Analyzing the impact of soil contamination on farmland values: A spatial hedonic approach using quantile regression

Eloi Schreurs[a], Steven Van Passel[a], Ludo Peeters[b] and Theo Thewys[a]

a. Research group of Environmental Economics, Centre for Environmental Sciences, Hasselt University, Agoralaan - Building D, 3590 Diepenbeek, Belgium;

b. Research group of Public Economics, Centre for Entrepreneurship and Innovation, Hasselt University, Agoralaan - Building D, 3590 Diepenbeek, Belgium;

eloi.schreurs@uhasselt.be; steven.vanpassel@uhasselt.be; ludo.peeters@uhasselt.be; theo.thewys@uhasselt.be

Abstract

Hedonic studies estimating the effect of environmental disamenities such as soil contamination have focused solely on residential property values thus far. However, since contamination of agricultural land can also cause considerable risks to food safety and hence public health, it is expected to impact farmland values as well. This empirical application aims to fill this research gap by incorporating soil contaminants into a hedonic farmland model. The Campine region, an agricultural area in Belgium that has been historically contaminated with heavy metals – particularly cadmium (Cd) – was used as a case study. Soil Cd concentrations were predicted by means of spatial interpolation techniques and added to 599 farmland transactions that have occurred in the area between 2004 and 2011. In order to take into account some of the issues related to standard spatial econometric techniques, classic linear regression is complemented by quantile regression and a spatiotemporal framework is introduced that only incorporates sales preceding other sales by maximum one year. Goal was to particularly explain the spatial spillover effect caused by previous sales. All regression models found that soil Cd levels did not significantly impact farmland values in the area. Apparently, other factors such as redevelopment potential, current land use and zoning regulations are more important price determinants for agricultural land buyers than soil contamination. The spatiotemporal lag coefficient was found to be highly significant in both mean and median regression models.

Keywords: hedonic pricing analysis; farmland values; soil contamination; quantile regression

1. Introduction

The contamination of agricultural soils can create a persistent and harmful problem to farmers as well as to society as a whole. Besides direct health risks for farmers working on these soils, the presence of contaminants can generate risks to crops grown on this land and thus to food safety (Dudka et al., 1996; Hough et al., 2003). Some foodstuffs have the capacity to easily transfer metals and other contaminants from the roots to the edible parts which can indirectly cause hazards to public health (Vromman et al., 2008). Since national as well as supranational (European) governments aim to ensure the consumer's food safety, strict guidelines have been established which food producers have to comply to in order to offer their products on the market. Farmers who try to market crops that exceed these food thresholds are running the risk of being unable to sell their output.

In order to obtain welfare estimates on the damages caused by environmental pollution, revealed preference techniques such as hedonic pricing analysis are an attractive alternative. The method is based on the premise that the price of a differentiated good is composed of the value that each characteristic appends to the product (Rosen, 1974). Therefore, product prices are adopted to extract the consumer's marginal willingness to pay for underlying characteristics. Empirical applications of the hedonic price method mainly focus on the valuation of non-marketable variables from real estate prices. Prices for housing and land are apt for application in hedonic models, because it concerns multi-attribute and multi-faceted products that can be linked relatively easy to an associated bundle of heterogeneous characteristics. Moreover, the location choice can often be related to neighboring (environmental) amenities and data with regard to real estate sales or appraisals are widely available in many countries.

When researching the economic effect of environmental pollution on real estate values, generally environmental quality indicators are used as a measure for the variable of interest. Hedonic studies focusing on the value of contamination often relate the level of polluting elements in an environmental medium such as soil (Clauw, 2007; Guignet, 2013), water (Leggett and Bockstael, 2000; Poor et al., 2007) or air (Kim et al., 2003; Yusuf and Resosudarmo, 2009) to property values. If objective risk measures are unavailable, the proxy that is most frequently used to account for the disamenity is the distance to a pollution source (Zabel and Guignet, 2012) or an undesirable land use such as waste sites (Braden et al., 2011).

However, a common aspect in these hedonic studies is that all research – for now – has focused on residential property values to estimate the economic consequences. To the best of our knowledge, the effect of contamination on agricultural land prices has never been empirically analyzed before. This paper aims to fill this research gap by applying the hedonic methodology to the farmland market in the Campine region, an area in Belgium that has been affected by heavy metal deposition from the metallurgic industry. An extensive dataset of soil Cd sample measurements was available, which allowed us to predict Cd concentrations using spatial interpolation techniques. These contaminant levels were then linked to farmland sales that have occurred in the area between 2004 and 2011 in order to reveal to what extent agricultural land buyers value the presence of soil contaminants.

This paper is structured as follows. First, we will elaborate on the hedonic model and spatial econometric techniques that can be applied to farmland values. In section 3, the Campine region will be situated in Belgium. Section 4 will describe the data that are used in the analysis, while the most important results will be reported in section 5. In the last section some concluding remarks will be given.

