

The Impact of Production Intensity on Agricultural Land Prices

Der Einfluss der Produktionsintensität auf Pachtpreise in der Landwirtschaft

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Summary

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, land prices, production intensity

Zusammenfassung

Der Beitrag versucht, die regionalen Unterschiede landwirtschaftlicher Pachtpreise auf der Grundlage der Neuen Ökonomischen Geographie zu erklären. Wir verwenden ein von Pflüger und Tabuchi (2010) entwickeltes Modell, das Land als Produktionsfaktor explizit berücksichtigt. In einem kurzfristigen Marktgleichgewicht besteht eine Beziehung zwischen der Höhe der Pachtpreise und der Produktionsintensität, die als Höhe Lohnkosten pro Flächeneinheit gemessen wird. Zusätzlich wird die Viehdichte als Indikator herangezogen. Eine empirische Anwendung des Modells auf Landkreise in Westdeutschland bestätigt den theoretischen Zusammenhang.

Schlagworte: Neue ökonomische Geographie, Landpreise, Produktionsintensität

1 Background and Motivation

Land markets underwent a global boom period in the last decade. At the same time, the evolution of agricultural land prices is characterized by pronounced spatial heterogeneity. In West Germany, for example, the average land rent increased by 48% from 234 €/ha in 2007 to 346 €/ha in 2016, while at the federal state level, growth rates vary between 8% for the Saarland and 65% for Lower Saxony. This spatial heterogeneity of land price developments calls for an economic explanation. Unfortunately, most spatio-temporal models, which so far have been applied in empirical analyses are reduced form models that primarily aim at identifying statistical properties of times series, such as co-integration, co-trending and convergence (e.g. Yang et al., 2019). 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 agglomerations 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 important are immobile factors 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). 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.

Though the potential of NEG models for explaining production agglomeration in the agricultural sector has already been pointed out by Lippert (2006), empirical applications are rare. 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 agglomeration in agriculture on the other hand. Agglomeration, in turn, often comes along with high production intensity. 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.

2 Theoretical Model

Standard core-periphery models rest on the assumption that consumers use two types of products, manufactured and agricultural, in various varieties. Labor for manufactured goods are assumed to be mobile while agricultural workers are immobile and so is agricultural production. Krugman (1991) does not consider any congestions 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 core-periphery 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. 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. Other model components resemble common NEG models, specifically the Dixit-Stiglitz approach of monopolistic competition and iceberg transportation costs, i.e. the amount of a good “melts” proportionally with the distance between production and consumption. In a general setting, consumption includes all goods produced by all firms in an economy and labor costs relates all workers in a region. However, since we are interested in the emergence of agricultural production cluster, we focus on the rural economy as the relevant framework and use the wage rate of agricultural workers in our empirical application. For a detailed description of the model, we refer to Grau et al. (2019). The short-run equilibrium consists of four equations explaining income, the number of firms, land rental prices and wages in a region. In a short run equilibrium, not only land endowment S_i but also labor allocation L_i across regions is fixed. Using market clearing conditions for products, labor and land, the endogenous variable r_i can be expressed through the short-run fixed variables S_i and L_i , the local wage rate w_i , and parameters of technology and preference. The rental price equation for region i is then:

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

Herein σ denotes a rate of substitution among produced agricultural goods and β and γ are cost shares of land in fixed and variable cost, 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. Thus, the price of land r_i 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 cost shares and elasticity of substitution are assumed to be equal across regions, differ-

ences 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 wage rates. 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 w , the determining factor of their utility, is equal across all regions so that workers do not have an incentive to relocate. 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. 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. 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. 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. Agricultural production in Germany is characterized by considerable regional heterogeneity. Livestock production is concentrated in the northwest (Lower Saxony, North-Rhine-Westphalia) and 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 (e.g. Henrichs-

meyer, 1977). 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 explanations, 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.

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. 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. Information about the soil quality of the land sold in 2011 is taken from the statistical reports of the federal states (see Grau et al. (2019) for details). This soil quality index indicates the potential productivity of land due to natural and climatic conditions and can take a maximal value of 120 points. Descriptive statistics of the final data set are reported in Table 1.

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 already provides a first impression that higher prices can be found in states that are represented by strong production clusters.

