

Grau, Aaron; Jasic, Svetlana; Ritter, Matthias; Odening, Martin

Working Paper

The impact of production intensity on agricultural land prices

FORLand-Working Paper, No. 09 (2019)

Provided in Cooperation with:

DFG Research Unit 2569 FORLand "Agricultural Land Markets – Efficiency and Regulation",
Humboldt-Universität Berlin

Suggested Citation: Grau, Aaron; Jasic, Svetlana; Ritter, Matthias; Odening, Martin (2019) : The impact of production intensity on agricultural land prices, FORLand-Working Paper, No. 09 (2019), Humboldt-Universität zu Berlin, DFG Research Unit 2569 FORLand "Agricultural Land Markets - Efficiency and Regulation", Berlin, <https://doi.org/10.18452/20103>

This Version is available at:

<https://hdl.handle.net/10419/213063>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

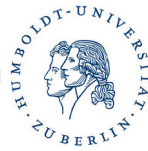
Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/3.0/de/>



FORLAND



The Impact of Production Intensity on Agricultural Land Prices

Aaron Grau, Svetlana Jasic, Matthias Ritter,
Martin Odening

FORLand-Working Paper 09 (2019)

Published by

DFG Research Unit 2569 FORLand, Humboldt-Universität zu Berlin
Unter den Linden 6, D-10099 Berlin
<https://www.forland.hu-berlin.de>



Tel +49 (30) 2093 46845, Email gabriele.wuerth@agrار.hu-berlin.de

Agricultural Land Markets – Efficiency and Regulation

The Impact of Production Intensity on Agricultural Land Prices

Aaron Grau *, Svetlana Jasic **, Matthias Ritter ***, Martin Odening ****

May 2019

Abstract

This paper is one of the first attempts to utilize the theoretical framework of the new economic geography for explaining agricultural land prices. We adopt a model proposed by Pflüger and Tabuchi (2010), which allows to consider land as a production factor. We derive a short-run equilibrium that relates land rental prices to production intensity. The latter is measured as labor intensity, i.e., the ratio of labor cost and land used for agricultural production and additionally by livestock density. The model is applied to the agricultural sector in West Germany using county level price and cost data of the FADN. A spatial lag model clearly rejects the null hypothesis of no impact of labor and livestock intensity on land rental prices.

Keywords: New economic geography, agglomeration, production clusters, Germany

JEL codes: O41, Q11, R12

Acknowledgements

Financial support from the German Research Foundation (DFG) through Research Unit 2569 “Agricultural Land Markets – Efficiency and Regulation” (www.forland.hu-berlin.de) is gratefully acknowledged.

* Aaron Grau, aaron.grau@hu-berlin.de

** Svetlana Jasic, svetlana.jasic@hu-berlin.de

*** Matthias Ritter, matthias.ritter@agrار.hu-berlin.de

**** Martin Odening, martin.odening@agrار.hu-berlin.de

All authors are at Humboldt-Universität zu Berlin, Faculty of Life Sciences, Department of Agricultural Economics, Unter den Linden 6, D-10099 Berlin.

1 Background and Motivation

The recent surge of agricultural land prices in many parts of the world has triggered intensive research about the reasons for this development. Several strands of literature can be distinguished. First, hedonic pricing models are employed that include potential drivers of farmland values or rental prices, such as biogas production (e.g., Hennig and Latacz-Lohmann 2016), livestock density (Huang et al. 2006; Lehn and Bahrs 2018), the engagement of financial investors (Hüttel et al. 2016), or competing forces of non-agricultural use, e.g., urban pressure (Goodwin et al. 2003). Within this framework, land price changes are explained by changes in price determinants. The second strand of literature rests on the present value approach of asset pricing. The focus here is the inspection of time series properties of sale and rental prices and the relation between both of them. Falk (1991) and more recently Olsen and Stokes (2015) use this approach to identify speculative bubbles in agricultural land prices. Plogmann et al. (2018) decompose the rent-price ratio of land into expectations of rent growth, real interests, and a land premium. For Germany, they show that growing farmland values in the last decade can be traced back to a great extent to decreasing interest rates.

Most of the aforementioned literature considers land price developments on a highly aggregated regional scale. This, however, ignores the pronounced spatial heterogeneity that characterizes the evolution of agricultural land prices. In Germany, for example, the average land rent increased by 36.5% from 183 €/ha in 2007 to 288 €/ha in 2016 while at the federal state level, growth rates vary between 8.2% for the Saarland and 96.0% for Mecklenburg-Vorpommern (Statistisches Bundesamt 2018). Differences in growth rates may reflect convergence processes of unequal prices, but this seems not to be the case here: rental prices in some federal state in Germany rather diverge in absolute and relative terms. This is striking, since though land is immobile, one would expect that mobility of farmers and capital will equate land prices heterogeneity across space (Waight 2018).

Empirical applications that analyze the spatial heterogeneity of land price dynamics are rare. So far, the development of land prices and rents as well as their differences across space and time have been primarily investigated separately in the agricultural economics literature. However, a few exceptions exist. Carmona and Roses (2012) apply panel unit root tests to explore the convergence of farmland prices in Spanish provinces at the beginning of the 20th century. They find that the Spanish land market is spatially integrated and interpret this finding as an indicator of land market efficiency. Using a price diffusion model proposed by Holly et al. (2010), Yang et al. (2019) provide evidence that land markets are integrated in the long-run and price developments are transmitted from county to county in the German federal state of Lower Saxony. Grau et al. (2018) confirm spatial integration of land markets on a county level, but identify the former German border as an obstacle to spatial land price diffusion. Yang et al. (2017) identify three regional “convergence clubs” in Lower Saxony (Germany) that are characterized by similar land price dynamics. These regions represent distinct production areas including the high priced livestock intensive production area in the mid-western part, mid-priced dairy farms in the north-eastern part, and lower priced less specialized production cluster in the eastern part of Lower Saxony. Within these regions, land prices converge in the long run while the price gap between booming and stagnating counties increases over time in

absolute and relative terms. The findings of Yang et al. (2017) suggest that land price development is related to the intensity of agricultural production.

The observed spatial heterogeneity of land price developments calls for an economic explanation. Unfortunately, the aforementioned spatio-temporal models are reduced-form models that primarily aim at identifying statistical properties of times series, such as co-integration, co-trending, and convergence. Common factors that drive land prices in all spatial units can be included into these models, but they do not offer an explanation for the divergence of land prices (Holly et al. 2010). Moreover, the specification of common factors is often ad hoc and lacks a clear theoretical justification. Against this backdrop, the main objective of this paper is to explore whether models related to new economic geography (NEG) are useful for explaining regional heterogeneity of agricultural land price dynamics.

