Spatial Pricing on Land Rental Markets

Marten Graubner
Leibniz Institute of Agricultural Development in Central and Eastern Europe,
Theodor-Lieser-Strasse 2, 06120 Halle (Saale), Germany. Phone: +49 345 2928 320,
Email: graubner@iamo.de

Alfons Balmann
Leibniz Institute of Agricultural Development in Central and Eastern Europe,
Theodor-Lieser-Strasse 2, 06120 Halle (Saale), Germany. Phone: +49 345 2928 300,
Email: balmann@iamo.de

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Spatial pricing on land rental markets

Marten Graubner and Alfons Balmann

This paper analyzes spatial competition on land rental markets. It contributes to the small body of literature that investigates the optimal spatial price policy under competition and extents previous work by considering economies of size. Because the consideration of increasing or decreasing returns of additional land and the endogenous choice of spatial pricing is analytically intractable, a computational economics approach is used to simulate spatial pricing in the presence of economies of size. This paper is a first step towards a spatial competition model of a land rental market and based on selected simulations it shows that price discrimination is likely to arise.

Introduction

Land is the most important production factor of agricultural firms. Because land is spatially distributed, the costs associated with the cultivation of a plot increase with the distance to the farmstead. These transport costs vary for the same plot among farms depending on the farm's location and thus land (rental) markets are markets of spatial differentiation. Whether and to what extent farms may want to consider these costs for the price they pay to the land owners is not well studied so far. In this paper, we focus on the theoretical foundations of spatial pricing and what we might expect to observe on land rental markets. We study these markets in the presence of large-scale agricultural firms and a polypolistic land ownership structure. I.e., only few farmers face many land owners. Such market structure is common in Eastern Germany as well as other former socialist countries.

While land markets are a topic of constant interest, only recently studies consider strategic interactions on land markets (Huettel and Magarian, 2009; Balmann and Happe, 2001). The spatial nature of the interactions is hardly considered in competition framework. Models of spatial competition incorporate positive transport costs and the spatial distribution of both, demand for and supply of a product or service. Literature on spatial competition shows that space does not only cause results to deviate considerably from traditional price or competition models, but it also induces a high degree of complexity. Because of the latter, most spatial competition models are limited to restrictive assumptions to keep the analysis mathematically tractable. One example is that economies of size are almost always absent in these models.

Greenhut and Norman (1986) consider a general cost function where the production at one location influences the production costs at another location. While the authors investigate monopoly pricing and the oligopoly under quantity competition, a price setting framework with spatially dispersed firms was not yet analyzed. Zhang and Sexton (2001) and Fousakis (2011) investigate spatial pricing on input markets but restrict the choice of available pricing regimes to free-on-board (FOB) and uniform delivered (UD) pricing. Graubner et al. (2011a) studied the endogenous choice of spatial pricing but as Zhang and Sexton (2001) and Fousakis (2011) did not consider economies of size. In this paper we compare FOB and

UD pricing under the consideration of size effects and also let farms endogenously determine the optimal price strategy.

Theoretical Background and Methodology

Within this study, a standard model of spatial competition is used in which two farms, A and B, locate at opposite end points of a line market with unit length. Both farms compete for land that is uniformly distributed along the line. The production on a plot causes transport costs that increase proportional with constant rate t and the distance x of the land to the farmstead. The price $r(x)$ paid to land owners is a linear function of the distance to the farm and land owners offer the land according to a perfectly price inelastic supply function $q(x)$. I.e., there are no alternative uses of the land. Given reasonable normalization we define:

1. $$q(x) = \begin{cases} 1 & \text{if } r(x) > 0, \\ 0 & \text{if } r(x) \leq 0. \end{cases}$$

Furthermore, a farmer can earn constant revenue R at each plot. A common assumption in spatial competition models is that the net revenue, i.e., R less other production costs but the land price and transport costs, is constant too. However, we consider variable net revenues for different plots that shall reflect economies or diseconomies of size. Under the linear market framework, this can be accomplished by the introduction of a distance dependent cost component $c(x)$.[1] For instance, assume that the net revenue $R - c(x)$ increases with the distance to the farmstead, i.e., $c'(x) \neq 0$ and $c''(x) < 0$ over some range of x. A possible interpretation is that additional land causes less (other) production costs relative to the last unit of land because there are unused production capacities. If not, renting additional land might require additional investments in capital or workforce, in short causes fix costs and thus $c''(x) > 0$.

