous. The Wu-Hausman test statistic is the t-value for testing $H_0: \lambda_i = 0$ in the augmented regression:

$$\Delta p_{it} = \gamma_i + \sum_{l=1}^{L_{ia}} a_{il} \Delta p_{i,t-l} + \sum_{l=0}^{L_{ib}} b_{il} \Delta\bar{p}_{i,t-l} + \phi_i \left(p_{i,t-1} - \delta_i - \beta_i \bar{p}_{i,t-1} \right) + \lambda_i \hat{\varepsilon}_{0t} + \varepsilon_{it}, \qquad (9)$$

where $\hat{\varepsilon}_{0t}$ denotes the residuals of the average prices of neighbors $\Delta\bar{p}_{it}$ regressed by $(\Delta\bar{p}_{i,t-L_{ib}-1}, \Delta\overline{p}_{it}^{S})$, $\overline{p}_{it}^{S}$ are the average prices of the second-order neighbors of region i, and the error correction coefficients are restricted as described above. If the Wu-Hausman test rejects H_0 at the 95% significant level, the variables $(\Delta\bar{p}_{i,t-L_{ib}-1}, \Delta\overline{p}_{it}^{S})$ are used as instrumental variables for $\Delta\bar{p}_{it}$. According to Table 3, this is only the case for Goslar. Moreover, the Breusch-Pagan test rejects error independence at the 95% significance level for all counties with exogenous contemporaneous terms, so that we use seemingly unrelated regressions (SUR) to estimate the system of price equations.

The estimation results for the price diffusion model (4) are shown in Table 3. The adjustment speed coefficients $\hat{\phi}_i$ are all significant and negative, which indicates that land prices move towards the long-run equilibrium with the average prices of their neighbors. The adjustment coefficients amount to 67 percent per quarter on average, which is rather slow compared to agricultural commodity markets, where the adjustment speed is usually higher than 90 percent per quarter (e.g., Wang and William 2007). This finding is not surprising since land is immobile and economic equilibria cannot simply be attained by trading and transport. Adjustment processes in the land market are more complex and are sometimes related to the diffusion of new technologies. For example, Hennig and Latacz-Lohmann (2017) show that the boom in biogas plants have led to an increase in land rental prices in Germany. Moreover, land markets are less liquid compared with commodity markets and information on price changes is processed more slowly. Note that there is regional variation in the adjustment speeds. Smaller absolute values imply a lower impact from the average prices of neighbors. We find that the five counties with the smallest adjustment speeds (Lüchow-Dannenberg 24%, Aurich 31%, Cuxhaven 43%, Cloppenburg 43%, and Göttingen 44%) are located on the state border, with the exception of Cloppenburg. Whereas border counties could also be affected by the price development beyond the border, which is not considered in our analysis, the slow adjustment of Cloppenburg to its neighbors could indicate that Cloppenburg is a dominant region.

Regarding the short-term development of land prices, we find that most of the values for the own lagged effects and some of the neighbors' lagged effects are significant. Most of these effects are negative, which means that short-term deviations are compensated in later periods. About 80 percent of the counties have a significant and positive coefficient b_{i0} for the neighbors' contemporaneous effects, i.e., land price changes in a region will immediately spillover to adjacent counties. Economic drivers of these price changes include, for example, subsidies or regulations that affect land prices in neighboring counties at the same time. To summarize, the evidence for static spatial autocorrelation of land prices within Lower Saxony, which we found from Moran's I, is confirmed in a dynamic context by our price diffusion model.