In general terms, NEG models target at rationalizing heterogeneity of economic activities across space. The main explanation for the uneven spatial distribution is that firms as well as workers benefit from concertation in certain areas, the so-called agglomeration, through technology spillovers or more variety in consumption, the so-called centripetal forces (Rossi-Hansberg 2005). The concentration processes, loosely spoken lead to a scarcity of factors, in particular of immobile factors. The higher trade costs are between economic regions, the more immobile factors appear, and the relative price differential increases. Scarcity and resulting higher factor prices in an agglomeration lead to the so-called centrifugal forces that foster dispersion in space, where factor prices are lower. Early NEG models assume a (partially) immobile factor, e.g., unskilled farm workers (Krugman 1991) or prohibitive trade levels with heterogeneous migration costs (Tabuchi and Thisse 2002; Murata 2003). However, in the long-run, there is only one immobile factor, land. Helpman (1998) and Pflüger and Tabuchi (2010) were the first to develop NEG models that use land as the immobile factor. In particular the latter work of Pflüger and Tabuchi provides a framework that allows the appraisal of (agricultural) land values as an outcome of centripetal and centrifugal economic forces.

Given the scope of this theoretical framework, it is somewhat surprising that only few empirical applications of NEG theory exist so far (Redding 2010). Most empirical applications are based on Helpman (1998) with land used solely for consumption and they focus on prices for office space, housing, or real estate (e.g., Ahlfeldt et al. 2015; Dekle and Eaton 1999; Hanson 2005; Kosfeld et al. 2008). Though the potential of NEG models for explaining production agglomeration in the agricultural sector has already been pointed out by Lippert (2006), to the authors' best knowledge only one empirical study involves agricultural land prices. Donaldson and Hornbeck (2016) investigate the impact of the historical expansion of the railroad network in the USA on the agricultural sector over the period 1870 to 1890 and show that the overall impact on each location can be captured in terms of its market access. The objective of our paper is to address this research gap and to investigate whether NEG models are helpful in understanding the relationship between land prices on the one hand and production intensity and agglomeration in agriculture on the other hand. To this end, we adopt the NEG model proposed by Pflüger and Tabuchi (2010) and interpret it in terms of agricultural production. We derive testable hypotheses about the relation between land prices and production intensity in agriculture. We use this framework to estimate regional land price equations for 261 counties in West Germany. A clear understanding of the drivers of agricultural land prices is informative for the current discourse on the necessity to tighten land market regulations: If high land prices

in agricultural production hot spots simply reflect the benefits from production agglomeration, this would question the narrative of excessive speculation by financial investors or at least constitute an alternative explanation pattern for increasing land prices.

The remainder of this paper is structured as follows. In Section 2, we introduce an NEG model that serves a theoretical foundation of our empirical analysis. More specifically, we derive a short-run equilibrium equation for the agricultural land rental price. Section 3 describes the study region and the available data set. Section 4 details the econometric approach and presents the results of the regression analysis. Section 5 concludes and derives some policy implications.

2 Theoretical Model

The agricultural sector has been an explicit part of NEG models from the outset. The standard core-periphery model of Krugman (1991) rests on the assumption that consumers use two types of products, manufactured and agricultural ones, in various varieties. Labor for manufactured goods is assumed to be mobile while agricultural workers are immobile and so is agricultural production. Krugman does not consider any congestion effects due to the scarcity of a fixed resource, such as land, but explains core and periphery equilibria through the level of transportation costs, the share of manufacturing in income, and the size of economies of scale in manufacturing. Helpman (1998), on the other hand, substitutes the tradeable agricultural good of the Krugman model with a non-tradeable good. He uses housing as an example, but this can be substituted by any immobile factor that is consumed by workers and leads to congestion costs (Redding and Sturm 2008).

Since we want to investigate regional concentration of agricultural production, we use the Helpman (1998) model as a starting point. We apply an extended version proposed by Pflüger and Tabuchi (2010), who allow land not only to be used for final consumption but also as a production factor. Our model is a special case where land is used for production only. From this model, we derive an empirical land price equation. Other model components resemble common NEG models, e.g., the Dixit-Stiglitz approach of monopolistic competition and iceberg transportation costs. Iceberg transportation costs do not solely comprise of physical transport costs, but also can incorporate informational, sales and support processes and even trade barriers (Puga 1999). At first glance, the assumption of monopolistic competition appears unrealistic in the agricultural sector since agricultural output in its unprocessed state is rather homogenous. However, it can be argued that distance between producers and consumers as well as certain consumer preferences can create heterogeneity in the agricultural product, e.g., “fresh” or “local”, even though the product is at the moment of production the same. Furthermore, the homogenous product case is a special case of the monopolistic framework, where the elasticity of substitution approaches zero the less differentiated the products are.

At this point, one may cast doubt that the premise of labor mobility, which underlies the Helpman model, is reasonable for describing agglomeration and dispersion in the agricultural sector. In developed economies, agricultural production is typically organized by family farms. These farms as well as the associated family workers are mostly stationary and this seems to contradict the assumption of mobile workers. However, when studying long-run effects, structural adjustment processes come into play. Though it is hard to imagine that farmers move

from one region to another, a similar effect results from entry and exit decisions of farms in the course of generational change. Apart from that, an increasing share of non-family workers facilitates regional labor mobility in agriculture.

In what follows, we outline the details of our model for a simplistic two-region case. The economy consists of two regions, region i and region k . In a multi-region model, k can represent all other regions but region i , and is a spatially weighted average of these.

Preferences and Demand

Consumer preferences are assumed to be of constant elasticity of substitution (CES) type:

$$U_i = C_i, \quad (1)$$

where C_i denotes a consumption index of differentiated products in region i . We assume Dixit-Stiglitz monopolistic competition, thus every firm produces one variety. Consequently, n_i equals the number of firms but also varieties of manufactured products in region i . Consumer demand is then

$$C_i = \frac{Y_i}{G_i} = \left(\int_0^{n_i} C_{ij}^i \frac{\sigma-1}{\sigma} dj + \int_0^{n_i} C_{ij}^k \frac{\sigma-1}{\sigma} dj \right)^{\frac{\sigma}{\sigma-1}} \quad (2)$$

$$\text{with } C_{ij}^k = Y_i p_{ij}^{k-\sigma} G_i^{\sigma-1}$$

Herein, C_{ij} is region i 's consumption of variety j , $\sigma > 1$ is the elasticity of substitution between the varieties, and p_{ij} is the price of variety j produced. The superscript indicates the originating region. Consumer prices p are the same as producer prices \hat{p} for products that are produced in the same region ($p_{ij}^i = \hat{p}_{ij}^i$), while iceberg trade costs $\tau \geq 1$ apply to products from other regions and hence $p_{ij}^k = \tau * \hat{p}_{ij}^k$ for imported products. G_i is a CES price index defined as

$$G_i = \left(\int_0^{n_i} p_{ij}^i 1-\sigma dj + \int_0^{n_k} p_{ij}^k 1-\sigma dj \right)^{\frac{1}{1-\sigma}} \quad (3)$$

and Y_i represents regional income, which consists of wages and a land rent:

$$Y_i = w_i L_i + (r_i S_i + r_k S_k) \frac{L_i}{L_i + L_k} = \int_0^{n_i} p_{ij}^i C_{ij}^i dj + \int_0^{n_i} p_{ij}^k C_{ij}^k dj, \quad (4)$$

where w_i and r_i denote wage rate and land rate, respectively. S_i and L_i represent the endowments of region i with land and labor. Following Helpman (1998), it is assumed that land is equally owned by individuals. Hence, income from land rent in region i is determined by the region's worker share in the worker sum of the entire economy. Since income has to equal

consumption, region i 's income also equals the total consumption of all varieties produced within the region or imported at consumer prices.

