Crisis and Agglomeration in the Hungarian Hog Sector

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Abstract

This paper analyzes agglomeration effects and spatial externalities in Hungarian hog sector between 2000 and 2010. Previous studies concentrate primarily on North-American and Western European countries, whilst the research on the Central-Eastern European countries is non-existent. Our study is the first step to fill this gap. We develop a spatial lag – spatial error regression model to capture horizontal and vertical spillover effects, as well as environmental restrictions determining production location in Hungarian hog sector at municipality (LAU-1) level. Our estimations confirms the rationale of distinction of individual and corporate farms in empirical analysis. The pig production were affected by different factors and different ways in the two subsection. From the point of view of spatial economics it seems that this subsections constitute two different "worlds". The "introvert world" of individual farms is very sensitive to agglomeration effects and spatial externalities. The "extrovert world" of corporate farms is more proof against agglomeration economies and spatial externalities.

1. Introduction

There is growing literature on agglomeration and spatial externalities during the last two decades. The research on agglomeration effects focuses on mainly in non-agricultural sectors. Agriculture plays a minor role in the theoretical models of New Economic Geography (NEG) (Fujita et al., 1999). It is usually assumed that within the agricultural sector, agglomeration effects are limited; they differ by the type of production and may also change over time. However recent studies highlights the relevance of agglomeration economies in agriculture More specifically, growing literature on organic farms concentrate on the agglomeration and neighbourhood effects (Allaire et al. 2015 Nyblom et al.,2003; Gabriel et al., 2009; Lewis et al., 2011; Schmidtner et al. 2012; Bjorkhaug and Blekesaune, 2013). Other strand of research analyze spatial differences in the diffusion of organic farming, based on concentration indices, at different levels and for different countries (Ilbery et al., 1999; Frederiksen and Langer, 2004; Eades and Brown, 2006; Risgaardet al., 2007; Ilbery and Maye, 2011). In addition some studies provide evidence on the relevance of agglomeration economies in the pig and dairy sectors (Antweiler and Trefler, 2002; Roe, Irwin and Sharp, 2002; Isik, 2004; Mulatu and Wossink, 2014). In short, the agglomeration effect is identified as an important driver shaping the spatial structure of agriculture.

The hog sector is one of the best example for the industrialized agriculture with strong input-output linkages to the manufacturing sector. The farm structure of the hog sector is strongly affected by economies of scale (Duff, 2009; Hsu, 2015). Increasing trend in the concentration of global hog production is accompanied by spatial concentration of pork production (Herath et al, 2005; Larue et al., 2008). The increased spatial concentration of pig production has been explained by agglomeration economies (e.g. Roe et al., 2002)

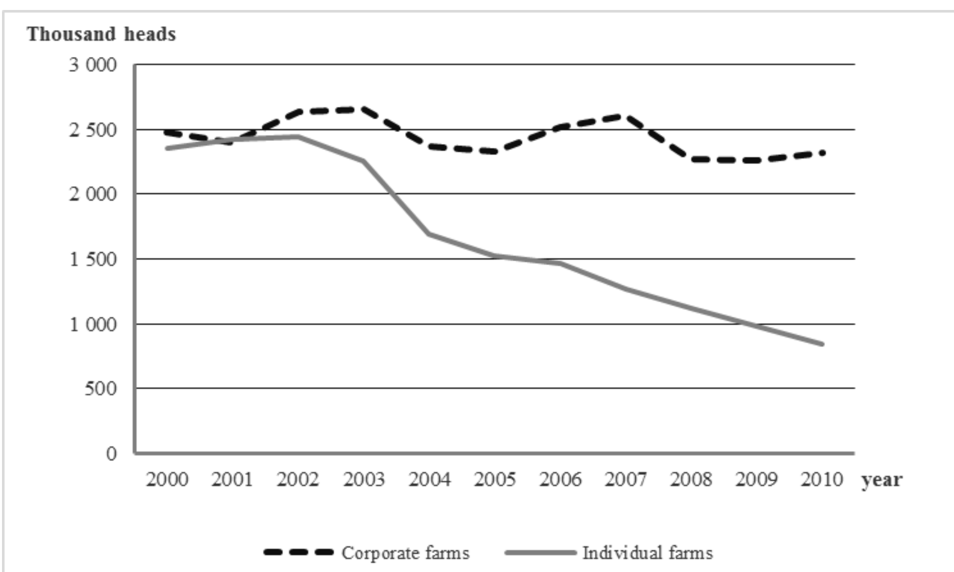
In sum, Hungarian hog sector is a good candidate to analyze the potential agglomeration effects. The well-known environmental problems associated with the nitrogen emission of hog production strengthens the relevance of this research field further. The increase in the spatial concentration leads to a high-level concentration of manure and nitrogen emission. There is a growing social pressure to solve environmental problems by legislation. It is an important question, that how the restrictions on manure application affects concentration processes (Gaigné et al, 2012; Latruffe et al, 2013; Hsu, 2015).