4 Empirical Model

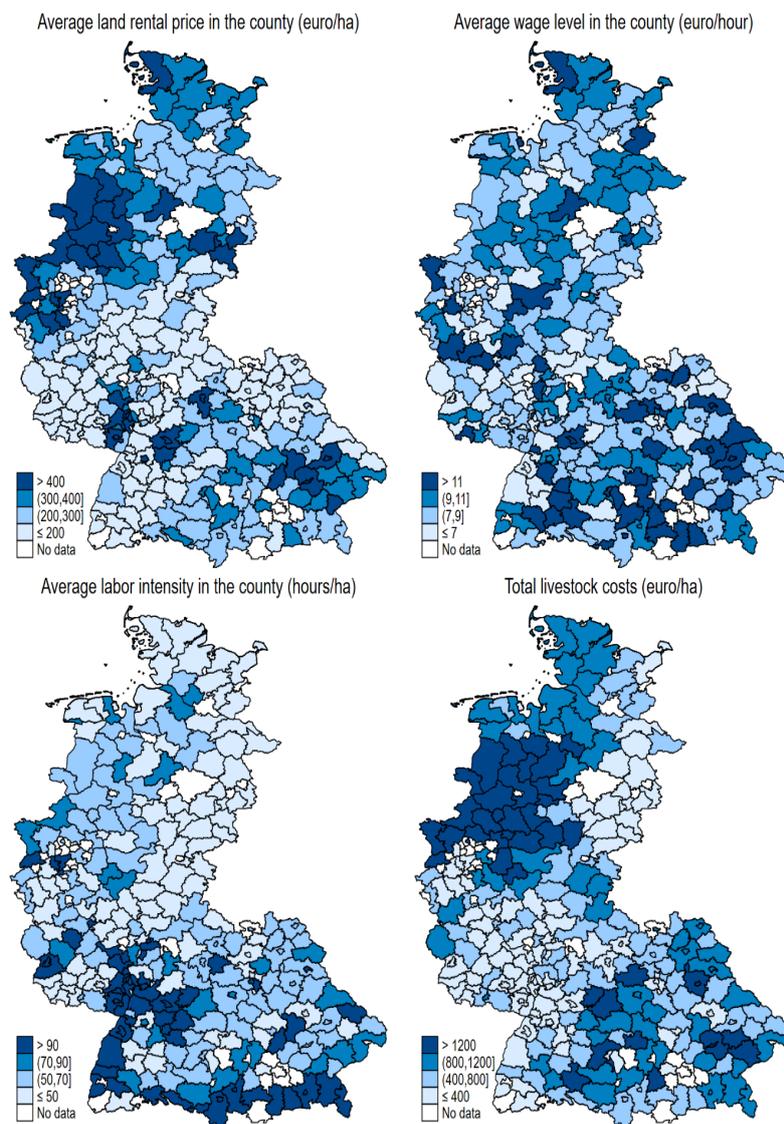
4.1 Model Specification

NEG models are typically used to investigate the impact of structural parameters (e.g. transportation costs, substitution elasticities of goods) on the type of spatial equilibrium (agglomeration or dispersion) and its stability. This kind of analysis is conducted via simulation describing the adjustment to the long run equilibrium. In contrast, empirical applications

Table 1: Descriptive statistics of the model variables 2011 (NUTS 3 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 livestock unit 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

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



mostly refer to the short equilibrium equations of the NEG model, and unfortunately, our application is no exception in this regard. This implies that we cannot directly test the relation between land prices and the dynamic process of agglomeration or dispersion.

To investigate whether the structural model (1) can explain the empirical spatial distribution of rental prices, the rental equation (1) has to be transferred into a regression equation:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \varepsilon_i \tag{2}$$

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 supported if the hypothesis $\alpha_1 \leq 0$ can be rejected.

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 factors 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 ρ -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, $\rho=0.230$; spatial lag: robust LM=21.396, $\rho < 0.001$), which is estimated by Generalized Spatial Two Stage Least Squares. Another issue is the heterogeneity of the production factor land. Its productivity relies on local amenities, such as soil quality and climate (e.g. Hüttel et al., 2013). To capture this heterogeneity at least partially, we include a soil quality index 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. Thus, Eq. (16) becomes:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \alpha_2 Q_i + \rho W r_i + \varepsilon_i, \tag{3}$$

which we refer to as Model 1. Finally, we have to account for endogeneity since in the systems of short-run equations (see Pflüger and Tabuchi, 2010), variable r_i depends on the local nominal wage level w_i . Thus, the dependent variables of the equations defining the short-run equilibrium can be interchanged as dependent and explanatory variables resulting in endogeneity as well as 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,

which would be infeasible without additional restrictive assumptions (Hanson, 2005). Empirical applications have frequently either ignored this issue or used an instrumental variables approach (e.g., 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 (1). 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 (ρ -value < 0.001). Following Mion (2004), we use temporally lagged values of county'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 strong instrument (*F*-value=446.85, ρ -value < 0.001).

To accommodate the empirically observed relationship between livestock intensity and land prices, we extend the regression equation (3) 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 (ρ -value=0.009). Following Mion (2004) again, we use temporally lagged values of the total livestock cost per utilized agricultural area as an instrument. Once more, an *F*-test of the first-stage regression for weak instruments confirms that this is a strong instrument (*F*-value=220.55, ρ -value < 0.001).

The rental price equation then becomes:

$$r_i = \alpha_1 \frac{L_i}{S_i} w_i + \alpha_2 \frac{C_i}{S_i} k_i + \alpha_3 Q_i + \rho W r_i + \varepsilon_i, \tag{4}$$

which we will refer to as Model 2.

4.2 Estimation results

Table 2 presents the estimates of Model 1 (Eq. (3)) and Model 2 (Eq. (4)). The parameter for total labor costs is statistically significant from zero with a ρ -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.

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 in the long-run (Pflüger and Tabuchi, 2010).

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 en-

Table 2: Regression results. Dependent variable: land rental price

Variable	Model 1 Coefficient	p-value	Model 2 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.

tire heterogeneity of land prices; we are rather interested in hypothesis testing. One should also recall that the variability 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).

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 prerequisite 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). In fact, 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). We conclude that policy interventions targeting directly at the detrimental environmental effects of intensive agricultural production are more appropriate than stricter regulations of land markets, such as price caps.

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