Production

Each product variety j is produced under increasing returns to scale with two inputs, labor and land. Assuming a Cobb-Douglas technology, the total costs for each variety can be written as:

$$TC_{ij} = w_i^{1-\beta} r_i^\beta q_{ij} + a w_i^{1-\gamma} r_i^\gamma \quad (5)$$

β and γ are the share of land in variable costs and in fixed costs, respectively. In the context of agricultural production, fixed costs for land may accrue from land for buildings, while variable costs are related to the extension of production, e.g., land for manure deposition or simply for cereal or fodder production. q_{ij} is the output of product variety j in region i and a is the fixed factor input. Under monopolistic competition, profit maximization implies markup pricing, i.e., producer prices exceed marginal costs by constant mark-ups and are given by:

$$\widehat{p}_{ij} = \frac{\sigma}{\sigma - 1} w_i^{1-\beta} r_i^\beta \quad (6)$$

These prices together with free market entry of firms imply that fixed costs consume all profits. Consequently, firms earn zero profits.

$$w_i^{1-\gamma} r_i^\gamma = \frac{\widehat{p}_{ij} q_{ij}}{\sigma a} \quad (7)$$

Short-Run Equilibrium

A short-run equilibrium, in which not only land endowment S_i but also labor allocation L_i across regions are fixed, is characterized by market clearing on product markets, labor markets, and land markets (Krugman 1991). Following Pflüger and Tabuchi (2010) and considering the special case that land is only used for production, a land and labor market clearing implies

$$S_i = a(\gamma + \beta(\sigma - 1)) n_i \left(\frac{r_i}{w_i} \right)^{\gamma-1} \quad (8)$$

$$L_i = a[(1 - \gamma) + (1 - \beta)(\sigma - 1)] n_i \left(\frac{r_i}{w_i} \right)^\gamma \quad (9)$$

Using the market clearance equations (8) and (9), all endogenous variables r_i , n_i , and Y_i can be expressed through the fixed variables S_i and L_i , the local wage rate, and parameters of technology and preference.

$$r_i = \frac{\gamma + \beta(\sigma - 1)}{\sigma - (\gamma + \beta(\sigma - 1))} \frac{L_i}{S_i} w_i \quad (10)$$

$$n_i = \left(\frac{\gamma + \beta(\sigma - 1)}{\sigma - (\gamma + \beta(\sigma - 1))} \frac{L_i}{S_i} \right)^{-\gamma} L_i [a((1 - \gamma) + (1 - \beta)(\sigma - 1))]^{-1} \quad (11)$$

$$Y_i = \left(1 + \frac{\gamma + \beta(\sigma - 1)}{\sigma - (\gamma + \beta(\sigma - 1))} \right) w_i L_i \quad (12)$$

Thus, the price of land depends on the labor input per land (labor intensity), the wage rate, as well as the share of land in variable and fixed costs and the elasticity of substitution. Since the shares and elasticity of substitution is assumed to be equal across regions, differences in local land price only depend on the wage rate as well as labor intensity. Labor intensive production regions with low wage rates will report similar land prices as labor extensive production areas with high wage rates. Regions with high land prices should thus be characterized by high labor intensity and high wage rates. The number of firms and so the number of varieties does not depend on income or the wage rate, but only on the amount of population and endowment of land. Income, in turn, is a function of the total labor costs.

The Long-Run Equilibrium

In a long-run equilibrium, the assumption of fixed labor supply is relaxed and workers are allowed to move across regions. Due to their utility maximization behavior, free mobility of workers, over a longer period, implies that workers will move to the county that grant them the highest level of utility. In equilibrium, utility levels of counties are equalized. In equilibrium, the nominal wage of region i equals the average utility of workers across counties times the price index in each county. Hence, a stable equilibrium is reached if the real wage rate ω , the determining factor of their utility, is equal across all regions so that workers do not have an incentive to relocate (Donaldson and Hornbeck 2016; Redding and Sturm 2008).

$$\frac{w_i}{G_i} = \frac{w_k}{G_k} = \omega \quad (13)$$

Pflüger and Tabuchi (2010) report from their numerical simulation that full agglomeration, i.e., all workers live in one region, is not a stable equilibrium. A very high productivity in the depopulated region will always be an incentive to relocate for workers and compensate them for the lack of choice. Rather a bell-shaped curve of spatial development emerges. This is contrary to the findings of Helpman (1998), when land is only used for consumption instead of solely production. Holding all other parameters constant, prohibitive trade costs will lead to the strongest expressions of agglomeration. The more transportation costs are lowered, the more dispersed the population and economic activities are, ranging from partial agglomeration to dispersion across space. Which of these equilibria emerges, depends on the strength of countervailing forces. Centripetal forces result from a greater variety of goods that is accompanied by a declining price index (cf. eq. (2), price index effect). Also, market size and firm profits (and thus factor incomes) increase if workers move into a region. On the other hand, agglomeration comes along with higher competition on product and factor markets. Land as an immobile production factor works as a congestion force, in particular.

From the real wage equilibrium condition (13), a long-run equilibrium for the relationship of the land rent prices in region i can be deduced. By solving (10) for the nominal wage and substituting into (13) the nominal local wages can be expressed by the local land rents and the labor-land-ratios.

$$r_i = \frac{G_i}{G_k} \frac{L_k}{S_k} r_k = \frac{w_i}{w_k} \frac{L_k}{S_k} r_k \quad (14)$$

In contrast to the short-run equilibrium, which is only affected by local factor allocation and prices, the long-run nominal land rent price of region i is influenced by the prices and factor intensity in other regions. Thus, the interdependencies between the different economies are present in (14). Assuming regions are initially equally endowed with the production factors and keeping the dynamics of labor mobility in mind, a growing agglomeration of agricultural production would lead to relative scarcity of local labor and land. Scarcity leads to higher wages and land rents. Higher wages, in turn, attract more workers, until utilities and real wages are equalized across regions. Land, however, remains immobile and its quantity fixed (Caliendo et al. 2018). As a result, the labor intensity per area would increase. Overall, production structures with high labor and low land input requirements should emerge in agglomerated areas plagued by high land rents.

3 Study Region and Data

We use (West) Germany as a study region for our empirical analysis. Germany is the third largest agricultural producer in the European Union (13.5% of the standard output generated by agriculture) behind France (16.9%) and Italy (14.2%, all 2016). With 16.7 million ha, it holds the third largest share of utilized agricultural area in the European Union (total: 173 million ha) behind France (27.8 million ha) and Spain (23.2 million ha, all 2016). Moreover, Germany is the largest producer of pig meat (23.3%) and raw milk (19.2%) in the EU and holds significant shares for other products as well, e.g., root crops (23.1%) or bovine meat (14.4%) (Eurostat 2018).

At the same time, agricultural production in Germany is characterized by considerable regional heterogeneity. Livestock production is concentrated in the northwest (Lower Saxony, North-Rhine-Westphalia) and southeast (Bavaria) (Bäurle and Tamásy 2012), whereas vegetable production is mostly located in North-Rhine-Westphalia, Rhineland-Palatinate and Lower Saxony (Klockgether et al. 2016). Wine and hop production form clusters in the south (Lippert 2006, BMEL 2018). Cereals are produced in most parts of West Germany, but maize only in the northwest and southeast (BMEL 2018).

