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USING ECONOMETRIC MODELS TO ANALYSE THE SPATIAL DISTRIBUTION OF OIL PUMPKIN CULTIVATION IN AUSTRIA

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Abstract

The liberalisation and globalisation of agricultural markets, has led to a shift of the EU common agricultural policy from quantity based to quality based policies and is accompanied by diversification of agricultural production in the European Union. For policy makers it is therefore relevant to better understand the drivers that influence the adoption and spatial distribution of emerging alternative practices and commodities in agriculture. Taking the Styrian Oil Pumpkin as an example, the aim of this study is to quantify the drivers of spatial variations in the cultivation of an emerging alternative crop. We estimate different econometric models, drawing on cross sectional data of the year 2010 of 549 municipalities in the Styrian Oil Pumpkin PGI area. Our findings indicate that (i) crop-specific factors, (ii) region-specific factors and (iii) spatial interdependencies influence spatial variations in oil pumpkin cultivated area and conclude that these factors also need to be considered for the promotion of other emerging alternative practices and commodities in agriculture.

Keywords

Styrian Pumpkin Seed Oil, PGI, Austria, spatial econometrics, SLX model

1 Introduction

In recent decades the ongoing liberalisation and globalisation of agricultural markets has led to an increasing exposure of agriculture in the European Union (EU) to competition on the world market (THOMPSON et al., 2000; MCNAMARA and WEISS, 2005). One strategy to confront this development is the diversification of agricultural production (MCNAMARA and WEISS, 2005), which has led to a growing interest in alternative practices like organic farming (DARNHOFER et al., 2005) or emerging alternative commodities like regional food products (TREGEAR et al., 2007) and marks a shift of the EU common agricultural policy (CAP) from quantity based to quality based policies (BECKER, 2009).

In the literature a wide range of factors has been identified that influence the adoption and spatial distribution of alternative practices/commodities in agriculture. However, it is often not considered that the relevant factors depend to a great extent on the specific crop/practice as well as the regional context of the analysis (KNOWLER and BRADSHAW, 2007). For example, adopting a crop is less complicated than adopting a practice like organic farming that is not divisible and it takes longer until results of the adoption can be observed (PANNELL et al., 2006). The regional context is relevant, because factors that facilitate the adoption of the same practice or commodity may differ among regions due to region-specific potentials (KNOWLER and BRADSHAW, 2007). Another important factor that is recognized in the theoretical literature (PANNELL et al., 2006), but mostly not controlled for in empirical studies, is spatial interdependence, meaning any form of strategic interaction, indirect effect or spatial correlation among neighbouring observations. If spatial interdependence is not considered in an empirical analysis, this can lead to biased results (STORM et al., 2015).

The aim of our study is therefore to analyse the drivers of spatial variations in the cultivation of an emerging alternative crop, considering (i) crop-specific factors, (ii) region-specific factors and (iii) spatial interdependence. For our analysis the cultivation of Styrian Oil

Pumpkin in Austria serves as an applied example. This has several reasons. Firstly, it is an alternative crop that has experienced a very dynamic development in recent years. Secondly, since 1996 the name "Styrian Pumpkin Seed Oil" is a protected geographical indication (PGI), which limits the production of Styrian Pumpkin Seed Oil to a defined area (CRETNIK, 2014). Within this PGI area the cultivation of Styrian Oil Pumpkin is very unevenly distributed and local agglomerations can be identified that may be related to spatial interdependencies. Thirdly, the PGI area consists of two separated regions (northern and southern part), which differ in terms of production and marketing structure and are therefore likely to have developed in a different manner. Finally, to the best of our knowledge, no previous study has analysed region-specific drivers of spatial variations of an alternative crop with an empirical model.

As methodology we apply an econometric approach. This decision is based on the fact that we have previously gained valuable information on possible drivers of oil pumpkin cultivation by interviews with experts and now have access to a unique cross sectional dataset of the year 2010 for the 563 municipalities in the PGI area. To consider regional differences, we estimate separate Tobit models for the northern and southern part of the PGI area. As a final step, we control our results for the presence of spatial interdependencies by additionally estimating a Spatial Lag of X (SLX) model, introduced by LESAGE (2009) and recently also advocated by HALLECK VEGA and ELHORST (2015).