Previous studies concentrate primarily on North-American and Western European countries, whilst the research on the Central-Eastern European countries is non-existent. Our study is the first step to fill this gap. The aim of this paper is to investigate agglomeration effects on the Hungarian hog sector and their changes between 2000 and 2010.

Comparing to previous analyses, the Hungarian case has two additional peculiarities. Generally, the spatial concentration of pig production is highly associated to the growing pig population. However the Hungarian hog sector fall into deep crisis between 2000 and 2010; pig stock decreased by 35 per cent, number of holdings fall down by more than 60 per cent. At the same time the spatial concentration increased against the decreased number of livestock and farms Fertő and Csonka, 2016*)*.

Additionally, the Hungarian hog sector has an extremely bipolar structure with a large number of small-scale individual farms on the one pole, and a few but very large corporate farms on another (Bakucs and Márkus, 2010). This two groups were affected differently by the crisis: the major part of individual farms moved out of the sector, but the pig population of corporates decreased only by 6 per cent (Figure 1). According to the special differences between the two groups mentioned above, the individual farms and corporates were treated separately in our analysis.

Figure 1 Number of pigs by legal status of farms 2000-2010



The structure of the paper is organized as follows. Second section provides a short overview on agglomeration effects in agriculture, especially in hog sector. Next, we explain the data used and the construction of our variables. We then present our econometric model and its specifications. Results are then presented and discussed. Final section concludes.

2. Agglomeration effects in agriculture

The core-periphery (CP) model of NEG (Fujita et al, 1999) treats agriculture as an attendant to the clustering of manufactures. According to CP model, (i) the main role of agriculture is to meet the demand of manufactures for food and other agricultural goods; (ii) the agglomeration of manufacturing is hindered by agricultural transport costs; (iii) the spatial dynamics of agriculture is just a subordinated phenomenon and depends on industrial-urban agglomeration economies. However, there is an expanding number of empirical research works, which indicate that the agricultural sector has its own special agglomeration processes. Hu (2014) – based on the example of China – points out, that the industrialization of agricultural production supports these processes. There are several static (institutional environment, technological renovations, human resources and costs) and dynamic (horizontal and vertical spillovers) agglomeration advantages, which are visible in the Chinese agriculture. A positive correlation can be found between agricultural economic growth and agriculture agglomeration in China. According to Holmes and Lee (2012) the one-thirds of field-level crop concentrations in North Dakota can be explained by density economies. McWilliams and Moore (2013) finds that the spatial dynamics of the crop production in the U.S. Corn Belt is driven partially by agglomeration externalities, especially input-output linkages. Herath et al (2005a) investigated spatial dynamics of the livestock sector in the United States between 1976 and 2000), mainly focused on the role of environmental regulations. The investigation covered three intensive livestock sector (hog, dairy and fed-cattle), using data from the 48 contiguous states. It was developed a state-specific, time-series environ-mental stringency measure and introduces instrumental variables to control for the possible endogeneity bias between livestock production decisions and regulatory stringency. Other explanatory factors (relative prices, livestock infrastructure, business climate, natural endowment) were also involved in a spatial regression model. The result supports the "animal clusters" argument and the significant role if the livestock infrastructure (especially slaughtering capacity) on changes in hog production levels. However, Business climate and natural endowment variables have little explanatory power. The main conclusion of the research is that differences in the severity of environmental regulations facing livestock producers have had a significant influence on production decisions in the dairy, and particularly the hog sector. Sneeringer (2009) used geographic shifts in the livestock industry to measure the impact of pollution on infant health. The article finds that a doubling of spatial production leads to a 7.4% increase in local infant mortality.