Some of the observed production agglomerations can be well explained by traditional location theory. Wine production in the Rhine area, for example, is facilitated by favorable climatic and natural production conditions, dairy production in Schleswig-Holstein by a comparative advantage of fodder production and vegetable production in the proximity of large cities by transportation costs. These explanation, however, do not hold for other production clusters, such as hog and poultry production in Lower Saxony and North Rhine Westphalia, vegetable production in Rhineland-Palatinate, or hop production in Bavaria.

The regional heterogeneity is also reflected in the rental and sales prices for agricultural land in the federal states: Rental prices for agricultural land are considerably higher in Lower Saxony (460 €/ha in 2016), North Rhine Westphalia (452 €/ha), Schleswig-Holstein (428 €/ha),

and Bavaria (338 €/ha) compared to the average rental price in whole Germany of 288 €/ha in 2016 (Statistisches Bundesamt 2018). The sales prices of agricultural land for these four federal states are also the highest in Germany in 2016 (Bavaria 51,945 €/ha, North Rhine Westphalia 44,531 €/ha, Lower Saxony 32,012 €/ha, and Schleswig-Holstein 27,101 €/ha) and significantly outreach the average for whole Germany of 22,310 €/ha (Statistisches Bundesamt 2018). These numbers already provide a first impression that higher prices can be found in states that are represented by strong production clusters.

For our econometric analysis, we use data from the Farm Accountancy Data Network (FADN) for 261 West German counties (NUTS 3 level) in 2011. We chose this regional scale, because it is a reasonable compromise between data availability and the desire to identify production agglomerations. Based on national surveys, FADN collects accountancy data for representative farmers. Though FADN data are not designed for statistical analysis on a disaggregated regional level, we resort to this source because it includes all required variables, particularly rental prices, wages, and expenses for livestock production. Alternative data sources, such as the agricultural census, cover only some of these variables. Due to the lower representability of the FADN data in East German, we focus on West Germany excluding the city states Bremen and Hamburg. In 2011, the sample consists of 6,471 farms. The farms are not evenly distributed among counties and in some cases, county averages are based only on a few farms. The data set includes information about the rent paid for the land, size of the rented agricultural area, wages paid, labor input, and livestock costs of the farms. Information about the soil quality of the land sold in 2011 is taken from Statistische Berichte (2012). This soil quality index indicates the potential productivity of land due to natural and climatic conditions and can take maximal value of 120 points.

To arrive at the final data set, some assumptions and data processing are required. Firstly, we assume that wages paid for hired labor also reflect the cost of family labor. This is important because 57% of the labor input of the farms in 2010 is provided by members of the farm household, for which labor costs are not observed (Statistisches Bundesamt 2012). In our dataset, about 40% of the labor input is represented by unpaid labor. Likewise, we assume that observed land rental prices reflect the value of leased land as well as of owned land. Land is defined as utilized agricultural area and includes arable land as well as grassland. Second, missing values are replaced by the mean of the variables observed in neighboring counties. This interpolation was applied to derive the wage level in 25 counties. Third, due to the low number of observations in some counties, the data set is vulnerable to outliers. As an outlier correction, we remove observations below the 1st percentile and above the 99th percentile for the variables land rental price, wage level, and labor intensity. The outlier removal is conducted for each state separately to take into account differences among states. The variables are then derived as averages of farms observed within a county. Moreover, we restrict our analysis to counties with at least two farms in the data set. Descriptive statistics of the final data set are reported in Table 1.

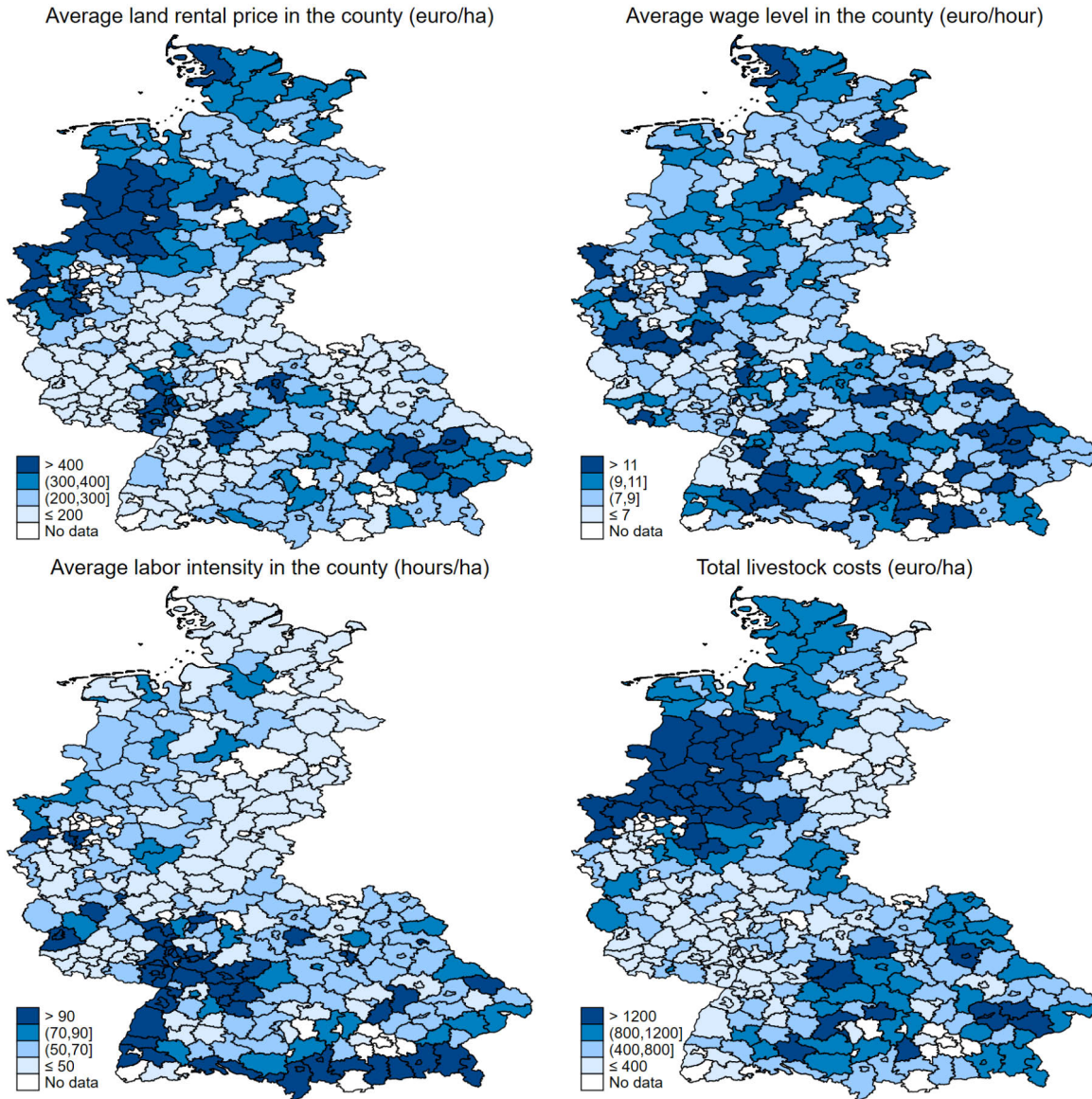
Table 1. Descriptive statistics of the model variables 2011 (NUTS3 level, 261 counties)