2 Background

2.1 Literature review of the adoption and spatial distribution of emerging practices and commodities in agriculture

Having developed from the analysis of technology adoption (LINDNER, 1987), literature on the adoption and spatial distribution of emerging practices and commodities in agriculture comprises practices like organic farming (PADEL, 2001) or conservation agriculture (RODRÍGUEZ-ENTRENA and ARRIAZA, 2013; ARSLAN et al., 2014) and commodities such as switchgrass (JENSEN et al., 2007) or soy (GARRETT et al., 2013). In such studies data from quantitative surveys or a farm census is analysed with either binary response (Probit/Logit) or censored (Tobit/double-hurdle) regression models that quantify the influence of determinants on the rate and/or intensity of adoption and spatial distribution of an emerging practice or commodity. Frequently identified factors are for example farm size, farm profitability, bio-physical quality of land or age and education level of the farmer among many others (RODRÍGUEZ-ENTRENA and ARRIAZA, 2013).

With regard to spatial interdependence, several studies use spatial regression models to analyse the spatial distribution of hog and dairy production (ROE et al., 2002; ISIK, 2004), maize and soy cultivation (ODGAARD et al., 2011; GARRETT et al., 2013) or alternative practices like organic farming (SCHMIDTNER et al., 2012; LÄPPLE and KELLEY, 2015; SCHMIDTNER et al., 2015). For example GARRETT et al. (2013) analyse the determinants of soybean cultivation in Brazil with a cross sectional spatial autoregressive (SAR) model on the county level. Their main findings are that beneficial biophysical conditions that lead to higher yields and certain supply chain configurations (cooperative membership and access to credit) promote soybean cultivation. SCHMIDTNER et al. (2015) analyse spatial variations of organic farming in the German federal states of Bavaria and Baden Württemberg on the municipality and county level with a cross sectional SAR model. They find that less favourable climatic conditions and a favourable social and political environment have a positive influence on organic farming and conclude that the share of organic farms in a municipality/county also depends on the share of organic farms in neighbouring municipalities or counties, which implies the presence of spatial interdependence.

2.2 The Styrian Oil Pumpkin

The Styrian Oil Pumpkin (*Cucurbita pepo subsp. Pepo var. Styriaca*) is a variety within the subspecies *Cucurbita pepo subsp. pepo.* It emerged in the Austrian federal state of Styria in the first half of the 19th century due to a spontaneous mutation, which led to the loss of the outer hull of its seeds, facilitating oil production and giving the oil a very distinct dark green colour and a nut-like taste (FRUHWIRTH and HERMETTER, 2007). The average yield of pumpkin seeds is about 500-600 kg/ha, but it is very sensible to weather conditions and can range from 400kg/ha up to 1,000 kg/ha and more. Seeds of highest quality are sold as a salty or sweet snack, but most are processed to pumpkin seed oil in oil mills (CRETNIK, 2015).

The PGI for Styrian Pumpkin Seed Oil is administered at the national level by the Styrian Pumpkin Seed Oil PGI Community Association ("Gemeinschaft Steirisches Kürbiskernöl g.g.A.") with about 3,000 members (2,500 farmers and 50 oil millers) (CRETNIK, 2014). Styrian Pumpkin Seed Oil PGI may only be produced form Styrian Oil Pumpkins cultivated in the south-eastern part of Styria and the southern part of Burgenland (southern PGI area) and 2 regions in Lower Austria (northern PGI area) (see figure 1). The processing of the seeds to oil is limited to the southern PGI area and has to be carried out using a defined production method (CRETNIK, 2014). Therefore, PGI seeds from the northern part have to be transported to oil mills in the southern part for the production of Styrian Pumpkin Seed Oil PGI. Even though this step in the production process is associated with additional transport costs, they are of minor importance, as the monetary value per unit of transported weight is relatively high (STYRIAN CHAMBER OF AGRICULTURE, 2015).