2. Methodology

2.1. Hedonic model for agricultural land

In Rosen's seminal article hedonic prices are described as the implicit prices of attributes which are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them (Rosen, 1974). A differentiated product can thus be represented by a vector of *k* characteristics $X = x_1, x_2, x_3, \ldots, x_k$ with sales price Y. A standard hedonic model is defined as follows:

$$Y = \alpha\iota + \beta X + \varepsilon \quad [1]$$

Where Y represents a 1 x n vector of property prices; α is a constant term to be estimated; ι is a 1 x n vector of ones; β is a 1 x k vector of coefficients to be estimated; X is a k x n matrix for property attributes; and ε is the vector of randomly distributed error terms.

Palmquist (1989) developed an theoretical model for the farmland market using agricultural rent prices. However, people that rent farmland will only be interested in the land's current productive capabilities. The equilibrium rent schedule will be determined by variables related to land productivity. In a competitive market the value of the land as an asset is determined by the present value of the future stream of rents produced by this land. Besides productivity variables, other characteristics that indicate a parcel might be more attractive or valuable in the future will affect the land's sales price while rental values will remain unchanged. Correspondingly, factors that are important in an agricultural setting might be discounted if that characteristic is not that important in an alternative land use that is anticipated in the near future (Palmquist and Danielson, 1989). In summary, differences in land values are accounted for by differences in the productivity of the land as well as the buyer's expectations with regard to its future development (Plantinga et al., 2002).

Therefore, Palmquist's model is modified in order to deal with sales prices. Petrie and Taylor (2007) easily resolved this by assuming the rental price R is a simple transformation of the sales price P. More specifically, if it is assumed that all farmers can apply to the same market-clearing interest rate, annuities of sales prices can be considered equivalent to rental prices.

$$R = f(P(x_1, x_2, x_3, \ldots, x_k)) \qquad [2]$$

This way, the rental price is dependent on a vector of *k* characteristics, in which the vector includes all characteristics that affect sales prices and thus is not limited to only those factors that affect rental prices. Theoretically, however, the derivation is the same.

Whether the hedonic model is able to estimate the value of changes in characteristics of farmland is also dependent on the extent of the impact (Palmquist and Danielson, 1989). If the change in a certain characteristic is only affecting an individual landowner or a small number of parcels within the land market, the equilibrium price schedule will remain constant because it will not have a significant impact on other parcels in the land market. In contrast, if the changes affect land prices for the greater part of the land market or the entire land market – for example, when national or regional land policies are altered – the price schedule will shift to a new equilibrium. In this case, it is only possible to derive the upper bound on the value of land improvements. Therefore, the hedonic method is more suitable for localized externalities (Palmquist, 1992).

2.2. Spatial econometric issues

In empirical applications of hedonic studies, generally two models are applied for taking into account spatial dependence, i.e. the spatial autoregressive model (SAR) and the spatial error model (SEM). Accumulating criticism on these classic spatial econometric techniques by regional scientists (Gibbons and Overman, 2012; McMillen, 2012; Pinkse and Slade, 2010) has encouraged us to go beyond the scope of these analyses. However, since the primary objective of this paper is to reveal the impact of soil contamination on farmland values, by no means we aspire to establish any groundbreaking modeling approach with regard to the weaknesses in current spatial econometric research. Nevertheless, we will consider the suggestions made by the these authors in order to overcome some of the issues. Our efforts in this setting are twofold.

First, a spatiotemporal lag of nearby property prices is included in the hedonic equation to capture the influence of localized (time-varying) omitted variables. This lagged value is basically a spatially weighted average of realized farmland prices in the recent past within some predefined neighborhood. Therefore, this spatiotemporal framework will be particularly focused at explaining the spatial causality effects that nearby observations are enforcing.

In this setting, two issues arise: (1) how to define the relevant 'neighborhood'; and (2) how to determine the 'recent past'. To address the first issue, we use the distances between parcels in the sample as a measure of proximity. Specifically, the spatial weights matrix **S** contains the inverse distances between observations, $s_{ij} = 1/d_{ij}$ for $i \neq j$, with diagonal elements, s_{ii}, set to zero. As regards the second issue, we choose a time window of 12 months. The temporal-dependence matrix **T**, with elements t_{ij}, is specified as a matrix containing blocks of ones to identify parcels sold on an earlier date within the 12-months time window (where the ones are replaced by zeros for those parcels sold on the same day). The ultimate spatiotemporal matrix **W** is the Hadamard (element-by-element) product of the spatial weight matrix **S** and the temporal matrix **T**. Unlike Maddison (2009), **W** is row-standardized only once, namely at the final stage. The specifics are as follows:

$$\mathbf{W} = \mathbf{S} \odot \mathbf{T} \qquad [3]$$

$$Y = \alpha\iota + \theta\mathbf{W}Y + \beta X + \varepsilon \qquad [4]$$

Where $\odot$ represents the Hadamard multiplication operator and θ is the spatiotemporal lag coefficient. Other parameters in equation [4] are the same as in equation [1].