To summarize we can define $P(x)$ as the local profit of a farm gained from the production on a plot at distance x that consist of the distance dependent net revenue $R - c(x)$ minus the land rental price $r(x)$ and the transport costs tx:

2. $$P(x) = R - c(x) - r(x) - tx.$$

In this paper, we define $R - c(x) - tx$ as the local economic land rent, i.e., the highest price a farmer can offer for land at the respective location.

If both farmers non-cooperatively aim to maximize their profits over a certain market area, the equilibrium outcome depends on the price schedule over $r(x)$ and the form of $c(x)$. We consider a cost function of the form $c(x) = \alpha x^2 + \beta x$ and let the price schedule be

3. $$r(x) = m - tx \,,$$

[1] We implicitly assume that a farmer who rents a plot at distance x_2 also rents all plots at x_1 with $x_1 < x_2$. To capture economies of size in a two-dimensional market is more complicated and depends on the allocation mechanism of land and the location of other farms. Though we do not formally investigate the two-dimensional scenario, the simulation model can be extended in this direction.

which is free-on-board (FOB) pricing where m is the price at the location of the farmer, usually called *mill price*. FOB pricing is commonly used in the economics literature and does not allow for spatial price discrimination. I.e., the price difference of two parcels complies exactly the transport costs between the locations of these plots from the perspective of the same farm.

Let us first assume that farm A has a monopsonistic position in the region, i.e., farm A is the only demander of land. As long as the local price $r(x)$ is positive, the land owner will rent the land to this farm, which results in a farm size (or market radius) defined by $\tilde{x} = \frac{m}{t}$. Because of the defined price schedule, the price at the farmstead m determines all local prices. Therefore, using equations (1) to (3) and the definition of $c(x)$, we calculate the optimal mill price m_M for the monopsony by differentiation of:

4. $$P_A = \int_0^{\tilde{x}} (R - \alpha x^2 - \beta x - m)\ dx,$$

with respect to m. The solution of the first order condition regarding a maximum yields:

5. $$m_M = \frac{t}{2\alpha}\left(-2t - \beta + \sqrt{(2t+\beta)^2 + 4R\alpha}\right).$$

The behavior of the optimal mill price crucially depends on the distance-dependent cost function $c(x)$. For instance, if $c(x) = 0$, the local profit $P(x)$ from (3) reduces to $R - m$ under substitution of (4) and normalization of R to $R = 1$. Solving for the monopolistic price yields $m_M = 1/2$.

Once there are economies of size, i.e., $c'(x) < 0$, $P(x)$ is no longer constant over the farm's rented locations and the optimal price m_M may increase or decrease with t and $m_M(c(x))$ is not necessarily monotonic regarding t. Figure 1 shows the optimal mill price m_M over t for selected specifications of $c(x)$.

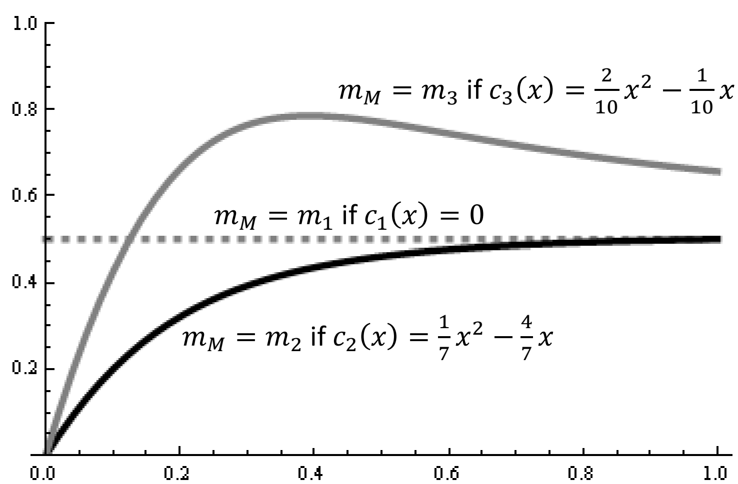

Figure 1: The optimal monopsonistic mill price m_M for different specifications of $c(x)$.