Table 3. Estimation results for the price diffusion equations with neighboring regions

County	Adjustment speed	Own lagged effects	Neighbors' lagged effects	Neighbors' contemporaneous effect	Wu-Hausman test
Ammerland	-0.714***	-0.144*	-0.219*	0.423***	0.17
Aurich	-0.310***	-0.426***	-0.025	0.192***	0.92
Bentheim	-0.557***	-0.365***	-0.057	0.388**	0.97
Celle	-0.704***	-0.369***	0.101	0.754***	0.57
Cloppenburg	-0.426***	-0.181**	0.004	0.271**	0.20
Cuxhaven	-0.425***	-0.513***	-0.203**	0.177**	0.38
Diepholz	-0.760***	-0.236**	-0.127	0.325***	0.49
Emsland	-0.549***	-0.166*	-0.231***	0.232***	0.03
Friesland	-0.702***	-0.135*	-0.175	0.410***	0.58
Gifhorn	-0.472***	-0.233**	0.023	0.510***	1.56
Goslar	-0.807***	-0.074	0.781*	1.734*	5.69**
Göttingen	-0.433***	-0.368***	-0.015	0.383***	0.57
Hamelin-Pyrmont	-0.722***	-0.183**	–	0.311***	2.03
Hanover Region	-0.764***	-0.151**	–	0.731***	0.44
Harburg	-0.718***	-0.122*	0.305*	0.562***	0.02
Heidekreis	-0.957***	0.154*	-0.405***	0.262**	1.25
Helmstedt	-0.811***	-0.062	-0.114	0.304***	0.72
Hildesheim	-0.573***	-0.068	–	0.157	0.25
Holzminden	-0.912***	-0.180*	–	0.732***	0.04
Leer	-0.710***	–	-0.153	0.842***	0.86
Lüchow-Dannenberg	-0.241***	-0.245***	–	0.088*	0.20
Lüneburg	-0.718***	-0.394***	-0.245*	0.128	0.05
Nienburg	-0.576***	-0.227***	-0.115	0.341***	0.63
Northeim	-0.556***	-0.289***	–	0.291***	0.05
Oldenburg	-0.674***	-0.300***	-0.069	0.387***	0.46
Osnabrück	-0.622***	-0.340***	0.158	0.449***	0.03
Osterholz	-0.871***	-0.178**	-0.513**	-0.172	0.91
Osterode	-0.576***	-0.277**	-0.134	0.313***	0.54
Peine	-0.744***	-0.138	-0.073	0.171	0.45
Rotenburg	-0.443***	-0.351***	-0.155	0.251**	0.13
Schaumburg	-0.774***	-0.151*	-0.048	0.208*	0.33
Stade	-0.685***	-0.170*	0.293**	0.575***	3.19*
Uelzen	-1.247***	-0.158	-0.498**	0.519***	0.14
Vechta	-0.887***	-0.114	-0.270	0.435**	2.69
Verden	-0.519***	-0.275***	-0.089	0.146	0.03
Wittmund	-0.657***	-0.167**	–	0.603***	0.44
Wolfenbüttel	-0.914***	–	-0.446***	-0.127	0.16

The lag-order for each region is selected separately using the Bayesian information criterion using a maximum lag order of four. The reported coefficient for the lagged effects is the value with the lowest p-value. "–" denotes that the lag order equals zero. All regressions include an intercept term. *, **, and *** denote significance at the 90%, 95%, and 99% level, respectively.

To put more structure on the price diffusion process, we now examine whether land prices in Lower Saxony are not only driven by prices in neighboring counties, but also by a dominant region. In this case, land price changes would be unidirectional and ripple out from a center to the periphery. In contrast to studies in the housing market in which large metropolitan areas are a natural candidate for a dominant region, it is not obvious where such a region is located in the agricultural land market of Lower Saxony, if it exists at all. To select a potentially dominant region from the set of 37 counties, we proceed as follows: First, we focus on counties showing the highest land price level and the most pronounced price increase during the observation period. According to Table 1, these are Vechta, Cloppenburg, Emsland, and Oldenburg, i.e., counties that are characterized by intensive livestock production.