Obviously, this procedure requires making specific choices. Many different decision rules can be used, since theory provides no clear guidance. Our choice of the inverse distances is based on the observation that spatial correlations are far much stronger among sale prices within a short distance range. Also, our choice of the length of the time period over which agents are assumed to base their information is partly motivated by the modest size of the dataset (599 observations). We decided to choose a 12-months time window, which implies that the first 64 observations of our dataset (10.7% of the original sample) are lost. If a time frame of 24 months was selected, we would have lost already 160 observations (26.7% of the original sample). The 12-months time window seemed to be the most reasonable way to compromise between losing observations and taking into account spatiotemporal effects.

Secondly, classic linear regressions will be complemented by quantile regression (QR) in order to test the robustness of the results. Although QR has been around for quite some time (Koenker and Bassett, 1978), it has only recently found its way into the hedonic farmland literature (Kostov, 2009; Uematsu et al., 2013). While linear regression presents conditional mean estimates, QR is able to produce conditional estimates of explanatory factors for the full distribution of the dependent variable. Therefore, its principal advantage is the provision of much more information in comparison with conditional mean estimates. This allows to get a more comprehensive view and a better understanding of the relationship between variables. Moreover, the results are more robust against heteroskedasticity and outliers in the response variable. Additionally, since QR estimates can be presented alongside OLS estimates, the results can be compared between different estimation procedures (McMillen, 2013).

3. Case study

The Campine region is a sandy agricultural area in the northeast of Belgium (Figure 1). Zinc smelters have contaminated the area with heavy metals such as cadmium (Cd), zinc (Zn), lead (Pb) and copper (Cu) (Vangronsveld et al., 1995). The factories have stopped polluting the area after the transfer from a pyro-metallurgic to an electrolytic refining process and the adoption of strict emission guidelines in the middle of the 1970's. Nevertheless, an extensive area of 700 km^2 in both Belgium and the Netherlands has been diffusely contaminated (Hogervorst et al., 2007; Witters et al., 2012). However, only Cd concentration levels exceed current threshold values set by the Flemish government (Table 1) in some nature, residential and agricultural areas.

Figure 1: Situating the Campine region and the study area in Belgium

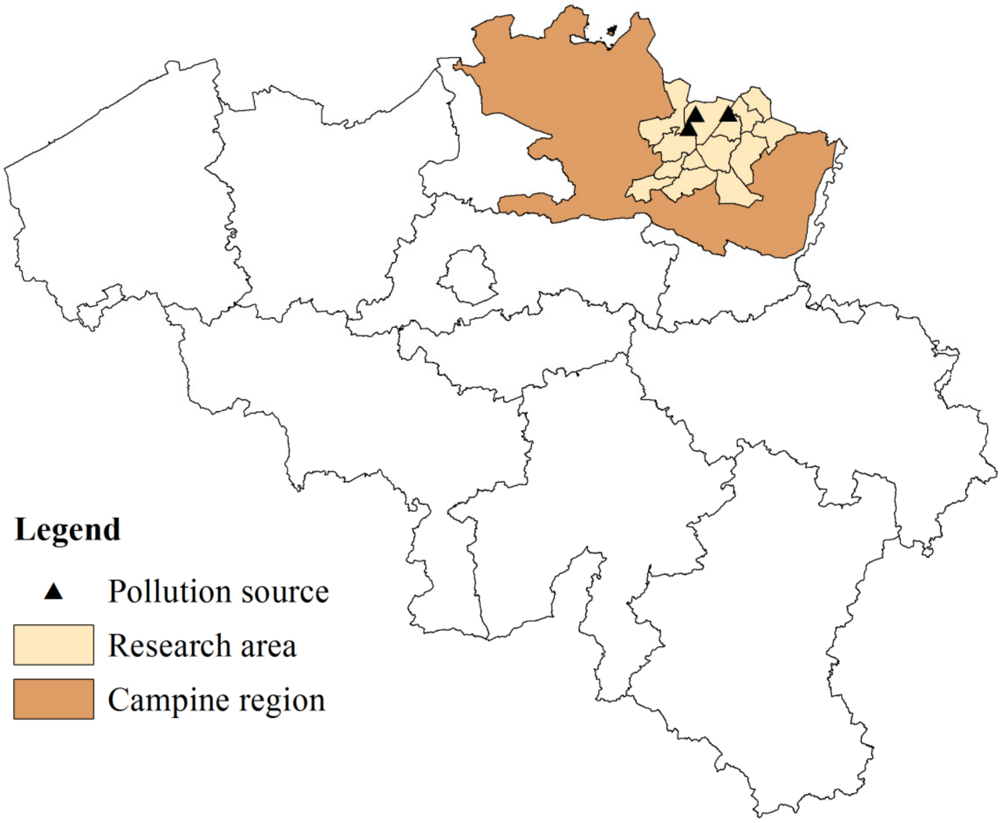


Table 1: Soil standards for Cd in Flanders (in ppm)