For the same cost specifications, Figure 2 highlights that economies of size can enforce or compensate effects that are induced by transport costs. In general, FOB pricing is a proper pricing regime under decreasing returns to scale, where additional land yields less revenue than the previous plot of land as long as the decrease in revenue is not too high. However, if the farm operates under increasing revenues or decreasing costs for additional land, FOB pricing seems to be inappropriate because it prevents the farm to exploit the higher revenues at distant plots if the price policy $m - tx$ (see equation 2) forces local prices to be non-positive (e.g., see $m_3 - tx$ in the case of $c_3(x)$ in Figure 2). In this case, other price regimes as uniform delivered (UD) pricing are likely more profitable.

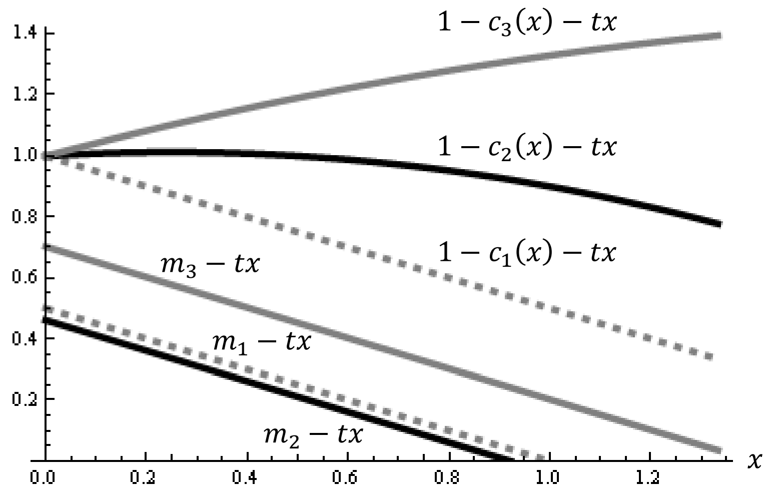

Figure 2: Local prices and local land rent for different specifications of of $c(x)$.

In spatial economics, UD pricing is a common price strategy and it is also discussed in agricultural market settings (Durham et al. 1992, Alvarez et al., 2000, Graubner et al., 2011b). Under UD pricing, local prices do not differ, i.e., land owners receive the same price for their land independent of their respective location to the farm. This price strategy features spatial price discrimination because local prices do not reflect differences in transport costs among locations. Instead, the farm averages these costs out over locations (land owners) and thus UD pricing allows for cross-subsidization from proximate to more distant land owners, i.e., the latter can benefit from UD pricing because for distant plots UD prices are higher than FOB prices.

In the case of UD pricing, the farmer has not only to decide over the optimal price, but also the market area or farm size, i.e., the maximum distance where it is still profitable to rent land. This problem is analytically tractable if net revenues of additional land monotonically decrease with x (or once a certain farm size is reached) or if the revenue increases with x but less than the increase of transport costs. However, if the increase in net revenue for additional land more than compensates the increase in transport costs, the optimal farm size may be infinite. While this problem is of minor interest for the monopsony framework, increasing revenues or decreasing costs of additional land may have crucial effects under competition. If, e.g., the revenue maximum/cost minimum cannot be exploited by sharing the market equally or even if the competitor is active at all. In such events, multiple equilibria may exist.