The spatial economic analysis of the hog sector appeared in the early 2000's in the international literature. Roe et al (2002) posited a spatially explicit, county-level model of the hog production sector and estimate how numerous firm-specific, locality-specific, and spatial agglomeration factors affect the location, movement, and intensity of hog production within 15 key hog production states. Their results suggest, that spatial agglomeration, urban encroachment, input availability, firm productivity, local economy, slaughter access, and regulatory stringency variables affect the sample regions' spatial organization. This research was the first, which investigated (and confirmed) agglomeration effects by spatial lag model in the hog sector. There are a few studies dealt with similar topic (focused mainly on the role of environmental regulation) appeared during the next ten years (Herath et al, 2005a, 2005b; Weersink and Eveland, 2006; Sneeringer, 2009; Sneeringer and Key, 2011), but they applied other, typically non-spatial econometric methods.

Larue et al (2011) applied a spatial lag model again to investigate the determinants of pig production location in Denmark at municipality (LAU-1) level. The research on the traditional determinants of agglomeration (i.e. horizontal and vertical spillovers), as well as the spatial impact of environmental regulation. The empirical model used economic data from 1999 and 2004. It examined the factors affecting the pig density in municipality as proxy for local pig production. The investigated explanatory factors were: agglomeration externalities, accessibility to slaughterhouse capacity, effect of gross input prices, population density, competition for land for spreading manure, population density, and the distance to the German border (export market). The results show the significant effects of spatial externalities. More specifically, the traditional agglomeration effects has a solid relevance on pig production location, but the effect of environmental regulations are ambiguous. Population density and accessible land for spreading manure in the neighbor areas were identified as negative externalities. The econometric analysis proves, that it is important to consider the spatial endogeneity of explanatory variables and potential spatial dependence in the error terms.

Gaigné et al (2012) examine whether the restrictions on manure spreading weaken productivity gains arising from agglomeration in the French hog sector at canton (LAU-1) level. The developed spatial lag – spatial error model shows that while regulating the manure application rate encourages dispersion, it also stimulates farmers to adopt systems of manure treatment that favor the agglomeration of hog production. The main conclusion of the investigation is that land limitations induced by the restrictions on manure application do not favor the dispersion of hog production, and may boost agglomeration economies based on the significant horizontal and vertical spillovers found by the investigation.

Mulatu and Wosink (2013) analyze the extent to which environmental regulation influences pig production location in 43 regions of 6 European countries. The analysis is based on a general empirical location model that captures interactions between region and sector characteristics in determining production location. They found, that environmental restrictions may not have measureable effect on the EU pig industry location, nevertheless it is a strong impact on the structure of the industry.

3. Empirical model, econometric issues and data

Based on Larue et al (2011) and Gaigné et al (2012) we use a spatial lag – spatial error regression model to capture horizontal and vertical spillover effects, as well as environmental restrictions determining production location in Hungarian hog sector at municipality (LAU-1) level.

The spatial regression model is described by equation 1 and equation 2.

$$\mathbf{H} = \rho\mathbf{WH} + \gamma_F\mathbf{F} + \gamma_S\,\mathbf{(W{+}I)S} + \gamma_P\mathbf{P} + \gamma_{WP}\,\mathbf{WP} + \gamma_N\mathbf{N} + \mathbf{u} \quad \text{(Equation 1)}$$

$$\mathbf{u} = \lambda \mathbf{W}\mathbf{u} + \varepsilon \text{ (Equation 2)}$$

The dependent variable (**H**) is natural logarithm of the pig density at municipality level. Virtually, there are two dependent variables: one as proxy for pig production of individual farms, and the other as proxy for production of corporate farms. Based on these two dependent variables, we run two different type of model.

WH is the spatial lag of the dependent variable to catch the horizontal spillover effects. **W** is a spatial weight matrix, more specifically a row-standardized distance based binary contiguity matrix. The elements of the matrix were calculated by the following rules (before the row-standardization):

– $w_{ij} = 0$, if the Euclidean distance between gravity centers of municipalities i and j is more than 40 kilometers.

– $w_{ij} = 1$, if the Euclidean distance between gravity centers of municipalities i and j is less than 40 kilometers.

The coordinates of the (virtual) gravity center in a given municipality is calculated as arithmetic mean of the coordinates of all settlements related to the municipality and weighted by the number of pig heads in these settlements. This matrix were used as weight in other spatial lag variables as well.

F is the proxymatrix for manure spreading and forage growing potential consisting of two variables: (i) ratio of the area of arable land used by individual farms to the total area of the municipality (F1); (ii) ratio of the area of arable land used by corporate farms to the total area of the municipality (F2). We can measure the competitive advantages of low forage and manure transport costs by these variables.