Table 4. Cointegration tests with neighbors and a dominant region (Cloppenburg)

County	Cointegrating vector		Trace statistic
	Neighbors $\hat{\beta}_i$	Cloppenburg $\hat{\beta}_{i0}$	
Ammerland	0.493***	0.396***	122.00***
Aurich	0.418***	0.347***	111.85***
Bentheim	0.552***	0.194	133.77***
Celle	0.225*	0.373***	155.52***
Cuxhaven	0.345***	0.371***	144.41***
Diepholz	0.901***	0.201***	164.00***
Emsland	0.395***	0.573***	120.77***
Friesland	0.272**	0.556***	106.86***
Gifhorn	0.768***	0.328***	122.52***
Goslar	0.536***	-0.047	110.03***
Göttingen	0.240**	0.158***	108.63***
Hamelin-Pyrmont	0.277**	0.152***	121.15***
Hanover Region	0.897***	-0.035	116.91***
Harburg	0.441***	0.242**	127.72***
Heidekreis	0.835***	0.181**	126.32***
Helmstedt	0.450***	0.140**	128.16***
Hildesheim	0.589***	0.094**	96.65***
Holzminden	0.673***	0.039	142.70***
Leer	0.879***	0.028	96.48***
Lüchow-Dannenberg	0.380***	0.422***	127.91***
Lüneburg	0.498***	0.223**	150.54***
Nienburg	0.946***	0.146**	119.18***
Northeim	0.497***	0.177***	124.17***
Oldenburg	0.629***	0.381***	139.65***
Osnabrück	0.626***	0.205***	145.78***
Osterholz	0.296	0.269	152.15***
Osterode	0.571***	0.218***	118.46***
Peine	0.616***	-0.015	124.73***
Rotenburg	0.721***	0.383***	138.50***
Schaumburg	0.201**	0.179***	130.10***
Stade	0.590***	0.378***	145.48***
Uelzen	0.860***	0.013	152.82***
Vechta	0.709***	0.165	154.96***
Verden	0.469***	0.319***	126.92***
Wittmund	0.789***	0.287**	114.62***
Wolfenbüttel	0.362**	0.173***	135.57***

The trace statistic for testing H0: r=0 vs. H1: r≥1 was estimated with unrestricted intercepts and restricted trend coefficients; r denotes the number of cointegrating vectors. *, **, and *** denote significance at the 90%, 95%, and 99% level, respectively.

Next, we estimate the pairwise error correction models (Equations (5) and (6)) for these four counties with all other counties in Lower Saxony. The results are presented in Table A1. We expect a dominant region to have significant adjustment speeds ϕ_{i0} and to not have a reverse effect, i.e., ϕ_{0i} are not significant. Appendix 1 reveals that Cloppenburg and Oldenburg pass this test (with one exception in each case). Recalling the previous finding that Cloppenburg has a slow adjustment speed in the price diffusion model (4), we finally select this county as the candidate for a dominant region.

Table 4 depicts the results of the cointegration test for the extended model (8), which allows for joint effects of neighbors and a dominant region. We observe that the coefficient β_{i0} in the cointegrating vector is significant in most, but not all cases, meaning that Cloppenburg contributes significantly to the joint long-run equilibrium. Counties that are influenced by their neighbors, but not by Cloppenburg are either remote from Cloppenburg (Goslar and Uelzen), adjacent to the Netherlands (Leer and Bentheim), or show a very similar production structure (Vechta) so that is remains unclear, which county actually leads or follows in the price diffusion process.

Estimation of the diffusion model (8) follows the same procedure as before, that is, we test for endogeneity and use instruments, if necessary. The results for this model are provided in Table 5. Again, the coefficients $\hat{\phi}_i$ are all significant and negative, which implies a correction towards a long-term equilibrium with neighbors and the dominant region.

It is, however, difficult to disentangle this effect and to separate the contribution of Cloppenburg. Comparing the results with the previous model (4) shows that the inclusion of Cloppenburg has increased the absolute value of the coefficients $\hat{\phi}_i$ on average, i.e., the observed adjustment is faster now. Regarding the short-run effects, we find that Cloppenburg has a significant impact on land prices only in a few counties. Spillover effects can be measured for some neighboring counties, e.g., Emsland and Oldenburg.