In general, spatial competition under UD pricing does not feature Nash equilibria in pure strategies (D'Aspremont et al., 1979). Considering economies of size further complicates the analysis. Additionally, UD or FOB pricing are only two options and there might be more, even superior price policies that can be used. However, in such cases, the endogenous choice of pricing is analytically intractable. Therefore, we use a computational economics approach based on agent-based modeling and numerical simulations.

In particular, we use the Spatial Agent-based Competition Model (SpAbCoM) developed by Graubner (2011) to simulate land market interactions for different price regimes as well as the endogenous choice of spatial pricing. In this simulation model, the concept of agent-based modeling (ABM) is used to account for spatial heterogeneity and strategic interaction. I.e., we differentiate land owners through the location of their plots as well as we capture the spatial and strategic interactions of farms on the land rental market. Another advantage of ABM is the potential to link this approach with powerful numerical optimization algorithms to solve, e.g., the analytically intractable objective functions of the farmers. For a detailed description of SpAbCoM see Graubner (2011) and for a first application see Graubner et al. (2011a).

Simulation Model

The Spatial Agent-based Competition Model considers two types of agents, in our case farmers and land owners, which can be distributed in a grid of cells or locations. To be consistent with the theoretical framework, there is a finite number of small land owners (typically we model 300 land owners) uniformly distributed between the locations of two farmers. Land owners rent the land to the farmer that offers the highest rental price at the respective location of the land owner. To determine the optimal pricing over all locations, the farmers' decision making is modeled by a genetic algorithm (GA).

Genetic algorithms are a heuristic search method based on the principle of the "survival of the fittest" (Dawid, 1999) through the selection of successful strategies. That is, strategies which are regarded as superior based on an evaluation criterion are more likely to be selected as the solution to a problem. GA differs from other random search methods in two important ways (Goldberg, 1989): the GA works on coded parameters and not with the parameters themselves and it evaluates a population of points rather than a single point at one time. These features make the GA robust and efficient in handling "problems of far greater complexity and size than most other methods" (Judd, 1998, p.285).

Although the design of GA may vary depending on the corresponding application, there are three basic components: a pool of candidate solutions (called population), the objective (or fitness) function, and genetic operators as selection, crossover, and mutation. The population of strategies represents a number of possible solutions to the problem that are randomly initialized. These candidate solutions are coded, e.g., in binary strings. Based on the exogenous given fitness function (e.g., maximum profit), the quality of these solutions can be determined which assigns a fitness value to each strategy. In a further step, good strategies are selected, e.g., proportional to their fitness, while less fit strategies are sorted out. This decreases the variability within the population. Because the population was randomly initialized and good or even optimal strategies are not necessarily elements of the population, additional procedures are applied to find new, potentially better solutions. This is the task of mutation and crossover. The first alters the encoded information of a strategy (by changing the binary representation) while crossover exchanges parts of two different strategies to generate new strategies. The sequence of fitness evaluation and application of genetic operators forms a generation and over a high number of generations the average fitness of the population increases and eventually converges against the optimal solution.

In the framework of the presented spatial competition model, we use the GA optimization to determine the profit maximizing price (or price strategy) under strategic interactions, i.e., the farmers identify optimal strategies simultaneously. In such settings, conventional Nash equilibrium search algorithms are likely to miss the globally optimal strategy by following a local optimization path (Son and Baldick, 2004). Thus a coevolutionary implementation of the GA is used in which each decision making unit exhibits an individual population.

For instance, in the case of FOB pricing the farm's objective is to maximize (6) over the competitive farm size $\tilde{x}$, i.e., where the local rental prices of the farm $m_A - tx$ equates the local price of the competitor $m_B - t(1 - x)$ and $\tilde{x} = \frac{m_A - m_B + t}{2t}$. Hence, farm A's population consists of a number (e.g., 15) of randomly initialized mill prices $\mathbf{m_A} = \left(m_{A,1}, m_{A,2}, \ldots, m_{A,15}\right)$. Correspondingly, the population of farm B is $\mathbf{m_B} = (m_{B,1}, m_{B,2}, \ldots, m_{B,15})$. Playing one strategy of farm A against a randomly selected strategy of farm B yields a certain market allocation (i.e., farm size) for both farms and we can assign a profit to the chosen strategies. Of course, this profit (or fitness) of a strategy depends on the strategy of the competitor and thus we need to implement a tournament where a farm's strategy is tested against a random vector of the competitor's strategies. This process yields an average fitness value for each strategy in both populations and we can proceed by applying the genetic operators.