The supply chain accessibility matrix (**S**) consists four variables, each of them represent the economic size (number of employed persons) of a related input or output industry: (i) the mixed feed production industry (S1), (ii) wholesale of cereals and forages (S2), (iii) wholesale of livestock (S3), (iv) meat manufacturing and processing (S4). The variables are multiplied by **(W+I)** matrix in Equation 2, where **W** is the binary contiguity matrix described above and I is an identity matrix. Vertical spillover effects may be captured by the multiplied variables.

The population density of the municipality (**P**) is expected as negative externality, but its spatial lag **WP** (population density in the neighbor municipalities) can be a positive factor being a consumption area.

In order to capture the effect of manure restrictions we use the percentage of settlements laying in nitrate vulnerable zones (**N**) in relation to the total number of settlements in the given municipality. The regulation on nitrate vulnerable zones entered into force in 2007.

Equation 2 describes the regression disturbance vector (**u**) allowing heteroscedasticity, where ε is the vector of innovations, and λ is an unknown autoregressive scalar parameter. We used the method developed by Kelejian and Prucha (2010) to estimate λ.

To estimate the spatial lag – spatial error model we use the generalized spatial two stage least squares (GS2LS) spatial econometric approach with GMM (general method of moments) estimation method based on Kelejian and Prucha (1998), and Drukker et al

(2011), applied by Larue et al (2011) and Gaigné et al (2012). This approach consists of a first stage estimation for the endogenous spatial lag **WH** with the first order spatial lags of the exogenous variables as instrument variables. It is allowed to use other instruments for the other endogenous variables. The endogeneity of **WH** is evidence, but - opposite to the previous studies – we assume that each of the other explanatory variables are exogenous. We keep this assumption until $\mathbf{H_0}$**:** λ=0 hypothesis is acceptable (at $p<0.05$ significance level).

Four models were tested in the research process. The models were differentiated by the dependent variable (described above) and the investigated period (2000 or 2010). Table 1 presents the four model.

Table 1 The Models tested during the research process

Model	Dependent variable	Year investigated
I.	pig density of individual farms (natural logarithm)	2000
II.	pig density of individual farms (natural logarithm)	2010
III.	pig density of corporate farms (natural logarithm)	2000
IV.	pig density of corporate farms (natural logarithm)	2010

Empirical analysis based on data provided by Hungarian Central Statistics Office (CSO). Based on General Agricultural Census in 2000 and 2010, and the yearly data collection for the Hungarian Settlement Statistics Database (T-STAR system) CSO published data at settlement (LAU-2) level. We aggregated these data to municipality (LAU-1) level, then we created a GIS dataset with 175 records of LAU-1 municipalities. The list and description statistics of the dependent and explanatory variables can be seen in Table 2 and Table 3.

Table 2 Description Statistics of the variables (2000), n=175

Variables	Mean	Std. Dev.	Minimum	Maximum
H (individual farms)	3.05	0.66	0.46	4.49
H (corporate farms)	1.83	2.18	- 4.42	5.94
WH (individual farms)	3.05	0.50	2.10	4.16
WH (corporate farms)	1.83	1.06	- 0.68	4.03
F1	0.19	0.09	0.03	0.45
F2	0.21	0.16	0.00	0.47
(W+I)S1	62.02	69.21	0.00	338.17
(W+I)S2	70.21	64.79	4.29	424.86
(W+I)S3	15.91	18.99	0.00	146.71

(W+I)S4	195.10	153.79	2.50	998.63
P	99.94	84.40	34.47	590.34
WP	102.38	48.67	41.56	262.70
N	0.46	0.34	0.00	1.00

Table 3 Description statistics of the variables (2010), n=175

Variables	Mean	Std. Dev.	Minimum	Maximum
H (individual farms)	2.07	0.72	- 0.20	3.88
H (corporate farms)	1.40	2.33	- 5.59	5.67
WH (individual farms)	2.06	0.53	1.00	3.21
WH (corporate farms)	1.42	1.15	- 1.90	4.18
F1	0.20	0.09	0.02	0.44
F2	0.19	0.15	0.00	0.41
(W+I)S1	45.05	64.56	0.00	375.44
(W+I)S2	77.47	73.61	7.90	555.95
(W+I)S3	22.24	26.96	0.63	206.21
(W+I)S4	237.23	206.88	2.50	1 413.25
P	100.42	101.57	28.83	758.97
WP	103.58	61.67	37.71	310.24
N	0.46	0.34	0.00	1.00

4. Results

The results will be presented in two parts. At first the results of Model I and Model II (pig density in individual farms in 2000 and 2010) can be seen in table 4.

