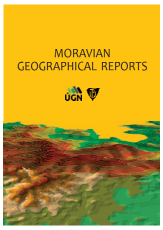

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Spatial changes in the Hungarian and Slovenian cattle sector before and after accession to the European Union

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Abstract

A comparative analysis of the spatial transformation of two different farm-size cattle systems, in Hungary and Slovenia, is presented in this paper. Concentration, mobility, and spatial autocorrelation measures are used to study spatial cattle-stock distribution and their changes over time, as well as spatial cattle-stock clustering using data from two agricultural censuses. Results confirm the decline in cattle stock on large-size farms in Hungary and on small-size farms in Slovenia, with a relative increase in the importance of medium-size farms in both countries. The decline and spatial changes in cattle stock are greater in Hungary than in Slovenia. Hungarian cattle clusters are concentrated in flat areas with medium- and large-size largely commercial farms, whilst in Slovenia they predominate in mainly hilly grassland and partly corn-silage areas on small and some medium-size family farms. Such specific cattle clustering is linked to geographical and farm-size structural characteristics that can also be linked to agricultural-policy-measure-related support for cattle and dairy, associated with less-favoured or disadvantaged-area status linked to geographical and structural land and farm characteristics typical of Slovenian mountain and particularly hilly areas. These spatial changes in the cattle sector have socioeconomic, land use, and environmental implications in terms of ecological sustainability and rural livelihoods.

Keywords: *spatial cattle stock clustering, spatial concentration, spatial mobility, spatial autocorrelation, Hungary, Slovenia*

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1. Introduction

The EU is one of the world's leading producers, consumers, and traders of beef meat and dairy products (Greenwood, 2021; Smeets Kristkova et al., 2015; Bojnec and Fertő, 2014a, 2014b; European Communities, 2006). According to recent reports by the Directorate-General for Agriculture and Rural Development (European Commission, 2020; Peyraud et al., 2020), the livestock sector, especially milk and beef production, contributes substantially to the European economy and rural areas. Furthermore, the EU is the leading exporter of dairy products, having maintained a continuous trade surplus over the past decades. Beef also contributes significantly to the EU's international livestock trade, although the trade balance for beef shows a deficit (Chatellier, 2021; Bojnec & Fertő, 2014a, 2014b).

Like other livestock sectors, dairy and beef production can significantly impact the development and employment level in rural areas (Lika, 2021). For example, the livestock sector can support the economic and wellbeing of remote, hilly, and mountainous rural communities (Bettencourt et al., 2015; Pecher et al., 2017).

Meanwhile, from the nutritional point of view, dairy products, and beef play an important role in meeting the protein needs of Europeans (European Commission, 2019; Westhoek et al., 2015), while the EU's dairy sector also plays an important role in the global supply of high quality and safe dairy proteins (Lagrange et al., 2015).

Besides the factors discussed above, another strand of literature deals with the spatial distribution of different regional and territorial economic, social, and environmental factors and other phenomena. Bone et al. (2013) developed a GIS-based risk rating for forest-insect outbreaks using aerial overview surveys and the local Moran's I statistic. Stürck et al. (2015) investigated land-use change and the spatio-temporal dynamics of regulating ecosystem services in Europe using long historical data. Csonka et al. (2021) analysed concentration and spatial autocorrelation in the Hungarian and Slovenian pig sector. For the above reasons, it would be useful to study the spatial distribution of cattle and its change, but while such methods have been used for other farm-based sectors, there are only a few studies on cattle. The related literature is limited to North American and Western European countries.

The objective of the article is to analyse spatial changes in the Hungarian and Slovenian cattle sector after accession to the EU in 2004. The selection of these two neighbouring countries is interesting and relevant because of their different agricultural,

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farm structure, and spatial geographical characteristics. More specifically, we aim to answer the following three research questions. First, how did spatial concentration and the spatial mobility of cattle populations evolve in Hungary and Slovenia between the two censuses of agricultural holdings before (2000) and after (2010) accession to the EU? Second, can the presence of clustering effects be identified in either or both countries? Third whether some nexus can be detected between farm-size structural transformations and spatial distributions in the cattle sector?

We use Markov transition probability matrices to identify the spatial mobility of the cattle stock between 2000 and 2010. In addition, we contribute novel empirical results regarding the spatial distribution and transformation of cattle stock in Hungary and Slovenia, with associated spatial socio-economic implications.

The structure of the rest of this paper is as follows: the following section provides a literature review. The third section provides an overview of Hungarian and Slovenian cattle sector and farm structure. The fourth section briefly presents data and methods. Next, we illustrate country-level results and compare them. The penultimate section discusses the results and derives policy implications. The final section concludes.