Land use	Nature/Forest	Agricultural	Residential	Recreational	Industrial
Target value	0.7	0.7	0.7	0.7	0.7
Guide value	1.2	1.2	1.2	1.2	1.2
Threshold value	2	2	6	9.5	30

Since cadmium is the only contaminant that exceeds threshold values in the Campine region, this research will focus solely on soil Cd concentrations. In this setting, soil Cd concentrations for the study area have been predicted in Schreurs et al. (2011) using spatial interpolation techniques. These predictions were based on a database of 2189 soil sample measurements[1]. However, in the meanwhile this database has been expanded to 11,885 soil Cd samples, which has greatly improved the quality of the predictions. The new prediction maps are created using ordinary kriging and are based on an exponential model of logtransformed Cd samples. The results show that the amount of farmland exceeding soil Cd thresholds of 1.2 ppm and 2 ppm equals 3027 ha and 1782 ha, respectively, indicating that the extent of the contamination is quite considerable.

[1] See Schreurs et al. (2011) for an elaborate description of the data and the prediction methodology.

4. Data

The Cadastre, the governmental institution which is responsible for the registration of real estate transactions in Belgium, provided the data for all farmland transactions that have occurred in the research area during the time frame 2004-2011. The study area included fourteen municipalities in the Campine region that have been affected to some extent by soil contamination or that are relatively close to the pollution sources. The dataset included price, lot size, cadastral information, sales method and date of 651 farmland transactions. The cadastral information was used to georeference the agricultural parcels in ArcGIS 10.0. Fifty two transactions were excluded because they lacked information or because the transaction could not be located geographically due to cadastral numbers that have been altered in the meanwhile. In the end, 599 sales transactions were maintained for statistical analysis. The nominal prices were adjusted to real prices of 2011 using a monthly indicator for the Consumer Price Index (CPI) in Belgium to correct for inflation.

Seeing that the goal of the paper is to determine the impact of historic soil pollution on farmland prices, environmental risk factors consisting of soil Cd concentrations are appended to the model. The prediction maps described in section 3 are used to relate predicted Cd levels to the location of the parcel. Furthermore, no additional environmental measures were appended to the model. Since the size of study area is quite small and the Campine region is rather homogeneous with regard to soil structure, there are hardly any differences in soil productivity between parcels. The climatic conditions are also the same throughout the entire study area.

Other agricultural factors such as current land use might influence farmland values. Flemish farmers have to report what was cultivated on every parcel of land dedicated to agricultural activities as a result of strict fertilizing restrictions. Consequently, it is observable which crop was cultivated on each parcel at the time of sale. Approximately half of them were used as pastures. Most of these parcels were labeled as permanent pasture, which implies that they are not included in a crop rotation scheme for at least five years. This may be due to the ratio of permanent pasture vis-à-vis complete agricultural land the farmer is obliged to maintain as a result of the European Common Agricultural Policy (CAP). Mostly, land which is least suitable for crop production will be allocated to pastures in order to comply to this condition. However, some parcels are required to stay pasture permanently because of other regulations. In any case, the agricultural potential of pastures is rather low. Additionally, when the land transaction accommodated a stable according to cadastral information, this was controlled for as well.

Location variables do not address attributes of the parcel itself, but aspects from its broader surroundings that might have an impact on the willingness to pay for farmland. With respect to these variables, the zoning typology farmland is located in might be an important factor. Given the scarcity of land in a densely populated region as Flanders, there is an increasing pressure on agricultural land for redevelopment into other land uses such as residential, nature and industrial zoning. Consequently, land that has historically been dedicated to farming purposes can have its destination type adjusted by means of governmental decisions. Although most observations were still located in an agricultural zoning type at the time of sale, there are a number of parcels that have been sold in a non-agricultural zoning type. These observations particularly include residential and nature zoning types. This can be an indication that the land is destined to serve other purposes after the transaction.

An important price effect in farmland is due to urban sprawl and rural redevelopment. The level of urbanization is mostly accounted for by introducing the distance to the nearest city center as a proxy for potential future redevelopment. However, since there is no clear urban center in the vicinity of the research area, the number of housing units within a radius of 1000 m (referred to as address density) from each observation is inserted to account for the speculation effect. A location aspect that is quite specific to this case study is the proximity of the Dutch border. In the Netherlands, farmland values are roughly 50 to 100% higher than in Belgium. Therefore, it might seem reasonable for Dutch farmers to cross the border in order to buy agricultural land at substantially lower prices than in the Netherlands.