Table 4 Results of Model I and Model II (individual farms)

Variables	Model I (individual farms, 2000)		Model II (individual farms, 2010)	
	Regression coefficient	*Average elasticity*	*Regression koefficient*	*Average elasticity*
Inttercept	1.0407***	-	0.4968***	-
WH	0.4379***	0.4374	0.3865***	0.3853
F1	3.7587***	0.2355	3.876***	0.3745

F2	0.6467***	0.0451	0.4357***	0.0408
(W+I)S1	0.0004	0.0076	0.0007	0.0151
(W+I)S2	-0-0012**	- 0.0287	-0.0006	- 0.0223
(W+I)S3	0.0034***	0.0179	-0.0001	- 0.0013
(W+I)S4	-1.6E-05	- 0.0010	0.0004***	0.0467
P	0.0003	0.0119	-0.0008	- 0.0374
WP	-0.0007	- 0.0245	0.0004	0.0212
N	-0.2814***	- 0.0423	-0.2816***	- 0.0625
lambda	0.0105	-	0.0934	-
Pseudo R^2	**0.7816**		**0.7386**	
Spatial pseudo R^2	**0.7503**		**0.7026**	

****, **, *: significance level of the coefficient is 1, 5 or 10%*

The relatively high R^2 values indicate that both of the models can estimate the spatial structure of pig production in individual farms with a relative good explanatory power. We can accept the $\mathbf{H_0}$: λ=0 hypotheses in models, the disturbance vectors are free from spatial autocorrelation.

The results provide support to the existence of positive horizontal spillover effects in 2000 and as 2010 as well. The geographical proximity to each other gives competitive advantages to individual farms and leads to clustering and agglomeration. Elasticity values show, that agglomeration power has far more relative importance than other explanatory variables (except F1). This difference can be found in both of investigated years, however the elasticity of agglomeration power had slightly decreased from 2000 to 2010. It means that the tough decrease of pig population did not erased but lessened the impacts of horizontal spillovers.

The spatial ratio of arable land has a significant positive impact in the models: the local potential for forage production and manure application increase the local pig density mainly because of the low transport costs. The elasticity is nine times higher against F1 (arable land used by individual farms) than against F2 (arable land used by corporate farms). This result suggests that there is a wide gap between small-scale individual farms and large agriculture corporates in the field of input-output cooperation. The forage supply and manure spreading of individual farms is limited mainly to the own arable land areas of farms. The elasticity against F1 had ascended by 60 per cent from 2000 to 2010. The impact of local arable land had considerably increased during the crisis period. In other words, the low cost transportation of forage and manure could partially save individual farms from the effects of crisis.

We have less unambiguous results on vertical spillovers. The significant but weak impacts in wholesale sectors (S2 and S3) had disappeared during the investigation period. It is quite hard to explain correctly the negative coefficients related to S2, S3 and S4, and no attempt would be made for that in this paper. Elasticity values are very low. Nevertheless, the impact of meat industry (S4) had an interesting development between 2000 and 2010: the elasticity ascended from -0.001 to 0.047 and the coefficient became significant at 1%. This process suggests, that positive vertical spillovers from the meat industry were strengthened by the crisis.

The ratio of nitrate vulnerable areas (**N**) had a significant negative effect on pig density at the same elasticity level in both of investigated periods. This is a surprised result, because the manure restriction for these areas came into force just in 2007. Our results suggest, that individual farms had avoid the environmental sensitive areas before the legal restrictions, probably motivated by economical drivers. The relative importance of N is pretty low.

In contrast to previous analyses, neither population density (**P**) nor its spatial lag (**WP**) affects the pig production location, probably because of the relative low concentration of the Hungarian hog sector, which is significant lower than the concentration of French or Danish pig production. Thus, there is a smaller probability of conflicts between the urban areas and livestock farms. The irrelevance of the accessibility of consumer markets (**WP**) is in accordance with the lack of vertical spillovers presented above.

Results regard to corporate farms (Model III and IV) are presented in Table 5. R^2 values bear testimony to low explanatory power of the models: the analyzed spatial variables explain only the 44 and 34 per cent of variance of dependent variables. We can accept the $\mathbf{H_0}$: $\lambda=0$ hypotheses in models, the disturbance vectors are free from spatial autocorrelation.