Variable	Mean	Std. Dev.	Min	Max
Average land rental price (€/ha)	260.76	135.53	41.97	752.18
Total labor costs $\frac{L \cdot W}{S}$ (€/ha)	698.04	615.25	162.08	5,837.45
Average wage level in the county (€/hour)	9.06	2.45	4.65	19.23
Average labor intensity $\frac{L}{S}$ (hours/ha)	81.04	79.69	20.56	647.48
Soil quality index	46.77	10.86	16	76
Total livestock costs $\frac{C_i}{S_i} k_i$ (€/ha)	710.68	614.07	0	3,452.90
Average costs per LSU k_i (€/LSU)	560.21	281.56	0	3,515.78
Average livestock density $\frac{C_i}{S_i}$ (LSU/ha)	1.18	0.88	0	4.96

According to Table 1, the average land rental price in West Germany derived from the FADN data amounts to 261 €/ha. This value reflects the average rental price of 229 €/ha provided by the Federal Statistical Office (Statistisches Bundesamt 2011) based on the agricultural census in 2010. The rental price varies from 42 €/ha in Westerwaldkreis, Rhineland-Palatinate, to 752 €/ha in Bad Dürkheim, Rhineland-Palatinate. When interpreting these figures, one has to recall that average county values may be based on a low number of sample farms so that the variance of rental prices between counties is overestimated. Also the average wage level in our sample (9.06 €/hour) is similar to the average wage level in 2011 of 9.40 €/hour for all working groups represented by the Federal Ministry of Food and Agriculture (BMEL 2012). The lowest wage of about 4.70 €/hour is observed in Wunsiedel, Bavaria, whereas the highest wage level of 19.23 €/hour could be found in Augsburg, Bavaria. The labor intensity varies in the county varies from 20.56 hours/ha in Gifhorn, Lower Saxony, to 647.48 in Nuremberg, Bavaria, with an average of 81.04 hours/ha. The total livestock costs vary from 0 (no livestock is observed in 16 counties) to about 3,453 €/ha in Vechta, Lower Saxony. The high value in Vechta is associated with a high livestock density (about 5 livestock units (LSUs)/ha of utilized agricultural area). The variation of the soil quality index reflects the heterogeneity of natural production conditions in Germany.

The spatial distribution of the variables is illustrated in the maps of Figure 1. A clear agglomeration pattern of land rental prices can be observed. For example, a concentration of high rental prices (above 400 €/ha) is found in parts of Lower Saxony and North Rhine-Westphalia, which corresponds to the aforementioned livestock production cluster (see also the map for total livestock costs in Figure 1). The clusters of the labor-intensive wine and hop production in the south can be found in the map of the average labor intensity.

Figure 1: Maps of spatial distribution of certain variables in 2011



4 Empirical Model

4.1 Model Specification

To investigate whether the structural model can explain the empirical spatial distribution of rental prices, the rental equation (10) has to be transferred into a regression equation:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \varepsilon_i \quad (15)$$

with $\alpha_1 = \frac{\gamma + \beta(\sigma - 1)}{\sigma - (\gamma + \beta(\sigma - 1))}$ being a compound parameter to be estimated that consists of the cost shares for labor and land and the elasticity of substitution. ε_i is a county-specific error term that captures unobserved county factors. Since $\sigma - 1$ is always positive, and the cost shares are smaller or equal to one, it follows $\alpha_1 > 0$, assuming that land is always required for agricultural

production, i.e., $\beta \neq 0$ or $\gamma \neq 0$. Hence the structural model is validated if the hypothesis $\alpha_1 \leq 0$ can be rejected.

The higher the share of labor in variable and fixed costs is, the smaller is α_1 . The magnitude of α_1 , however, does not allow conclusions on the level of agglomeration or dispersion of agricultural production since these outcomes also depend on transportation costs and the elasticity of substitution (see the wage equation (A3) in the technical appendix) and unfortunately, the resulting spatial equilibrium of production activity is highly sensitive to these parameters (Venables 1996).

Before proceeding with the empirical application, several econometric issues have to be considered. First of all, economic regions do not necessarily match administrative regions. Thus, prices and other economic variable can be determined by actors across administrative regions, which causes spatial autocorrelation (Kosfeld et al. 2008). Moran's I allows to test the data for spatial autocorrelation. The test statistic of Moran's I based on the standard contiguity spatial weight matrix of 1st neighbours reveals a value of 219.88 with a p -value<0.001 and shows a clear positive spatial autocorrelation for the dependent variable. A Lagrange Multiplier (LM) test indicates that the spatial autoregressive model (SAR) is appropriate for our data (spatial error: robust LM=133.283, p =0.230; spatial lag: robust LM=21.396, p <0.001), which is estimated by Generalized Spatial Two Stage Least Squares (Anselin 1988; Huang et al. 2006). Hence, the empirical equation accounting for the spatiality of the data is:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \rho W r_i + \varepsilon_i. \quad (16)$$

Another issue is the heterogeneity of the production factor land. Its productivity relies on local amenities, such as soil quality and climate. To capture this heterogeneity at least partially, we include a soil quality index Q_i into the rental price equation. Soil quality strongly varies between counties and almost all hedonic price studies show that it is a significant explanatory variable (Feichtinger and Salhofer 2013, 2016). Thus, Eq. (16) becomes:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \alpha_2 Q_i + \rho W r_i + \varepsilon_i, \quad (17)$$

which we will later refer to as Model 1. Finally, we have to account for endogeneity since in the systems of short-run equations (10) to (12), all variables r_i , Y_i , and n_i depend on the local nominal wage level w_i . Thus, the dependent variables of Equations (10) to (12) can be interchanged as dependent and explanatory variables resulting in endogeneity and biased estimates and standard errors. A general solution would be to estimate the entire system of equations simultaneously. However, this would involve estimation of a highly non-linear wage equation (see Eq. (A3) in the appendix), which would be infeasible without additional restrictive assumptions (cf. Hanson 2005). Empirical applications have frequently either ignored this issue (e.g., Dekle and Eaton 1999) or used an instrumental variables approach (e.g., Brakman 2006; Kosfeld et al. 2008). Income is then usually instrumented by population measures. In our case, fortunately, income is not part of our land rent equation (10). Nevertheless, the local wage level might be endogenous. A Wu-Hausmann test finds that the total labor costs per utilized agricultural area are, in fact, endogenous (p -value<0.001). Following Mion (2004), we

use temporally lagged values of county i 's total labor costs per utilized agricultural area, $\frac{L_i}{S_i} w_i$, as an instrument. An F -test of the first-stage regression for weak instruments confirms that this is a valid and strong instrument (F -value=446.85, p -value<0.001).