Furthermore, transaction variables comprise factors relating to the actual transition of land from seller to buyer. Although nominal sales prices are adjusted to real prices, the introduction of a time trend might be helpful to control for yearly influences on land prices. Additionally, the sales method – either private or public – may be an important aspect in Belgium (Ciaian, 2012). In private transactions, the parties involved might be engaged in mutual interests or having personal relationships. This increases the probability that price negotiations will result in agreeing to a below-market price. Excluding all private transactions, which probably include non-arm's length transactions, was not possible since merely 18% of all observations were public sales (Table 2).

Table 2: Descriptive statistics

Variable	**Unit**	**Mean**
Real price	€/m²	2.83
Nominal price	€/m²	2.54
Cd concentration	ppm	1.01

Lot size	m²	14005.55
Address density	# housing units in 1 km radius	413.68
Distance to Dutch border	m	10463.51
Dummy variables		**Count**
Building		31
Pasture		252
Residential zoning		47
Nature zoning		65
Public sale		110
Year 2004		50
Year 2005		100
Year 2006		91
Year 2007		80
Year 2008		69
Year 2009		68
Year 2010		76
Year 2011		65

5. Results

Four log-linear models have been estimated. The first two models are classic linear regression models using ordinary least squares (OLS) to estimate the effect of explanatory variables on farmland values. In the latter two models, conditional median effects are estimated by means of quantile regression. The spatiotemporal lag coefficient is included in model 2 and 4.

Table 3: Regression results

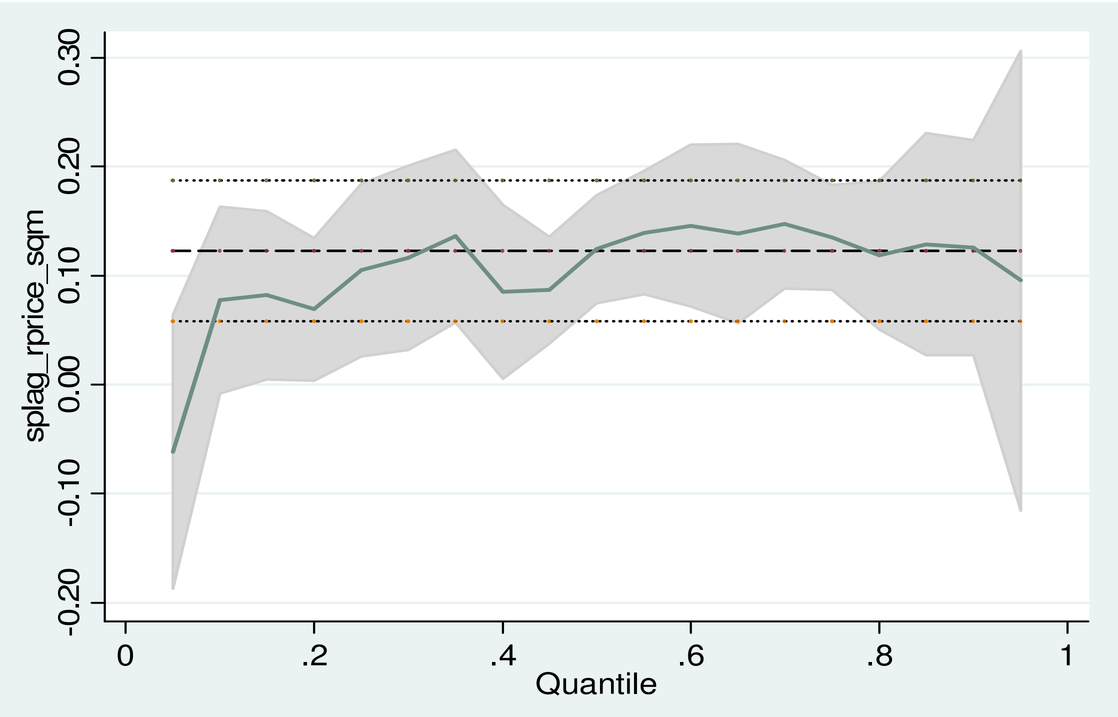
Dep. variable: log sales price/m²	Mean regression (OLS)		Median regression (QR)	
Cd concentration	0.009	0.010	0.014	0.026
Log lotsize	-0.042*	-0.051**	-0.014	-0.017
Structures	0.138	0.160*	0.218***	0.212**
Pasture	-0.169***	-0.143***	-0.119***	-0.117***
Residential zoning	0.346***	0.276***	0.189***	0.175**
Nature zoning	-0.112	-0.092	-0.159***	-0.133**
Address density	2.480 E-4***	1.655 E-4**	1.585 E-4***	9.195 E-5
Distance to Netherlands	-1.768 E-5***	-1.560 E-5***	-1.257 E-5***	-1.202 E-5***
Public sale	0.203***	0.231***	0.226***	0.244***
Time trend	0.025***	0.025**	0.031***	0.031***
θ	/	0.123***	/	0.124***
Constant	-48.608**	-49.647**	-61.435***	-61.184***
N	599	535	599	535
R^2	0.196	0.203	/	/

Adjusted R^2	0.183	0.186	/	/
Pseudo R^2	/	/	0.103	0.105

*, **, *** represents significance at 10%, 5% and 1% level, respectively.