Overall, the contemporaneous effects of neighbors seem to be more relevant. We conclude that Cloppenburg cannot be clearly characterized as a dominant region and ripple effects are less pronounced in land markets compared with real estate markets. This finding can be explained by differences in the underlying economic mechanisms, which drive price diffusion. While in housing markets migration plays a central role for the emergence of ripple effects, it hinges on the mobility of farmers in case of farmland; the latter is restricted by transport costs, as well as natural and legal conditions.

Table 5. Estimation results of regional price diffusion equations with neighbors and a dominant region Cloppenburg

County	Adjustment speed	Own lag effects	Neighbor lag effects	Cloppenb. lag effects	Neighbors' contemp. effect	Cloppenb. contemp. effect	Wu-Hausman test
Ammerland	-0.682***	-0.160**	-0.137	-0.050	0.253**	0.090	1.24
Aurich	-0.520***	-0.298***	-0.004	-0.054	0.202***	-0.051	0.05
Bentheim	-0.555***	-0.353***	-0.064	0.077	0.329**	0.015	0.09
Celle	-0.939***	-0.158**	0.164	-0.078	0.589***	0.279**	0.03
Cuxhaven	-0.544***	-0.395***	-0.196**	-0.231**	0.105	0.094	0.01
Diepholz	-0.799***	-0.192**	-0.103	-0.081	0.259**	0.088	0.39
Emsland	-0.713***	0.090	-0.110**	-0.194***	0.107**	0.146**	0.02
Friesland	-0.936***	-0.081	-0.108	0.039	0.251**	0.213	0.14
Gifhorn	-0.794***	-0.069	-0.036	-0.233***	0.435***	-0.027	1.43
Goslar	-0.708***	-0.162*	0.181	0.043	0.180	-0.171	1.25
Göttingen	-0.537***	-0.327***	-0.034	0.094	0.306***	0.096	0.04
Hamelin-Pyrmont	-0.808***	-0.105	–	-0.134	0.033	-0.053	0.00
Hanover Region	-0.805***	-0.072	–	0.567***	0.381	0.870**	11.34***
Harburg	-0.769***	-0.114	0.306*	-0.194	0.412**	-0.136	0.25
Heidekreis	-0.915***	-0.093	-0.382***	0.062	0.080	0.159*	3.57*
Helmstedt	-0.856***	-0.031	-0.074	-0.074	0.194**	-0.101	0.04
Hildesheim	-0.661***	0.002	–	0.058	0.179	-0.047	0.06
Holzminden	-0.785***	-0.211**	–	-0.117	0.623***	0.190	0.32
Leer	-0.703***	–	-0.141	-0.103	0.566***	0.303	0.27
Lüchow-Dannenberg	-0.426***	-0.150*	–	-0.073	0.045	-0.060	0.16
Lüneburg	-0.729***	-0.392***	-0.192	-0.114	0.029	0.040	0.63
Nienburg	-0.585***	-0.262***	-0.166	0.072	0.130	0.054	0.29
Northeim	-0.657***	-0.232***	–	-0.103	0.190**	0.050	2.20
Oldenburg	-0.694***	-0.285***	0.083	-0.213**	0.289**	0.050	1.05
Osnabrück	-0.652***	-0.304***	0.052	0.097	0.346***	0.105	0.27
Osterholz	-0.852***	-0.196***	-0.462**	0.081	-0.453**	0.146	0.45
Osterode	-0.676***	-0.206***	-0.144	-0.140	0.292**	0.200*	1.16
Peine	-0.760***	-0.119	-0.111	0.008	0.127	0.130	0.34
Rotenburg	-0.532***	-0.298***	-0.131	0.030	0.150	0.103	1.97
Schaumburg	-0.823***	-0.182*	-0.012	-0.215*	-0.055	-0.301	4.01**
Stade	-0.815***	-0.073	0.306**	-0.056	0.415**	0.064	0.09
Uelzen	-1.274***	-0.099	-0.510***	-0.004	0.464**	0.007	0.24
Vechta	-0.891***	-0.095	-0.182	-0.101	0.405***	-0.022	1.69
Verden	-0.636***	-0.231***	-0.147	0.031	0.027	0.052	1.63
Wittmund	-0.637***	-0.177**	–	-0.144	0.432***	0.232	1.30
Wolfenbüttel	-0.945***	–	-0.433***	-0.159	-0.279**	0.000	0.02

The lag-orders for each region is selected separately using the Bayesian information criterion using a maximum lag order of four. The reported coefficient for the lagged effects is the value with the lowest p-value. "–" denotes a lag order zero. All regressions include an intercept term. *, **, and *** denote significance at the 90%, 95%, and 99% level, respectively.