While Eq. (17) is derived from the NEG model with two input factors, land and labor, in reality a variety of other input factors are employed, e.g., capital or livestock, to produce agricultural output. The maps of Figure 1, in particular of the land rental prices and livestock costs per ha, further suggest that wages and labor intensity are not the only input variables that are related to the value of agricultural land. Linking the previously elaborated theoretic model with agricultural economic literature, in particular on hedonic pricing, it can be argued and has empirically been observed that livestock density, another measure of agricultural production intensity, has an effect on the agricultural land sales and rental prices. For example, Huang et al. (2006) find a negative relation of hog density to agricultural land sales prices in the USA. While Sills and Caviglia-Harris (2009) find that distance to market explains about one third of the variation in farm value, cattle stocking rates, reflecting agricultural investment, are positively and significantly correlated with farm value. This implies that where land rents are greater, higher rates of cattle intensification are more likely than in areas where rents are smaller, which accommodates the following extended NEG framework. Concentrating on German land sales and rental prices, Hennig and Latacz-Lohmann (2016) and Lehn and Bahrs (2018) identify higher prices in livestock-dense regions. It has been argued that manure application regulations, high returns from livestock production due to increasing economies of scale, and tax regulations could explain the link between livestock density and farmland values (Lehn and Bahrs 2018).

To accommodate the empirically observed relationship between livestock intensity and land prices, we extend the regression equation (17) by the total livestock cost per utilized agricultural area $\frac{C_i}{S_i} k_i$. This extension appears ad hoc, but in principle, the model of Pflüger and Tabuchi (2010) can be extended to incorporate a third production factor, e.g., capital or livestock in addition to labor and land. In that case, the land rent price would depend on both measures of production intensity, $\frac{L_i}{S_i} w_i$ and $\frac{C_i}{S_i} k_i$. A Wu-Hausmann test shows that the total livestock costs per utilized agricultural area are endogenous (p -value=0.009). Following Mion (2004), we use temporally lagged values of the total livestock cost per utilized agricultural area as an instrument. Again, an F -test of the first-stage regression for weak instruments confirms that this is a valid and strong instrument (F -value=220.55, p -value<0.001).

The rental price equation then becomes¹:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \alpha_2 \frac{C_i}{S_i} k_i + \alpha_3 Q_i + \rho W r_i + \varepsilon_i, \quad (18)$$

which we will later refer to as Model 2. However, it is difficult to assess what implications the addition of another mobile factor would have on the long-run distribution of agricultural economic activities in space. In particular, assumptions on the ownership and the distribution of income of the mobile input factor as well as defining the equilibrium condition, e.g., equal

¹ We use again temporally lagged values of the total labor costs per agricultural area as an instrument to bypass endogeneity problems.

utilities of factor owners across region, would be necessary. A different assumption, e.g., livestock is owned by absent owners or income stays in region of production, would entail different spatial distributions of the mobile factor (Pflüger and Tabuchi 2010). At this point, we restrain from elaborating on the long-run effects of livestock or capital as a mobile factors. The purpose of the modification of the empirical equation (18) is rather to explore the explanatory power of other measures of production intensity for land rental prices.

4.2 Estimation results

Table 2 presents the estimates of Model 1 (Eq. (17)) and Model 2 (Eq. (18)), which is extended by livestock costs per agricultural area. The parameter for total labor costs is statistically significant from zero with a p -value smaller than 1% and the hypothesis that $\alpha_1 \leq 0$ is rejected for both models. Indeed, total labor costs per ha have a positive influence (0.051 and 0.066) on the land rental prices. Hence the structural model (10), predicting the positive relationship, is confirmed by both empirical models.

Table 2. Regression results Dependent variable: land rental price

Variable	Model 1		Model 2	
	Coefficient	p -value	Coefficient	p -value
Total labor costs (€/ha)	0.051***	0.001	0.066***	<0.001
Average livestock costs (€/ha)	–	–	0.088***	<0.001
Soil quality (points)	2.813***	<0.001	4.056***	<0.001
Weighted average of the neighbor land rental prices (€/ha)	0.075***	<0.001	0.250***	0.001
Constant	77.725**	0.026	–90.503***	0.009
	$R^2=0.14$		$R^2=0.32$	

Note: *** and ** denote significance at the 1 and 5% significance level, respectively.

As expected, the effect of soil quality, a proxy for the heterogeneity of land, is positive and statistically significant. The positive spatial parameter ρ confirms the spatial interdependencies of land rental prices across regions in both models. Even though we did not estimate a long-run NEG model, the estimation results show that the land rental prices of other regions influence region i 's price as predicted by the derived long-run rental price equation (14).

An R^2 of 0.14 indicates a rather poor overall fit of Model 1. We note, however, that our objective is not to explain the entire heterogeneity of land prices; we are rather interested in hypothesis testing. One should also recall that the viability of average county rental prices is high due to small sample size of the FADN data. The inclusion of total livestock costs per ha as a further measure of agricultural production intensity in Model 2 increases the model fit ($R^2=0.32$). This is not very surprising and in line with previous empirical studies, which provided the (statistical) link between livestock density and land sales and rental prices (e.g., Huang et al. 2006).

To test the robustness of the estimation results, we conduct a cross-validation between predicted and observed land rental prices. The cross-validation approach is performed using the leave-one-out method. The process includes the following steps. Firstly, from the given n

samples in the study area, we choose one and consider its value as unknown. Secondly, the spatial regression model is estimated with the remaining $n - 1$ samples in order to predict a price index of the excluded region. Thirdly, the predicted land rental price level is compared with the observed value of the sample (Gao et al. 2006). In our case, we randomly choose 10 counties to the analysis, and the mean absolute percentage prediction error (MAPPE) is used as a criterion to evaluate the model. The cross-validation approach applied to our models shows that the MAPPE is equal to 15.52% (Model 1) and 11.46 % (Model 2). Such a significant prediction error also reflects the relatively low R^2 of the models.

5 Conclusions

This paper is one of the first attempts to utilize the theoretical framework of the new economic geography for explaining agricultural land prices. We adopt a model proposed by Pflüger and Tabuchi (2010), which is based on the Helpman (1998) model and allows to consider land as a production factor. We derive a short-run equilibrium that relates land rental prices to production intensity. The latter is measured as labor intensity, i.e., the ratio of labor cost and land used for agricultural production and additionally by livestock density. The model is applied to the agricultural sector in West Germany using county-level price and cost data of the FADN. A spatial lag model clearly rejects the null hypothesis of no impact of labor and livestock intensity on land rental prices. The result is not surprising and it is also in line with traditional concepts of production and location theory in agriculture: heterogeneity of land quality or distance to markets lead to higher production intensity, higher land rents and, in turn to a higher willingness to pay for land. But there is more. Concepts of new economic geography offer an explanation for the emergence and the growth of production clusters, which can hardly be explained by traditional location theory due to its static nature. In this view, agglomeration of agricultural production is the result of an interplay of increasing returns to scale and transportation costs. Though our empirical findings cannot be interpreted as direct support of the long-run predictions of the theoretical model, a confirmation of the short-run effects can be considered as a necessary condition for the validity of NEG in an agricultural context. In this setting, high land prices constitute a centrifugal force, counteracting the further concentration of intensive agricultural production, which may come along with negative environmental effects (e.g., Mulatu and Wossink 2013). Actually, groundwater pollution as a negative external effect of intensive pig and poultry production is well documented in parts of Lower Saxony and North Rhine-Westphalia (e.g., Berkhoff 2008).