In none of the models significant results are found for the environmental risk variable (Table 3). Seemingly, farmland buyers do not value the presence of soil Cd in the prices they are willing to pay for agricultural land. Assuming that all parcels are bought for agricultural purposes, farmers might not intend to use the acquired land for hazardous crops. In this case, farmers would solely be missing out on the option value of converting the soil to different crop cultivations in the future. However, another explanation might be a lack of awareness among farmers with regard to the presence of soil contaminants. If soil certificates lack the necessary information concerning the polluting elements, farmland buyers are unable to take their presence into account in price setting. Alternatively, other factors might be plainly more decisive in determining farmland values.

Figure 2: Quantile estimates of the spatial lag coefficient θ

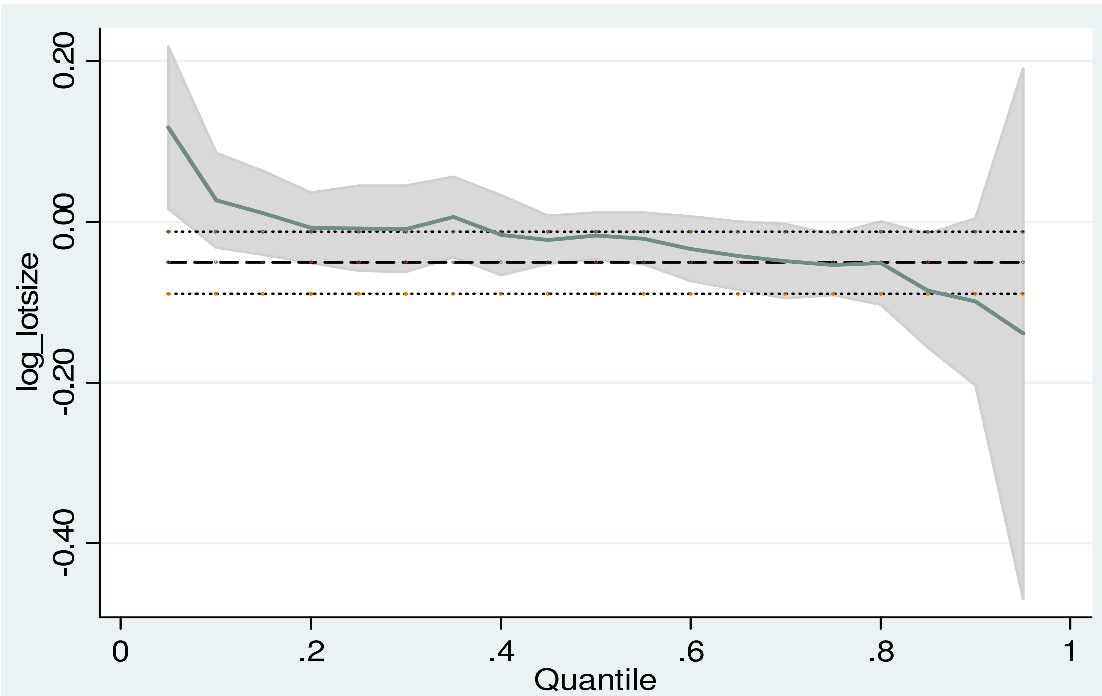


The green line represents the quantile estimates, the gray area represents the confidence intervals of quantile estimates and the dotted lines represent mean estimates (linear regression) and its confidence interval.

The spatiotemporal lag coefficient θ is highly significant in both mean and median regression. This illustrates that most likely a spatial spillover effect is at play in the regional farmland market. Since only observations that have occurred in the year prior to the sale under consideration are included in the spatiotemporal lag, it is prevented that implausible relations with other observations (such as future sales and sales from a long time ago) are made. Quantile estimates of θ in Figure 2 show that the effect of θ is relatively constant over the complete price distribution, except for the lower quantiles. Spatial dependence seems to play a less important role in lower price segments of the farmland market.

The estimates of all other explanatory factors show the expected sign and are significant in at least one of the models. However, for some variables there are differences in significance between mean and median estimates. For example, lot size is significant in the mean regression, but not in the median regression. Luckily, quantile estimates allow us to obtain a more comprehensive view on this discrepancy. In Figure 3, it is demonstrated that lot size is particularly exerting a negative effect in higher price segments, while there is even a positive coefficient in lower price segments. Perhaps, the result in upper quantiles can be explained by individuals buying smaller parcels of land for residential purposes. Another explanation can be related to horse farmers. This type of farming is not particularly interested in large pieces of farmland, but their willingness to pay for farmland is generally somewhat higher than other farming types. In lower price segments, farmers are willing to pay more for sizeable parcels to benefit from the economies of scale provided by these parcels.