In the following section, we present results of selected simulations. For these experiments, we used a population size of 15 candidate solutions for each farm, best chromosome selection (where the 12 best strategies of each population are selected), a mutation rate of 5 percent and a crossover rate of 10 percent. Ten simulations were conducted for each parameter setting and a simulation run consists of 2000 generations. Results are reported for the last 5 percent of the generations of each run. Hence, we get 1000 observations for each parameterization.

Selected Results from Simulations

In general, UD pricing is superior to FOB pricing if $c(x) = 0$ and if the local supply is perfectly price inelastic (as in the case of the land market) because the farmer can capture the entire supplier's surplus from the land owners by setting the UD price equal the supplier's reservation price (Kats and Thisse, 1989; Zhang and Sexton, 2001). Only competition forces the farmer to pay higher prices under the UD price strategy. The objective of the further analysis is to determine the optimal spatial price strategy under economies of size. First, we compare prices and profits under UD and FOB pricing before the endogenous choice of the spatial price regime is investigated.

Simulations are conducted for different levels of the transport rate t. It is common in spatial competition models to measure the competitiveness of a market by the importance of space, which is defined by the distance separating the competitors (inter-firm distance, here set to one) times the transport costs per unit distance t relative to the net value of the finished good R (Alvarez et al., 2000; Zhang and Sexton, 2001; Mérel and Sexton, 2010). Because we also set $R = 1$ and in slight abuse of notation, we can measure the competitiveness of the market by the normalized transport costs t.

Figure 3 shows prices and profits for UD and FOB pricing in the case of decreasing costs for additional land. In particular, we set $\alpha = 0$, $\beta = -0.1$ and thus define $c(x) = -0.1x$. In general, if $\beta < 0|_{\alpha=0}$, the local land rent will increase as long as $\beta < -t$. The figure highlights that the increasing local land rent causes prices to increase and profits to decrease for both UD and FOB pricing. However, once transport costs compensate for economies of size, the effect is reversed. That is, while increasing local land rents (decreasing costs with additional land/increasing farm size) yield higher competition in terms of higher land prices and lower farm profits, increasing spatial differentiation through increasing transport costs reduce the competitive pressure on the farm.[2]

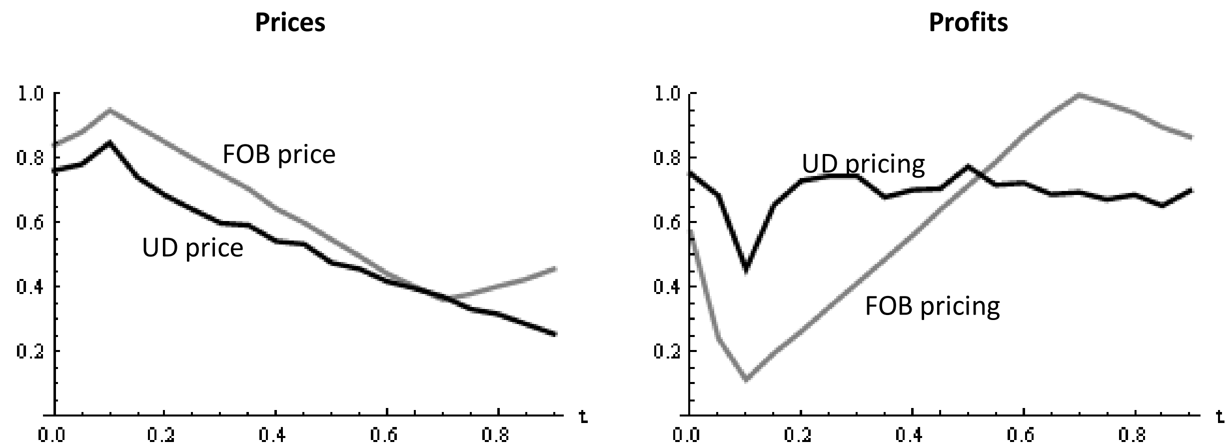

Figure 3: Profits and (mill) prices under the FOB and UD price strategy if $c(x) = -0.1x$.