5 Conclusions

Politicians and other stakeholders in agriculture are concerned about the recent surge in farmland prices that can be observed in many parts of the world. While this price increase is rather unambiguous on an aggregate level, the development of land prices is more subtle and differentiated on a regional level. Our case study from Germany documents that state land prices may grow with different rates even within a country or a state. Notably, despite extant empirical work on explaining the determinants of farmland price levels, detailed analyses on the spatial development of land prices on a regional level are rare. We contribute to this research by employing a price diffusion model that combines features of market integration models and spatial econometric models. This approach identifies long-run equilibrium relationships among local land markets and separates short- and long-run price transmission. An application of this model to farmland prices in the state of Lower Saxony shows that prices on a county level are in fact cointegrated, i.e., linked by long-run equilibria. However, this does not imply that land prices in all counties necessarily converge to the same level or a constant difference even after adjusting for quality differences. This result confirms earlier findings by Yang et al. (2017) that local land markets may exhibit distinct convergence clubs. Not surprisingly, the adjustment rates that we measure are smaller compared with commodity markets and similar to those of other real estate markets. In some cases, apart from convergence towards a long-run equilibrium, we find that price transmission also takes place through short-term adjustments caused by neighboring regions.

A modification of the price diffusion model allowed us to examine whether some regions dominate others in the sense that price diffusion is unidirectional, i.e., that price shocks spillover from dominant to neighboring regions, but not vice versa. We found that Cloppenburg, a center of intensive livestock production in Germany, actually mimics some of these behaviors. The region around Cloppenburg (including Vechta) is in the focus of agricultural policy due to severe environmental problems that industrialized hog finishing and poultry farms entail. In the aforementioned regions, more than every second measurement in 2012 found an exceedance of the critical nitrate value defined by the Drinking Water Ordinance (NLWKN, 2015). In response to these environmental problems, regulations have been put in place that aim at capping livestock density. In turn, the demand for land to dispose manure drove up farmland prices. Our results show that this shift of land prices in livestock-intense regions partly passed through to other regions. On the other hand, high farmland prices constitute a centripetal force that inhibits further concentration of livestock production in these regions.

In view of the recent land price surge, many EU countries have implemented price monitoring systems to increase transparency of price formation on farmland markets. Our results support this task, since knowledge of this diffusion process can be useful to predict how price changes in local land markets will affect neighboring regions. So far, our analysis targets the identification of patterns in farmland price diffusion. It is, however, rather silent about the economic forces that cause these patterns. Thus, a natural step towards a more comprehensive understanding of the spatial dynamics of land prices would be the inclusion of covariates, such as interest rates, land rental prices, or structural variables that characterize local economic activities.