Figure 3: Quantile estimates of log lotsize



Judging from the significant effects of residential zoning and the address density near parcels, the potential for redevelopment of agricultural parcels seems to be an important price determinant in the Campine region. While land in densely populated areas is generally more apt for redevelopment in the long run, parcels located in residential zoning are more likely to be redeveloped in the short term. However, there does not seem to be a substantial difference between the effects, both of them clearly have a powerful inflating effect on farmland values. Another important price effect is found in parcels close to the Dutch border. The proximity to the Netherlands has a clear positive impact on farmland values in Belgium. This might be an indication that the Dutch farm holders are crossing the border in search for opportunities to expand their agricultural activities.

High administrative costs associated with buying a piece of (farm)land in Flanders and Belgium have resulted in the emergence of a grey market (Ciaian et al., 2012). Registration taxes in Flanders amount to 10% of land value. This effect can be derived indirectly from the regression results, which show that public sales transactions deal with a price markup of more than 20% in comparison with private sales. Furthermore, the time trend is highly significant in all models. Seeing that prices have been corrected for inflation using the CPI, this illustrates that agricultural land prices have increased with above-inflation percentages from 2004 to 2011. This result might be partially explained by the increasing pressure on farmland from other zoning types such as residential and nature zoning. Seeing that this will lead to an increasing scarcity in the farmland market, higher land prices would be an economically reasonable consequence.

6. Conclusion and discussion

Contamination of agricultural parcels can cause a number of adverse effects and risks to the farmer’s operations. Besides direct human health risks for farmers working on these soils, the presence of contaminants can also generate risks to crops grown on this land and thus to public food safety. Farmers that try to market crops that exceed food thresholds are running the risk of being unable to sell their output and facing a loss of income. Although the risks of contaminated farmland are considerable, soil contaminants have never been incorporated in empirical hedonic analyses of agricultural land before. This research aims to reveal to what extent farmland buyers value the presence of heavy metals in soils. Therefore, a hedonic model was applied to 599 sales transactions that occurred in the Campine region between 2004 and 2011.

In empirical applications of hedonic models, spatial econometric techniques have become standard tools to control for spatial effects possibly present in real estate data. Typically, the two dominant models of spatial autocorrelation, i.e. spatial lag and spatial error, are tested for. However, since these models have increasingly been criticized in recent years, we have tried to remediate some of the issues presented by these authors in this analysis. Firstly, by introducing a spatiotemporal framework only incorporating past sales with a time window of 12 months. This way, we aimed to particularly explain the spatial spillover effect caused by previous sales. On the other hand, quantile regression was applied in order to test the robustness of the results and to obtain a better understanding of the explanatory effects. The spatiotemporal lag coefficient was found to be highly significant in both mean and median regression models. Except for lower price quantiles, the coefficient was playing a prominent role throughout the entire price distribution.

All regression models indicated that soil Cd concentrations were insignificant determinants for farmland values. Despite the considerable risks associated with farmland contamination, soil Cd levels are apparently not a critical factor in the price setting of agricultural land in the region. There might be different explanations for this result. Possibly, farmers that do not intend to use the acquired land for crops with a considerable risk of exceeding food thresholds might not take their presence into account. For example, dairy farmers – the most important farming activity in the Campine region – predominantly need pastures and corn as a feed stock for their animals. These cultivations only have a limited capacity for taking up heavy metals, so there is little risk milk thresholds for heavy metals will be exceeded. Moreover, farmers who intend to expand their agricultural activities need to comply with strict fertilizing restrictions in Belgium. Hence, these regulations in combination with farmland scarcity might forces them to purchase land with inferior characteristics.

However, another explanation might be that farmland buyers were unaware of the exact Cd concentrations present in the acquired parcels. In case the soil certificates were lacking the necessary information concerning the polluting elements, farmland buyers would have been unable to take their presence into account in price setting. Although the importance of soil contaminants to farmers probably differs between farm types, it is the government's responsibility to create policies that protect potential land buyers from buying parcels having undesirable characteristics of which they were unaware. One way of achieving this goal consists of informing land buyers about the condition the soil is in and the risks and land use restrictions they have to deal with when facing soil contamination. Whether the contamination is historic or recent is not particularly relevant in this setting, the consequences for buyers remain the same. In case agricultural land is concerned, disregarding potential risk factors in soils might lead farmers to use land inappropriately, thereby jeopardizing food safety and their income when their products are considered to be harmful.

References

Braden, J. B., Feng, X. and Won, D. (2011). Waste sites and property values: A meta-analysis. Environmental & Resource Economics 50(2): 175-201.

Ciaian, P., Kancs, A., Swinnen, J., Van Herck, K. and Vranken, L. (2012). Institutional factors affecting agricultural land markets. Brussels: Centre for European Policy Studies (CEPS).

Clauw, F. (2007). *The effect of soil contamination on real estate value: A hedonic pricing approach based on different risk measures.* (Ph.D. dissertation), Hasselt University, Diepenbeek.