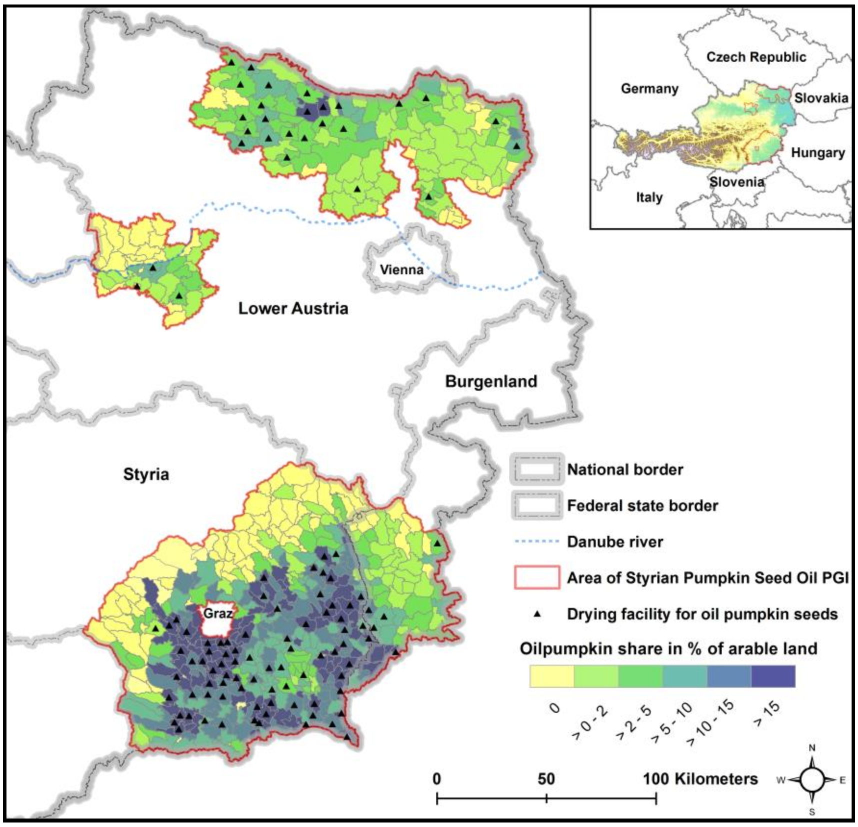

Figure 1: Oil pumpkin cultivation in municipalities located in the PGI area for Styrian Oil Pumpkin in 2010

Source: (BMLFUW, 2013; BMLFUW, 2014; STATISTIK AUSTRIA, 2013; STYRIAN PUMPKIN SEED OIL COMMUNITY ASSOCIATION, 2015; BASEMAP, s.a.; EUROGRAPHICS, s.a.)

Since the registration of the PGI in 1996, the cultivation of oil pumpkin in Austria has undergone a dynamic development. Driven by an increasing demand for products from the

Styrian Oil Pumpkin, the arable land cultivated with oil pumpkin increased from about 9.000 ha in 1995 to approximately 32.000 ha in 2015. Farmers receive a higher price for products that are produced according to the regulations of the PGI. Therefore, the vast majority of oil pumpkin (roughly 90 percent) is cultivated in the PGI area (AMA, 2015). Between 2000 and 2014 oil pumpkin cultivation within the PGI area increased in the northern part from 1.700 to 8.200 ha and in the southern part from 8.500 to 13.700 ha (STATISTIK AUSTRIA, 2015). The potential for oil pumpkin cultivation in these areas, considering crop rotation limitations[1], are 65.000 ha and 16.000 ha, respectively (CRETNIK, 2014).

3 Data basis and derivation of model variables

For our empirical model we draw on data from the municipality database (GEDABA) (BMLFUW, 2013), the Integrated Administration and Control System (IACS) database (BMLFUW, 2014), the Agricultural Structure Survey (STATISTIK AUSTRIA, 2013) and the STYRIAN PUMPKIN SEED OIL COMMUNITY ASSOCIATION (2015). The analysis is carried out at the municipality level, using cross sectional data from the year 2010 of the 563 municipalities located in the Styrian Pumpkin Seed Oil PGI area. Before estimation of the models, several observations are removed from the dataset, to reduce the effect of outliers and very small municipalities in terms of arable land (less than 5 ha). After this step 549 municipalities remain and represent the basis for our further analysis.

We now develop an overview of factors that may influence the spatial variations of oil pumpkin cultivated area in the PGI area for Styrian Pumpkin Seed Oil. First, we define the *share of arable land cultivated with oil pumpkin* as our dependent variable. In crop production, different crops compete for a finite amount of arable land. The share of arable land cultivated with a specific crop should therefore reflect its relative profitability, compared to other crops (GARRETT et al., 2013) and to a certain extent also to livestock production (depending on the amount of arable land that is required for the production of fodder). We hypothesize that the relative profitability of oil pumpkin production in a cross sectional setting with fixed price differences between competing crops depends on the *natural quality of arable land*, access to *special machinery* required for oil pumpkin production, as well as *production*- and *marketing*-related, *political, social, spatial, temporal* and *regional* factors, which we describe subsequently in more detail. To limit the discussion on the broad range of possible factors, we focus on variables that are available for our analysis.