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Appendix

Table A1: Pairwise error correction models for dominant counties

County	Cloppenburg		Vechta		Emsland		Oldenburg	
	ϕ_{i0}	ϕ_{0i}	ϕ_{i0}	ϕ_{0i}	ϕ_{i0}	ϕ_{0i}	ϕ_{i0}	ϕ_{0i}
Ammerland	-0.613***	-0.004	-0.601***	-0.004	-0.736***	-0.004	-0.565***	-0.012
Aurich	-0.419***	-0.002	/	/	-0.503***	-0.003	/	/
Bentheim	-0.757***	-0.002	-0.627***	-0.025	-0.756***	-0.008	-0.693***	-0.001
Celle	-1.024***	-0.002	-0.840***	-0.002	-1.027***	-0.001	-1.046***	-0.002
Cloppenburg	–	–	-0.505***	-0.016	-0.452***	-0.052**	-0.349***	-0.034
Cuxhaven	-0.617***	-0.001	-0.601***	-0.007	-0.557***	-0.003	/	/
Diepholz	-0.399***	-0.023	-0.231***	-0.032	-0.446***	-0.028	-0.327***	-0.037
Emsland	-0.451***	-0.021	-0.212**	-0.194***	–	–	-0.276***	-0.048*
Friesland	-0.914***	-0.001	-1.086***	0.003	-0.937***	0.003	-0.789***	-0.001
Gifhorn	-0.609***	-0.002	-0.618***	-0.002	-0.700***	0.000	-0.573***	-0.002
Goslar	-0.725***	0.000	-0.798***	0.003	-0.721***	0.002	-0.702***	0.000
Göttingen	-0.650***	0.001	-0.545***	0.000	-0.656***	0.001	-0.632***	0.000
Hamelin-Pyrmont	-1.009***	0.000	-0.879***	0.003	-0.970***	0.003	-0.932***	0.001
Hanover Region	-0.640***	0.000	-0.688***	0.001	-0.652***	0.000	-0.670***	0.000
Harburg	-0.840***	-0.001	-0.658***	-0.008	-0.958***	0.000	-0.864***	-0.001
Heidekreis	-0.613***	-0.005	-0.564***	-0.005	-0.694***	-0.001	-0.570***	-0.001
Helmstedt	-0.727***	0.000	-0.720***	0.000	-0.737***	0.001	-0.676***	-0.001
Hildesheim	-0.507***	0.000	-0.437***	0.000	-0.473***	0.000	-0.435***	0.000
Holzminden	-0.859***	0.000	-0.926***	0.000	-0.912***	0.002	-0.968***	0.002
Leer	-0.586***	0.000	-0.531***	-0.004	-0.639***	0.000	-0.590***	-0.004
Lüchow-Dannenberg	-0.434***	-0.002	/	/	-0.392***	-0.011	-0.400***	-0.002
Lüneburg	-0.666***	0.000	-0.650***	0.001	-0.680***	0.001	/	/
Nienburg	-0.400***	-0.004	-0.349***	-0.017	-0.458***	-0.006	-0.348***	-0.005
Northeim	-0.566***	0.000	/	/	-0.561***	0.001	-0.519***	0.000
Oldenburg	-0.562***	0.461***	-0.386***	0.398***	-0.641***	0.645***	–	–
Osnabrück	-0.597***	-0.016	-0.426***	-0.036	-0.586***	-0.044**	-0.538***	-0.013
Osterholz	-0.797***	0.000	-0.798***	-0.003	-0.790***	0.000	-0.838***	0.000
Osterode	-0.581***	0.000	-0.535***	0.000	-0.588***	0.000	-0.579***	0.000
Peine	-0.614***	0.002	/	/	-0.643***	0.002	-0.580***	0.001
Rotenburg	-0.425***	-0.003	-0.186**	-0.036	-0.499***	-0.011	-0.452***	-0.011
Schaumburg	-0.829***	0.001	-0.708***	-0.001	-0.712***	0.001	-0.763***	0.000
Stade	-0.801***	-0.009	-0.647***	-0.025	-0.778***	-0.002	-0.681***	-0.002
Uelzen	-1.166***	-0.001	-1.225***	0.000	-1.204***	0.000	-1.125***	0.000
Vechta	-0.832***	-0.018	–	–	-1.195***	-0.002	-0.587***	-0.006
Verden	-0.576***	-0.004	-0.526***	-0.019	-0.594***	-0.016	-0.503***	-0.005
Wittmund	-0.587***	-0.001	/	/	-0.661***	0.001	-0.543***	-0.002
Wolfenbüttel	-0.871***	0.000	-0.764***	0.001	-0.854***	0.000	-0.813***	0.000

“/” denotes that there is no cointegration relationship between candidates and other counties. *, **, and *** denote significance at the 90%, 95%, and 99% level, respectively.