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owners uniform prices independent of their distance to the farmstead as long as transport costs are not too high. Once the spatial differentiation between the farms exceeds a certain threshold it seems profitable for both firms to switch to FOB pricing. However, as Graubner et al. (2011a) point out, this result may be biased by reducing the choice of pricing to FOB and UD pricing. In fact, other strategies could be more profitable in response to the competitor's use of FOB or UD pricing. Therefore, we allow farms to choose any price strategy between FOB and UD pricing, i.e., a linear price distance function $r(x) = m - \varphi tx$ that can be characterized by partial absorption of the transport costs by the farmer. Additionally, we do not restrict the slope of this function to be negative because reverse price discrimination, i.e., increasing local prices despite increasing transport costs, may be beneficial. Hence, we define $\varphi = [-1,1]$ which yields a slope of the price distance function in the interval $[-t, t]$.

Adapting the simulation of Graubner et al. (2011a), we introduce different cost functions to model economies of size. First, we set $c_1(x) = 0.3x$ and $c_2(x) = -0.3x$ to exemplify the effects of decreasing and increasing costs for additional land. Figure 4 summarizes the results for prices and the slope parameter of the price distance function, i.e., the degree of spatial price discrimination φ.

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[2] We observe more or less the same effects with a positive value of the quadratic term ($\alpha > 0$) in $c(x)$, e.g., we conducted simulations for $c(x) = 0.2x^2 - 0.1x$ where the minimum of $c(x)$ is close to the farms location ($x = 0.25$).

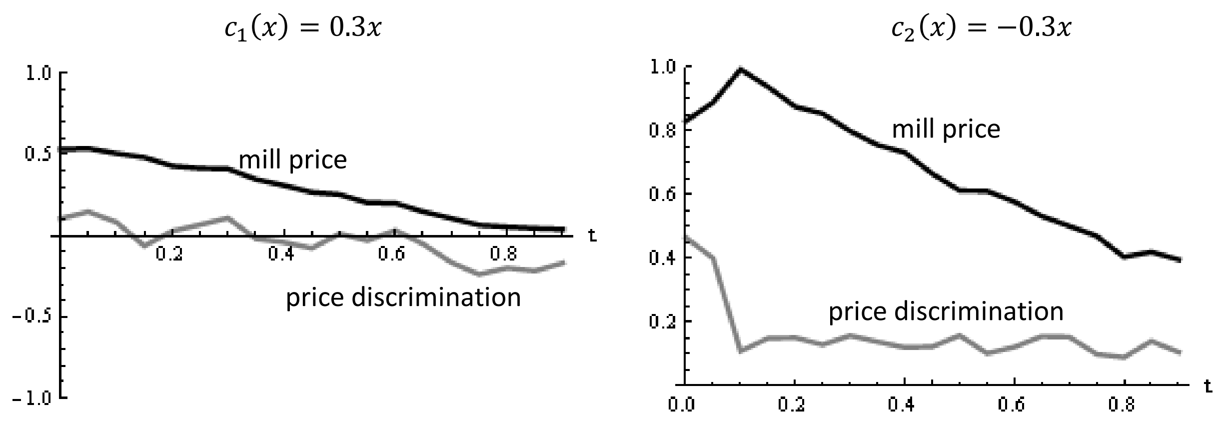

Figure 4: The optimal spatial price strategy (m, φ) if local land rents decrease over the entire (c_1)or some range (c_2) of x.