The *natural quality of arable land* influences the yield potential. Moreover, pumpkins are not frost tolerant and therefore require favourable climatic conditions during their vegetative period from April to September, (DIEPENBROCK et al., 1999). We therefore introduce the soil quality index of arable land *(soilqual)* as our first independent variable. It is an index number that ranges from 0 to 100 and describes the quality of arable land, considering soil quality, climatic conditions and topography.

While cultivation of oil pumpkins can be carried out with a precision drill, which is also used for e.g. maize, other steps of the production process require *special machinery*. Pumpkin seed harvesters pick up and crush the pumpkins and collect the seeds (HEYLAND et al., 2006). After harvest, the seeds have to be washed and dried within a relatively short time frame (approximately 6 hours) in stationary washing and drying facilities, to prevent them from decay and prepare them for further processing (CRETNIK, 2015). Proximity to a washing and drying facility for pumpkin seeds is therefore another prerequisite for oil pumpkin cultivation and is introduced in our analysis with the variable *distdry* which measures the distance to the next washing and drying facility in kilometres. As the machinery required for the harvest as

[1] According to HEYLAND et al. (2006) due to phytopathological aspects, the share of oil pumpkin within crop rotation should not exceed 25 percent.

well as for washing and drying is relatively expensive, these steps of the production process are often carried out by agricultural service companies or organised collaboratively via agricultural communities (BRANDSTETTER, 2014). We therefore include the variable *agriserv* that indicates the amount of agricultural service provided to farms in working days.

The northern and southern part of the PGI area differ in terms of *production* and *marketing* structure. The southern part is characterized by a very long tradition in oil pumpkin cultivation, small farms and a high proportion of direct marketing farms (CRETNIK, 2014). In the northern part farms are larger, oil pumpkin cultivation also has a certain tradition, but it is not so important for regional identity and therefore direct marketing of pumpkin seed products is also less prevalent. Still, in the northern PGI area the oil pumpkin is an interesting crop for organic farms (BRANDSTETTER, 2014). Oil pumpkins are well suited to organic farming, since after harvesting of the pumpkin seeds, the pulp mostly remains on the field and provides nutrients for subsequent crops (Heyland et al., 2006). Moreover, a special product line, “Organic Styrian Pumpkin Seed Oil PGI”, guarantees organic farms an additional price premium. The farm size may have a positive or negative effect on oil pumpkin cultivation. It can either facilitate investment into machinery or limit oil pumpkin production, as it is rather labour intensive. To control for the effect of farm size in our model, we include the variable *farmsize*, measured as utilized agricultural area (UAA) in ha per farm. The next variable, share of organic farms per municipality *(organic)*, should reflect the differing production and marketing conditions of organic farms. To consider the different marketing possibilities of direct marketing farms, we include the share of direct marketing farms *(dirmark)*. The competition with livestock production is considered by adding the variable *livestock*, measured in livestock units per ha UAA.

Subsidies may be a *political* factor that influences spatial variations in oil pumpkin cultivation. The UBAG-subsidy[2] for example was granted for extensive land use practices on arable land and grassland within the previous Austrian agri-environmental program. For arable land, these practices included for example a wider crop rotation (less than 75% cereals and maize) and low fertilizer input (BMLFUW, 2015). Therefore, this subsidy may have been an incentive for farmers to cultivate oil pumpkin in order to widen their crop rotation. We control for an effect of this subsidy with the variable *(ubagarable)* that measures the sum of UBAG-subsidy in € granted for arable land per municipality.

In terms of *social* factors, the responsiveness of farmers to the dynamic development of oil pumpkin cultivation in recent years may be relevant for explaining spatial variations in oil pumpkin planted area. Literature shows that farmer characteristics like education or age and the social environment often play a role in this context (e.g. LÄPPLE et al., 2015). For our analysis we only have data on the education level of farmers, which we consider with the variable *education* that describes the share of farmers with a higher agricultural education. Within the agricultural structure survey this is defined as an agricultural education that comprises at least 3 years (STATISTIK AUSTRIA, 2013).