Given that high land prices reflect (and influence) dynamic adjustment of spatial production structures in the agricultural sector, proposals for policy interventions in land markets may be criticized for at least two reasons: First, the narrative of the engagement of financial investors and the inflow of capital into the agriculture is challenged. It appears that competition among farmers in intensive production regions is more important for the development of agricultural land prices than competition between farmers and non-farmers, at least for the land rental market. In this view, increasing land rents are not caused by “excessive speculation”, but they rather reflect returns generated by positive externalities of agricultural production concentration that are capitalized via a competitive land market. Second, attempts to dampen the increase of land prices either by direct capping or by reducing competition through the exclusion of potential market participants will undermine the allocative role of price signals. Ill-designed policy interventions might actually hinder the effectiveness of land markets and their ability to

shift unproductive land to productive producers (Swinnen et al. 2016). Even if the market is inefficient, the costs of policy intervention might outweigh the benefits due to unobserved transaction costs. Neglecting the economic drivers behind agglomeration processes and possibly high agricultural land and rental prices might lead to ill-advised and overall welfare losses.

Even though the estimation results support the idea that land rental prices in West Germany can be explained by NEG concepts, our empirical analysis is only a first step towards a validation of NEG models in the context of agricultural production. Regarding theory, an inclusion of further mobile factors, particularly capital would make the model more realistic. Moreover, due to the lack of quality data, we were only able to estimate the models for one year. NEG, however, has been proposed to explain agglomeration and dispersion of economic activities, i.e., dynamic processes. Thus, it would be promising for future empirical research to compare estimates at different points in time and to test hypotheses about the dynamics of agricultural production clusters.

References

- Ahlfeldt, G. M., Redding, S. J., Sturm, D. M. and Wolf, N. (2015). The Economics of Density: Evidence From the Berlin Wall. *Econometrica* 83(6): 2127–2189.
- Anselin, L. (1988). *Spatial Econometrics: Methods and Models*. Dordrecht: Springer.
- Bäurle H, Tamásy C (2012). Regionale Konzentrationen der Nutztierhaltung in Deutschland. Vechta: Institut für Strukturforchung und Planung in agrarischen Intensivgebieten (ISPA). Universität Vechta.
- Berkhoff, K. (2008). Spatially explicit groundwater vulnerability assessment to support the implementation of the Water Framework Directive – a practical approach with stakeholders. *Hydrology and Earth System Sciences*, Vol. 12, 111-122.
- BMEL (2012). Statistischer Monatsbericht 09(2012). Bundesministerium für Ernährung und Landwirtschaft. https://www.bmel-statistik.de/fileadmin/user_upload/monatsberichte/MBT-0090000-2012.pdf
- BMEL (2018). Landwirtschaft verstehen: Fakten und Hintergründe. Bundesministerium für Ernährung und Landwirtschaft. <https://www.bmel.de/SharedDocs/Downloads/Broschueren/Landwirtschaft-verstehen.html>
- Brakman, S., Garretsen, H. and Schramm, M. (2006). Putting new economic geography to the test: Free-ness of trade and agglomeration in the EU regions. *Regional Science and Urban Economics* 36(5): 613–635.
- Caliendo, L., Parro, F., Rossi-Hansberg, E. and Sarte, P.-D. (2018). The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy. *The Review of Economic Studies* 85(4): 2042–2096.
- Carmona, J. and Roses, J.R. (2012). Land markets and agrarian backwardness (Spain, 1904-1934). *European Review of Economic History* 16(1): 74-96.
- Dekle, R. and Eaton, J. (1999). Agglomeration and Land Rents: Evidence from the Prefectures. *Journal of Urban Economics* 46(2): 200–214.
- Donaldson, D. and Hornbeck, R. (2016). Railroads and American Economic Growth: A “Market Access” Approach. *The Quarterly Journal of Economics* 131(2): 799–858.
- Eurostat (2018). Agriculture, forestry and fishery statistics: 2018 edition. European Union. <https://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-FK-18-001>
- Falk, B. (1991). Formally Testing the Present Value Model of Farmland Prices. *American Journal of Agricultural Economics* 73(1): 1.
- Feichtinger, P. and Salhofer, K. (2013). What Do We Know about the Influence of Agricultural Support on Agricultural Land Prices? *German Journal of Agricultural Economics* 62(2): 71–85.

- Feichtinger, P. and Salhofer, K. (2016). The Fischler Reform of the Common Agricultural Policy and Agricultural Land Prices. *Land Economics* 92(3): 411–432.
- Gao, X., Asami, Y., Chung, C. (2006). An empirical evaluation of spatial regression models. *Computers and Geosciences* 32: 1043–1045.
- Goodwin, B. K., Mishra, A. K. and Ortalo-Magné, F. N. (2003). What's Wrong with Our Models of Agricultural Land Values? *American Journal of Agricultural Economics* 85(3): 744–752.
- Grau, A. Odening, M. and Ritter, M. (2018). Land price diffusion across borders: The case of Germany. Humboldt-Universität zu Berlin. FORLand-Working Paper 03(2018). <http://dx.doi.org/10.18452/19263>.
- Hanson, G. H. (2005). Market potential, increasing returns and geographic concentration. *Journal of International Economics* 67(1): 1–24.
- Helpman, E. (1998). The size of regions. In: D. Pines, E. Sadka and I. Zilcha (eds), *Topics in public economics: Theoretical and applied analysis*. Cambridge: Cambridge University Press, 33–54.
- Hennig, S. and Latacz-Lohmann, U. (2016). The incidence of biogas feed-in tariffs on farmland rental rates – evidence from northern Germany. *European Review of Agricultural Economics* 13(2): 221.
- Holly, S., Pesaran, M. H. and Yamagata, T. (2010). A spatio-temporal model of house prices in the USA. *Journal of Econometrics* 158(1): 160–173.
- Huang, H., Miller, G. Y., Sherrick, B. J. and Gomez, M. I. (2006). Factors Influencing Illinois Farmland Values. *American Journal of Agricultural Economics* 88(2): 458–470.
- Hüttel, S., Ritter, M., Esaulov, V. and Odening, M. (2016). Is there a term structure in land lease rates? *European Review of Agricultural Economics* 43(1): 165–187.
- Klockgether, K., Garming, H., Dirksmeyer, W. (2016). Strukturen und Strukturwandel im deutschen Freilandgemüsebau. *Thünen Rep* 44:113–133. Thünen-Institut für Betriebswirtschaft. https://literatur.thuenen.de/digbib_extern/dn057667.pdf
- Kosfeld, R., Eckey, H.-F. and Türck, M. (2008). New economic geography and regional price level. *Jahrbuch für Regionalwissenschaft* 28(1): 43–60.
- Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy* 99(3): 483–499.
- Lehn, F. and Bahrs, E. (2018). Analysis of factors influencing standard farmland values with regard to stronger interventions in the German farmland market. *Land Use Policy* 73: 138–146.
- Lippert, C. (2006). Zur Relevanz der Neuen Wirtschaftsgeographie für den deutschen Agrarsektor. *Schriftenreihe der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaus (Gewisola)*, 41: 483–492.
- Mion, G. (2004). Spatial externalities and empirical analysis: The case of Italy. *Journal of Urban Economics* 56(1): 97–118.
- Mulatu, A., Wossink, A. (2013). Environmental Regulation and Location of Industrialized Agricultural Production in Europe. *Land Economics* 2013, 1-49.
- Murata, Y. (2003). Product diversity, taste heterogeneity, and geographic distribution of economic activities. *Journal of Urban Economics* 53(1): 126–144.
- Olsen, B.C., Stokes, J.R. (2015). Is Farm Real Estate the Next Bubble? *The Journal of Real Estate Finance and Economics* 50(3): 355–376.
- Pflüger, M. and Tabuchi, T. (2010). The size of regions with land use for production. *Regional Science and Urban Economics* 40(6): 481–489.
- Pines, D., Sadka, E. and Zilcha, I. (eds) (1998). *Topics in public economics: Theoretical and applied analysis*. Cambridge: Cambridge University Press.
- Plogmann, J., Mußhoff, O., Odening, M. and Ritter, M. (2018). What Moves the German Land Market? A Decomposition of the Land Rent-Price Ratio. FORLand-Working Paper 05(2018). <http://dx.doi.org/10.18452/19486.2>.
- Puga, D. (1999). The rise and fall of regional inequalities. *European Economic Review* 43(2): 303–334.
- Redding, S. J. (2010). The Empirics of New Economic Geography. *Journal of Regional Science* 50(1): 297–311.