The figure shows that the price regimes are similar to UD pricing, i.e., they feature a high degree of spatial price discrimination (full absorption of transport costs). Only in the range of t that enables increasing local land rents, as in the case of $c_2(x)$, mill prices increase and price discrimination is lower relative to the cases where local land rents decrease with the distance to the farmstead. A similar pattern, i.e., lower price discrimination in the range of increasing local land rents could be observed for cost functions which feature a minimum close to the farmstead, as in the case of $c_3(x)$ in Figure 5. This figure shows the outcome if we consider quadratic cost functions with a cost minimum for a small farm size ($c_3(x) = 0.2x^2 - 0.1x$) or a larger farm size ($c_4(x) = 0.05x^2 - 0.1x$) where the cost minimum coincides with the location of the competitor. That is, the farm needs to rent all land in the region to exploit the cost minimum. Nevertheless, high price discrimination dominates the pricing also under quadratic cost functions.

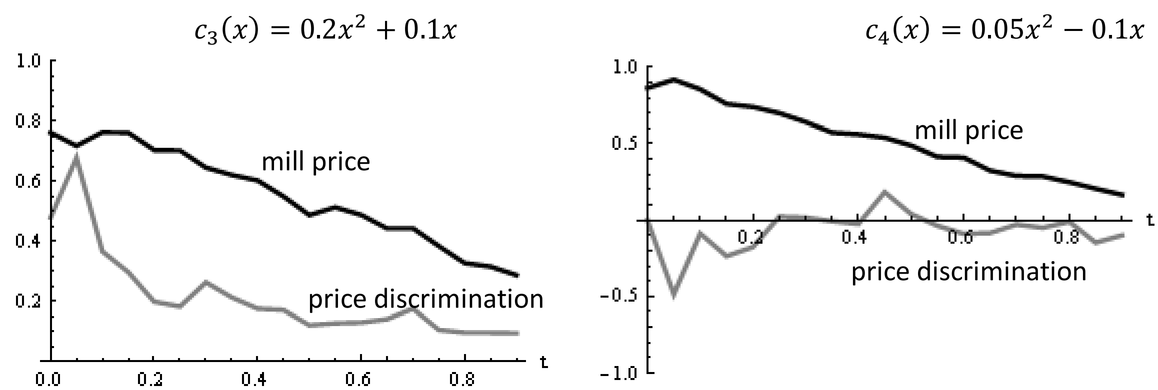

Figure 5: The optimal spatial price strategy (m, φ) under quadratic cost functions.

Conclusions

The comparison of UD and FOB pricing under economies of scale shows that UD pricing can generate higher profits than FOB pricing for farmers renting land. This is not surprising because farmers can extract most of the land owner's surplus under UD pricing and perfectly inelastic land supply (Zhang and Sexton, 2001). However, the analysis shows also that under certain conditions UD pricing is less profitable if farmers operate under increasing local land rents. The slope of the price distance function is negative under FOB pricing and if returns $(R - c(d))$ increase with distance, the local profit increases as well, which would make FOB pricing superior compared to UD pricing.

However, due to a high price at the market border a farm could overbid its neighbor for more distant plots, which more than compensates the disadvantages regarding the local profit relative to FOB pricing. This is shown if farms are allowed to choose their price strategy endogenously. Based on a linear price distance function that nests FOB and UD pricing but also includes reverse price discrimination, i.e., the slope of the price distance function is within the interval $[-t, t]$. For instance, we illustrate that the competitive advantage of UD pricing can be surpassed with a price distance function that has a positive slope in an environment of increasing returns to scale and despite the existence of transport costs. As a consequence, competition increases and farmers' profits decrease. Nevertheless, the slope of the price distance function is close to UD pricing for the investigated cost specifications and reverse price discrimination seems to play a minor role in this setting of spatial competition.

The conducted simulations gave us a first impression of the effects induced by economies of size into a spatial price competition model. However, more work needs to be done to provide a proper theoretical explanation of these effects. The objective of future work is to develop a spatial competition model with appropriate specified cost and pricing functions that shall help us to explain observations on the land rental market. The insights form the presented simulations are a first step in this direction.

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