Finally, *temporal* and *regional* aspects also play a crucial role. For example, historical factors like a longer tradition in oil pumpkin cultivation may also influence current differences in oil pumpkin shares. To consider such unobserved heterogeneity among municipalities in a cross sectional analysis with aggregated data, a temporal lag of the dependent variable (mean of the oil pumpkin share of 2000 and 2001) is included as a control *(oilplag)*, a procedure proposed by WOOLDRIDGE (2012). Another control variable is the arable land per municipality *(arable)*, which allows us to estimate the share of oil pumpkin cultivated area of arable land, while holding arable land constant. A simple way to consider regional differences in a regression model is to include regional dummy variables. However, if the effects of the independent variables differ among regions, which is what we hypothesise in this analysis, this can be

[2] UBAG is an abbreviation for environmentally friendly management of arable land and grassland.

addressed by estimating separate regression models for the regions (northern and southern PGI area). For the analysis the variables *farmsize*, *ubagarable* and *arable* were logarithmized to approximate a normal distribution and reduce the effect of outliers (WOOLDRIDGE, 2012).

An overview of the variables used in our regression models is given in Table 1. A major pattern that can be observed is that means of most variables differ considerably between the two regions. Next to the description of the independent variables, we include the hypothesized sign of the independent variables.

Table 1: Descriptive statistics

Category	Variable (Hypothesized sign)	Code	Unit	Northern PGI area (n = 143)	Southern PGI area (n = 406)
Dependent variable	Share of oil pumpkin in percent of arable land (dependent variable)	oilp	%	2.3	10.7
Natural	Soil quality index of arable land (+)	soilqual	index	51.5	42.5
Machinery	Distance to next washing/drying facility (-)	distdry	km	4.0	4.2
Machinery	Agricultural service per farm (+)	agriserv	days/farm	1.0	0.8
Production	Farm size (+/-)	farmsize	ha UAA	36.2	12.7
Production	Share of organic farms (+)	organic	%	11.8	9.0
Production	Livestock density (-)	livestock	LU/ha	0.4	1.0
Political	UBAG-subsidy for arable land (+)	ubagarable	€	120,150.3	13,671.8
Marketing	Share of farms with direct marketing (+)	dirmark	%	4.5	7.5
Social	Share of farmers with higher agricultural education (+)	education	%	33.9	17.1
Control	Arable land (+)	arable	ha	1.928.6	413.1
Control	Temporal lag of oil pumpkin share (mean of 2000 and 2001) (+)	oilplag	%	0.6	5.4

Note: Values are means; UAA = utilized agricultural area; LU = livestock unit
Source: Various sources given in the text.

4 Econometric model

As the share of oil pumpkin cultivated area is zero in roughly 20% of the observed municipalities, estimation of a linear model, estimated by ordinary least squares would lead to biased results due to censoring (WOOLDRIDGE, 2012). We address this issue by estimating a Tobit model that takes censoring into account and is often applied in similar studies (e.g. CONSMÜLLER et al., 2010; JENSEN et al., 2007; LANGYINTUO and MEKURIA, 2008). The Tobit model expresses the dependent variable Y of a linear regression model in combination with an underlying latent variable Y* (WOOLDRIDGE, 2012)

$$Y^* = \alpha + \beta X + U \qquad (1)$$

, where Y* equals Y if it takes on a value greater than 0, but it takes on a negative value if Y is zero. α is a constant term, β is a vector of k regression coefficients, X is a matrix with the n values of the k independent variables and U is a vector of n normally distributed errors. In contrast to an ordinary least squares regression, the partial effect of an independent variable (X) on the dependent variable (Y) in a Tobit model varies with the values of X. We therefore use the partial effect at the average (PEA) which expresses the effect of X on Y when all X are evaluated at their mean values. The PEA can be interpreted in the same way as the regression coefficients from an OLS regression and is calculated by multiplying Tobit coefficients with the following adjustment factor (WOOLDRIDGE, 2012):

$$\Phi\left(\frac{\bar{x}\hat{\beta}}{\hat{\sigma}}\right) \qquad (2)$$

In a second step, we control our results for the existence of spatial interdependence. Basically, spatial interdependence can be introduced into a regression model either through global or local spillover effects. Local spillover effects are present, if a change in a characteristic of an observation affects the outcome of neighbouring observations. Global spillover effects on the other hand imply that a change in a characteristic/outcome of one observation influences the outcome of all observations in the sample, ultimately leading to endogenous feedback effects (LeSage, 2014). In the literature, in most empirical applications statistical tests are used to choose between competing model specifications, which are very often the spatial autoregressive (SAR) model that produces global spillover effects and the spatial error (SEM) model, which filters spatial correlation out of the error term to provide unbiased standard errors of estimates, but does not produce spillover effects.