- Redding, S. J. and Sturm, D. M. (2008). The Costs of Remoteness: Evidence from German Division and Reunification. *American Economic Review* 98(5): 1766–1797.
- Rossi-Hansberg, E. (2005). A Spatial Theory of Trade. *American Economic Review* 95(5): 1464–1491.
- Sills, E. O. and Caviglia-Harris, J. L. (2009). Evolution of the Amazonian frontier: Land values in Rondônia, Brazil. *Land Use Policy* 26(1): 55–67.
- Statistische Berichte (2012).
Kaufwerte für landwirtschaftliche Grundstücke in Baden-Württemberg 2011.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/BWHeft_derivate_00000914/3466_11001.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Bayern 2011.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/BYHeft_derivate_00003234/M1700C%20201100.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Hessen 2011.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/HEHeft_derivate_00000750/MI7_j11.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Niedersachsen 2011.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/NIHeft_derivate_00001172/M_I_7_2011_pdfa.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Nordrhein-Westfalen 2011.
<https://webshop.it.nrw.de/gratis/M179%20201100.pdf>
Kaufwerte für landwirtschaftliche Grundstücke in Rheinland-Pfalz 2011.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/RPHeft_derivate_00002012/M1073_201100_1j_K.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Saarland 2011.
https://www.saarland.de/dokumente/thema_statistik/STALA_BER_MI7-J-11.pdf
Kaufwerte für landwirtschaftliche Grundstücke in Schleswig-Holstein 2011.
https://www.statistik-nord.de/fileadmin/Dokumente/Statistische_Berichte/wirtschaft_und_finanzen/M_I_7_j_S/M_I_7_j11_S.pdf
- Statistisches Bundesamt (2011). Statistisches Jahrbuch 2011, Kapitel 13: Land- und Forstwirtschaft.
<https://www.destatis.de/DE/Publikationen/StatistischesJahrbuch/StatistischesJahrbuch2011.pdf?blob=publicationFile>
- Statistisches Bundesamt (2012). Statistisches Jahrbuch 2012, Kapitel 19: Land- und Forstwirtschaft.
https://www.destatis.de/GPStatistik/servlets/MCRFileNodeServlet/DEAusgabe_derivate_00000139/1010110127004.pdf
- Statistisches Bundesamt (2018). Statistisches Jahrbuch 2018, Kapitel 19: Land- und Forstwirtschaft. <https://www.destatis.de/DE/Themen/Querschnitt/Jahrbuch/jb-land-forstwirtschaft.html>
- Swinnen, J., van Herck, K. and Vranken, L. (2016). The Diversity of Land Markets and Regulations in Europe, and (some of) its Causes. *The Journal of Development Studies* 52(2): 186–205.
- Tabuchi, T. and Thisse, J.-F. (2002). Taste heterogeneity, labor mobility and economic geography. *Journal of Development Economics* 69(1): 155–177.
- Venables, A.J. (1996). Equilibrium location of vertically linked industries. *International Economic Review* 37 (2):341-359.
- Waight, S. (2018). Does the law of one price hold for hedonic prices? *Urban Studies* 55(15): 3299–3317.
- Yang, X., Odening, M. and Ritter, M. (2019). The Spatial and Temporal Diffusion of Agricultural Land Prices. *Land Economics* 95(1): 108–123.
- Yang, X., Ritter, M. and Odening, M. (2017). Testing for regional convergence of agricultural land prices. *Land Use Policy* 64: 64–75.

Technical appendix

Region i 's short-run income equation is derived by substituting the respective regional short-run land rent equations (10) into (4), thus cancelling land rents. The income is now solely expressed in wages and labor endowment of both region.

$$Y_i = \left(L_i + \frac{L_i}{L_i+L_k} \frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} L_i \right) w_i + \left(L_k \frac{L_i}{L_i+L_k} \frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \right) w_k \quad (A1)$$

The derived income equation can now be used to find the so-called wage equation by substituting the short-run equilibrium income equation (12) into (A1). Therefore the nominal wage of region i depends on the labor and land endowment in all regions, transport costs, the wage level in region k as well as the elasticity of substitution and the cost shares:

$$w_k = \frac{\left(\frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \frac{L_i}{S_i} \frac{1}{A} L_i \frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \frac{L_i+\tau L_k}{L_i+L_k} \left(\frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \frac{L_i}{S_i} \right)^{-\gamma-1} \right)}{\frac{1}{a} L_k \left(\frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \frac{L_i+\tau L_k}{L_i+L_k} + \tau \right) \left(\frac{\gamma+\beta(\sigma-1)}{(1-\gamma)+(1-\beta)(\sigma-1)} \frac{L_i}{S_i} \right)^{-\gamma-1}} w_i \quad (A2)$$

The relation of the price indices of both regions can be derived from the wage equation, by using the equilibrium condition for the real wage rate (13):

$$\frac{G_i}{G_k} = \frac{\frac{1}{a} L_k \left(\frac{L_i+\tau L_k}{L_i+L_k} + \tau \right) \left(\frac{\gamma+\beta(\sigma-1)}{\sigma-(\gamma+\beta(\sigma-1))S_i} \frac{L_i}{S_i} \right)^{-\gamma-1}}{\left(\frac{L_i}{S_i} \frac{1}{a} L_i \frac{L_i+\tau L_k}{L_i+L_k} \left(\frac{\gamma+\beta(\sigma-1)}{\sigma-(\gamma+\beta(\sigma-1))S_i} \frac{L_i}{S_i} \right)^{-\gamma-1} \right)} \quad (A3)$$