Dudka, S., Piotrowska, M. and Terelak, H. (1996). Transfer of cadmium, lead, and zinc from industrially contaminated soil to crop plants: A field study. Environmental Pollution 94(2): 181-188.

Gibbons, S. and Overman, H. G. (2012). Mostly pointless spatial econometrics? Journal of Regional Science 52(2): 172-191.

Guignet, D. (2013). What Do Property Values Really Tell Us? A Hedonic Study of Underground Storage Tanks. Land Economics 89(2): 211-226.

Hogervorst, J., Plusquin, M., Vangronsveld, J., Nawrot, T., Cuypers, A., Vanhecke, E. et al. (2007). House dust as possible route of environmental exposure to cadmium and lead in the adult general population. Environmental Research 103(1): 30-37.

Hough, R. L., Young, S. D. and Crout, N. M. J. (2003). Modelling of Cd, Cu, Ni, Pb and Zn uptake, by winter wheat and forage maize, from a sewage disposal farm. Soil Use and Management 19(1): 19-27.

Kim, C. W., Phipps, T. T. and Anselin, L. (2003). Measuring the benefits of air quality improvement: a spatial hedonic approach. Journal of Environmental Economics and Management 45(1): 24-39.

Koenker, R. and Bassett, G. (1978). REGRESSION QUANTILES. Econometrica 46(1): 33-50.

Kostov, P. (2009). A Spatial Quantile Regression Hedonic Model of Agricultural Land Prices. Spatial Economic Analysis 4(1): 53-72.

Leggett, C. G. and Bockstael, N. E. (2000). Evidence of the effects of water quality on residential land prices. Journal of Environmental Economics and Management 39(2): 121-144.

Maddison, D. (2009). A Spatio-temporal Model of Farmland Values. Journal of Agricultural Economics 60(1): 171-189.

McMillen, D. P. (2012). Perspectives on spatial econometrics: Linear smoothing with structured models. Journal of Regional Science 52(2): 192-209.

McMillen, D. P. (2013). Quantile regression for spatial data. New York: Springer.

Palmquist, R. B. (1989). Land as a differentiated factor of production - A hedonic model and its implications for welfare measurement. Land Economics 65(1): 23-28.

Palmquist, R. B. (1992). Valuing localized externalities. Journal of Urban Economics 31(1): 59-68.

Palmquist, R. B. and Danielson, L. E. (1989). A hedonic study of the effects of erosion control and drainage on farmland values. American Journal of Agricultural Economics 71(1): 55-62.

Petrie, R. A. and Taylor, L. O. (2007). Estimating the value of water use permits: A hedonic approach applied to farmland in the southeastern united states. Land Economics 83(3): 302-318.

Pinkse, J. and Slade, M. E. (2010). The futute of spatial econometrics. Journal of Regional Science 50(1): 103-117.

Plantinga, A. J., Lubowski, R. N. and Stavins, R. N. (2002). The effects of potential land development on agricultural land prices. Journal of Urban Economics 52(3): 561-581.

Poor, P. J., Pessagno, K. L. and Paul, R. W. (2007). Exploring the hedonic value of ambient water quality: A local watershed-based study. Ecological Economics 60(4): 797-806.

Rosen, S. (1974). Hedonic prices and implicit markets - Product differentiation in pure competition. Journal of Political Economy 82(1): 34-55.

Schreurs, E., Voets, T. and Thewys, T. (2011). GIS-based assessment of the biomass potential from phytoremediation of contaminated agricultural land in the Campine region in Belgium. Biomass & Bioenergy 35(10): 4469-4480.

Uematsu, H., Khanal, A. R. and Mishra, A. K. (2013). The impact of natural amenity on farmland values: A quantile regression approach. Land Use Policy 33: 151-160.

Vangronsveld, J., Van Assche, F. and Clijsters, H. (1995). Reclamation of a bare industrial area contaminated by non-ferrous metals: in situ metal immobilization and revegetation. Environmental Pollution 87(1): 51-59.

Vromman, V., Saegerman, C., Pussemier, L., Huyghebaert, A., De Temmerman, L., Pizzolon, J. C. et al. (2008). Cadmium in the food chain near non-ferrous metal production sites. Food Additives and Contaminants 25(3): 293-301.

Witters, N., Mendelsohn, R. O., Van Slycken, S., Weyens, N., Schreurs, E., Meers, E. et al. (2012). Phytoremediation, a sustainable remediation technology? Conclusions from a case study. I: Energy production and carbon dioxide abatement. Biomass & Bioenergy 39: 454-469.

Yusuf, A. A. and Resosudarmo, B. P. (2009). Does clean air matter in developing countries' megacities? A hedonic price analysis of the Jakarta housing market, Indonesia. Ecological Economics 68(5): 1398-1407.

Zabel, J. E. and Guignet, D. (2012). A hedonic analysis of the impact of LUST sites on house prices. Resource and Energy Economics 34(4): 549-564.