This procedure is common in applied econometrics (see e.g. Anselin, 2010) and has also found broader acceptance in an agricultural context (e.g. Roe et al., 2002; Schmidtner et al., 2012; or Holloway et al., 2007 for a broader review), but has recently also been object to growing criticism. Specifically, Gibbons and Overman (2012) argue that most applied spatial econometric research is bedevilled by identification problems of the causal relationships at work and has too much focus on statistical tests when determining the appropriate model specification. Instead of the mainly used SAR and SEM models, they advocate the use of the simpler Spatial Lag of X (SLX) model, first introduced by LeSage (2009), which produces local spillover effects and call for more focus on theoretical considerations and precisely defined research questions, when analysing spatial interdependence. In response to this criticism Halleck Vega and Elhorst (2015) also propose the SLX model as a point of departure, when controlling for spatial interdependence. Simply put, local spillovers offer a more flexible way to model spillovers, impose less restrictions in terms of model assumptions and are also more likely in the majority of cases (LeSage, 2014; Halleck Vega and Elhorst, 2015). For example, in the SLX model spillover effects may differ for every independent variable to an extent that they can even take on different signs, whereas in the SAR model the ratio between direct and spillover effects is by definition constant for all variables and the spillover effects have the same sign as direct effects, which is a rather restrictive and undesirable property (Pace and Zhu, 2012). We therefore consider local spillover effects to be more flexible and also more credible, when considering their possible influence on spatial variations in the cultivation of alternative crops like the oil pumpkin.

$$Y^{*} = \alpha + \beta X + \gamma WX + U \qquad (3)$$

, where W is a N x N neighbourhood matrix, often based on continuous neighbourhood for administrative units. In a continuous neighbourhood matrix, observations which share a border are neighbours and receive the value 1, all other observations receive the value 0. Additionally, the diagonal elements of the matrix are also 0, as an observation cannot be a neighbour of itself. Before estimation of the model, the neighbourhood matrix has to be row standardized, so that all rows sum up to 1. The result of the multiplication of X with W is a spatial lag variable that represents the average X value of neighbouring observations. In the SLX model, the PEA of β measures the direct effects of X on Y, while the PEA of γ measures local spillover effects of WX on Y. If the PEA of γ is statistically significant, local spatial interdependence is present.

To test the robustness of our model specification, we estimate all models with 2 different neighbourhood matrices, one based on continuous neighbourhood and one based on a cut-off distance of 10 kilometres (euclidean distance between geographic centroid points of municipalities), where neighbours are additionally weighted according to their inverse distance. The decision for the cut-off distance is based on expert knowledge regarding the structure of the oil pumpkin market in Austria and on comparison with other work that analysed spatial interdependencies in agriculture (Schmidtner et al., 2015). However, as the results of both specifications do not differ substantially, we only present the results based on the continuous neighbourhood matrix.

5 Results

The results of the estimated regression models are provided in Table 2. To enable direct interpretation of the effects of the independent variables on the share of arable land cultivated with oil pumpkin, the PEAs are presented instead of the estimated coefficients. Overall, most signs of the PEAs are in line with their hypothesized effect on the share of arable land cultivated with oil pumpkin. In regard to the spatial models, the results do not differ substantially from the non-spatial models. We therefore focus mainly on the PEAs of the Tobit model for interpretation of the results and only refer to the PEAs of the SLX Tobit model, when differences arise. In the SLX Tobit models, we only include spatial lags of the variables *dirmark, organic, agriserv* and *education*. The two variables *arable* and *oilplag* are not included as spatial lags, because they primarily serve as controls and therefore it is of no interest to interpret their marginal effects. The other independent variables are not included as spatial lags, because the high correlation with their spatial lags (WX) does not allow us to identify their marginal effects[3].