Table 5 *Results of Model III and Model IV (corporate farms)*

Variables	**Model III (corporate farms, 2000)**		**Model IV (corporate farms, 2010)**	
	Regression coefficient	*Average elasticity*	*Regression koefficient*	*Average elasticity*
Intercept	-0.8138	-	-0.6674	-
WH	-0.0276	- 0.0275	0.3606	0.3666
F1	6.3609***	0.6627	3.3917*	0.4842
F2	6.2431***	0.7246	4.4674***	0.6179
(W+I)S1	0.0054***	0.1825	3.24E-05	0.0010
(W+I)S2	0.0031	0.1186	0.0029	0.1608
(W+I)S3	0.0065	0.0564	0.0091**	0.1448
(W+I)S4	-0.0009	- 0.0957	0.0005	0.0849
P	-0.0018	- 0.0980	0.0009	0.0647
WP	-0.0043	- 0.2399	-0.0022	- 0.1631
N	0.6737*	0.1683	-0.8754*	- 0.2872
lambda	0.1899	-	-0.1907	-
Pseudo R^2	**0.4464**		**0.3434**	
Spatial pseudo R^2	**0.4481**		**0.3457**	

****, **, *: significance level of the coefficient is 1, 5 or 10%*

The significance levels are above 10 per cent in the major part of coefficients. **WH** is one of the variables, which are non-significant to the pig density: agglomeration advantages and positive horizontal spillovers are non-existent in the subsection of corporates. It seems that this large farms acting like isolated islands without synergic interactions related to technology, knowledge and information. Meanwhile, it should be noted that the elasticity against WH changed from -0.0276 to 0.3667 between 2000 and 2010, and the significance level of the coefficient is just above 10 per cent (p=0.1010). This great change indicates that first weak signs of clustering had appeared within the subsection by 2010.

Arable land variables (**F1** and **F2**) carry the highest elasticity related to pig density of corporate farms. Contrary to the first two models, there is no big difference between the elasticity values of **F1** and **F2**. Corporates can use croplands held by individual farms as other corporate farms as well.

Similar to the models of individual farms, the vertical spillovers are unstable with time in the case of corporates as well. Neither Model III nor Model IV proves a significant spatial impact of meat industry. The only significant impact was held by feedstuffs industry (**S1**) in 2000, but this effect had disappeared by 2010. In model IV, the wholesale of livestock (**S3**) seems to be the only one spatially relevant sector within the pork supply chain. This instability suggests that the balance of forces had changed during the crisis in the chain.

The ratio of nitrate vulnerable areas play significant ($p<0.1$) role in both models, however in different directions. In the first model (2000) the proportion of environmental sensitive areas influenced positively pig production. After restrictions had come into force in 2007, the ratio of nitrate vulnerable areas changed to a negative externality and became the fourth biggest spatial impact on pig density. In sum, environmental regulation stringency changed the spatial structure of pig production in corporate farms.

Similar to individual farms, neither population density (**P**) nor its spatial lag (**WP**) affects the pig production location in the corporate models.

5. Conclusions

This paper analyzes agglomeration effects and spatial externalities in Hungarian hog sector. Our estimations confirms the rationale of distinction of individual and corporate farms in empirical analysis. The pig production were affected by different factors and different ways in the two subsection. From the point of view of spatial economics it seems that this subsections constitute two different “worlds”. The “introvert world” of individual farms is very sensitive to agglomeration effects and spatial externalities. The “extrovert world” of corporate farms is more proof against agglomeration economies and spatial externalities.

The degree of clustering is the biggest difference between the two groups. The agglomeration power based on horizontal spillovers is the most important influencing factor to the spatial structure of the pig production in individual farms. Meanwhile a weak agglomeration power and clustering had appeared just by 2010 in the subsection of corporates. Paradoxically, we found strong agglomeration effects in the less industrialized, semi-professional, small-scale agricultural units. It is seems, that horizontal spillovers are very weak in the industrialized, more productive, pure profit-oriented holdings. In accordance with Mulatu and Wosink (2013), Gaigné et al (2012) and Larue et al (2011) our result support that restrictions on manure application may strengthen the agglomeration economies in the hog sector.

The accessibility of local arable lands were found as a key factor in each of our four Models. The local accessibility of land provides low transportation costs to forage supply and manure spreading. The strong dependence on land were not decreased during the investigated period.

Contrary to Gaigné et al (2012) and Larue et al (2011) we found only very limited vertical spillovers, which are unstable with time. The geographical proximity of input-output linkages (Herath et al 2005a) has just a very limited impact on pig production.

The direct limitation of manure application has relevant effects in the world of corporate farms, but is almost irrelevant in the world of individual farms.

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