In the model for the northern PGI area, *soilqual, organic, education* and *oilplag* have a positive and statistically significant effect, even though for *education* it is only significant in the SLX Tobit model. With regard to the variable *oilplag* it has to be considered that the primary purpose of this variable is not to interpret its partial effect, but rather to control for unobservable heterogeneity that influences oil pumpkin shares. Next, the variables *distdry, farmsize* and *dirmark* show a statistically significant and negative effect. For example, one additional kilometre to the next washing and drying facility, is on average associated with a decrease of oil pumpkin cultivation by 0.25 percentage points. Finally, none of the spatial lag variables in the SLX Tobit model is statistically significant in the northern PGI area, which means that no local spatial interdependencies are present in the northern PGI area.

Moving on to the southern PGI area, the variables *soilqual, ubagarable, dirmark* and *oilplag* show a positive and statistically significant influence on oil pumpkin shares, while the effect of *distdry, farmsize* and *livestock* is negative and statistically significant. Note that *livestock* was multiplied by 10 to facilitate interpretation of its PEA. An increase of 0.1 livestock units per ha UAA is therefore associated with a decrease of oil pumpkin share by 0.24 percentage points. In comparison to the northern PGI area the effects of *soilqual farmsize, organic, livestock, ubagarable, dirmark* and *oilplag* differ. The effects of *soilqual* and *farmsize* are bigger and shows a higher significance level. Organic farming has no significant effect on oil pumpkin shares and the negative effect of *livestock* is higher and significant (1%-level). Next, UBAG payments for arable land have a positive and statistically significant effect on oil pumpkin shares in the southern PGI area, even though it is only significant at the 5% level in the Tobit model. Another region specific aspect is the positive effect (0.17) of direct marketing on oil pumpkin shares in the southern PGI area (significant at the 1% level). As in the northern PGI area, the control variable *arable* has no statistically significant effect on oil pumpkin shares. This means that oil pumpkin shares are independent from the size of the municipality in terms of arable land. Finally, the spatial lag variable *W.dirmark* has a positive and statistically significant effect (1% level) on oil pumpkin shares. An increase of the average direct marketing share of neighbouring municipalities by 1 percentage point, is therefore associated with an increase of the oil pumpkin share in a municipality by 0.26 percentage points.

[3] A similar problem occurred in the work of STORM et al. (2015), which also led them to exclude certain spatial lag variables from their analysis.

Table 2: PEAs of Tobit and SLX Tobit models for northern and southern PGI area

PEA	Northern PGI area (n =143)		Southern PGI area (n = 406)	
	Tobit	SLX Tobit	Tobit	SLX Tobit
Direct effects:				
soilqual	0.04*	0.05*	0.32***	0.32***
distdry	-0.25***	-0.26***	-0.52***	-0.48***
agriserv	0.10 n.s.	0.09 n.s.	-0.02 n.s.	-0.03 n.s.
log(farmsize)	-0.01*	-0.01**	-0.03***	-0.03***
organic	0.09***	0.09***	0.02 n.s.	0.02 n.s.
livestock	-0.08 n.s.	-0.07 n.s.	-0.24***	-0.26***
log(ubagarable	0.002 n.s.	0.003 n.s.	0.003**	0.002 n.s.
dirmark	-0.07*	-0.07*	0.17***	0.13***
education	0.02 n.s.	0.03*	-0.01 n.s.	-0.01 n.s.
log(arable)	0.0006 n.s.	0.0001 n.s.	-0.002 n.s.	-0.001 n.s.
oilplag	1.05***	1.04***	0.82***	0.78***
Local spillover effects:				
W.agriserv		0.10 n.s.		-0.11 n.s.
W.organic		-0.01 n.s.		0.02 n.s.
W.dirmark		-0.10 n.s.		0.26***
W.education		-0.02 n.s.		-0.01 n.s.

Note: the PEAs of the 3 log-transformed independent variables have been divided by 100 so that a change of x by 1% can be interpreted as a percentage point change of y. Spatial lag variables are denoted by the prefix "W." ***, ** and * and denote significance at the 1%, 5% and 10% levels, respectively; n.s. = not significant.

6 Discussion and conclusions

In our study we estimate different regression models to analyse the potential drivers of spatial variations in oil pumpkin cultivation within the Styrian Oil Pumpkin PGI area. To allow for region-specific effects in the northern and southern part of the PGI area, we separately estimate one regression model for each region, using the same set of variables for both models. Additionally, we control our results for the presence of possible local spatial interdependence, by estimating a SLX model, leading to a total of 4 regression models.

Starting with overall aspects, the positive effect of natural conditions is plausible and in line with the results of other studies that carried out such analysis for crops with similar climatic requirements, namely maize and soybean (ODGAARD et al., 2011; GARRETT et al., 2013). Also not surprising is the great extent by which historical factors explain spatial variations in oil pumpkin cultivated area. However, including this variable in the analysis allows us to measure the effects of the other independent variables, while holding historical factors, like a longer tradition or more experience with oil pumpkin cultivation and other unobservable factors constant (WOOLDRIDGE, 2012). Proximity to a washing and drying facility is also important for oil pumpkin cultivation. Even though we are able to quantify a negative effect of distance to the next washing and drying facility, a remaining shortcoming of our analysis is that we could not include the actual capacity of the washing and drying facilities in our model due to lack of data. Somewhat surprising is the negative effect of farm size on oil pumpkin shares. In the southern PGI area this may be explained in combination with the high share of direct marketing farms, whereas in the northern PGI area, organic farms, which are generally smaller in terms of UAA, are more likely to cultivate oil pumpkin.

Additionally, we are also able to identify region-specific factors that influence spatial variations in oil pumpkin cultivation. In the northern PGI area, the drier climate results in a lower yield potential, making organic farming more attractive. Thus, the positive effect of organic farming on oil pumpkin cultivation may reflect the good suitability of oil pumpkins for organic farming in this region.

In the southern PGI area the positive effect of direct marketing confirms the hypothesis of direct marketing as an important regional sales channel for oil pumpkin products. This regional importance may be explained by the smaller farm structure in combination with the long tradition with and therefore also strong contribution to regional identity by the Styrian Oil Pumpkin. The negative relationship between livestock production and oil pumpkin cultivation in the southern PGI area is likely to be based on a different orientation of agricultural production. While farmers in the northern PGI area mainly focus on cash crops, livestock production plays an important role for farmers in the southern PGI area. However, it cannot be clearly confirmed, whether the negative effect of livestock density arises due to competition (e.g. with hog production) or less suitability of oil pumpkin cultivation (negative correlation of oil pumpkin shares with grassland shares). A reason for the positive effect of UBAG payments could be that farmers in the southern PGI have a more cereal and maize dominated crop rotation and mostly extended their production to soybean or oil pumpkin, when they participated in the UBAG subsidy. On the contrary, farmers in the northern PGI area have a broader crop rotation, including for example sugar beet, sun flower or rape, which also explains the higher UBAG payments received in the northern PGI area, despite the lower oil pumpkin shares.

Finally, higher shares of direct marketing farms in neighbouring municipalities are associated with a higher share of oil pumpkin cultivated area. This local spatial interdependence may have different meanings. Firstly, more direct marketing in a neighbourhood could attract more potential customers, as it bundles supply and therefore leads to an increase of oil pumpkin cultivation. Secondly, like for the other independent variables, it is possible that the PEA of the variable *W.dirmark* simply describes correlation of neighbouring direct marketing shares with oil pumpkin shares and no marginal effect. As also stated in STORM et al. (2015), it is not possible to empirically assess, through which of the above described channels spatial interdependence arises.

Another shortcoming due to lack of data is that we were only able to carry out the analysis at the municipality level. This aggregated data may lead to the ecological fallacy problem (ANSELIN, 2002) and the modifiable areal unit problem (OPENSHAW, 1984), meaning that results from (artificially) aggregated data may be different or even reverse compared to the level on which economic agents (farmers) act. In a spatial econometric context, the aggregation of data may also lead to artificial spatial interdependence. Even though SCHMIDTNER et al. (2015) show that previously found evidence for spatial interdependence in organic farming in Germany on the county level, also holds at the municipality level, these aspects have to be considered, when interpreting our results. Another issue is that our results are only valid for a given point in time (the year 2010). Even though we control for historical unobservable factors by introducing a temporal lag variable into our model, an analysis with panel data would enable us to consider the temporal dynamics of spatial variations in oil pumpkin cultivated area in the PGI area and is therefore considered as a promising venue for future research, given data availability.

The conclusions that can be drawn from our results apply on a more general level also to other emerging practices or commodities in agriculture, as they point out that (i) practice- or commodity-specific, (ii) region-specific and (iii) spatial aspects need to be considered by policy makers, for the promotion of alternatives in agriculture. Like KNOWLER and BRADSHAW (2007) argue, researchers in this area should therefore pay increased attention to the thematic and regional context of their analysis instead of focussing on “universal” factors. Additionally, we recommend to control for spatial interdependence, as otherwise results may be biased.

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