2. Theoretical background

The economic and social contributions of livestock farming depend to a large extent on the territories where they are based (Peyraud et al., 2020). According to Hercule et al. (2017), globally- or locally integrated livestock farming should be analysed in a spatial context, to include ecological, technical, and social specificities. Neumann et al. (2009) show that beef and dairy cattle are the most important livestock types in terms of total numbers and economic value, thus it is crucial to explore the spatial distribution and determinants thereof of cattle farming.

Despite its importance, only a small number of studies have addressed this topic. Ievoli et al. (2017) reveal that spatial agglomeration externalities have a positive effect on the spatial pattern of milk production in the Molise region of Italy. Arfa et al. (2009), Weersink et al. (2005), Isik (2004), Mosnier and Wieck (2010), Neumann et al. (2009) also provide evidence of the existence of agglomeration externalities and spatial dependence in the dairy sector. Other studies (Baltenweck & Staal, 2000; Läpple et al., 2017; Lewis et al., 2011; Skevas, 2020; Skevas & Oude Lansink, 2020; Yang & Sharp, 2017) provide evidence that spatial externalities affect positively the adoption of efficient or sustainable technologies and practices on dairy farms. Similar, but more scanty findings (Bowman et al., 2012; Deblitz et al., 2008; Hua et al., 2018; Rodriguez et al., 2013; Vittis, 2019) can be found about the spatial pattern of beef production. Hinojosa et al. (2019) highlight for the presence of geographical heterogeneity in mountain grasslands dynamics in the Austrian-Italian Tyrol region. In short, research underlies the importance of spatial distribution in the dairy sector, including factor endowment, market potential, and spatial agglomeration externalities.

Research has developed on the spatial dynamics of cattle farming in Central and Eastern European (CEE) countries showing the spatial transformation of the cattle sector in relation with the implementation of the Common Agricultural Policy (CAP), following the accession of CEE countries to the EU. The topic is particularly important given that since the last decade of the twentieth century, the agriculture of CEE countries has been undergoing continuous structural transformation. Since 2004, several countries in the region have also joined the EU in stages. In the new EU Member States, the restructuring of agriculture has been driven and contributed to by processes associated with the Single European Market and the CAP – and cattle farming is no exception (Némethová et al., 2014). Cattle farms in new Member States from CEE countries (EU-13) have a lower survival probability due to their smaller average scale and smaller share of total EU production (Ihle et al., 2017). Consequently, deep structural change in the sector has been inevitable during the first decade of the twenty-first century. The main characteristics, processes, and determinants of this structural transition are well-documented in the literature (e.g. Ihle et al., 2017; Kuipers et al., 2013; Cochrane & Jorgji, 2013). The spatial dimensions of the CEE cattle farming transition, however, remain less explored, except for a (non-EU) study by Nivievskyi (2009), who found significant spatial dependency in pure efficiency and technological components of total factor productivity in Ukrainian dairy farms, supporting the neighbouring farms effect on efficiency and technological progress.

3. Data and methodology

For our empirical analysis, we use data from the Hungarian and the Slovenian Central Statistical Offices. Cattle-stock data (in heads) are based on the Agricultural Censuses in 2000 and 2010 at local administrative unit (LAU) level, comparable with the Nomenclature of territorial units for statistics (NUTS) classification. Until 2016, two levels of LAU existed: the upper LAU level 1, formerly NUTS level 4, and the lower LAU level 2, formerly NUTS level 5, consisted of municipalities or equivalent units in the EU Member States. We use the pre-2007 NUTS classification for technical reasons, with LAU-2 for Slovenia and LAU-1 for Hungary as the observation units. Agricultural and other policies can affect cattle farming implemented at these levels in the two countries: for example, due to spatial farm type specialisation or if the territory is situated in Less Favoured Areas for agricultural production as eligible for specific subsidies or other budgetary support. In Hungary, 175 district/microregions are investigated, and in Slovenia 192 municipalities out of 212 municipalities due to the exclusion of 20 LAUs with urban status and without cattle production. For Hungary, only Budapest had to be excluded for similar reasons. Furthermore, Budapest, as the capital and an urban area with a high density of population, was by definition not classified as a LAU-1 district in the Hungarian administrative system (see more details on comparability issues in Csonka et al., 2021). We refer to the observation units as “local administrative units” (LAU) for simplicity.

We are interested in different dimensions of the spatial distribution of cattle stocks – inequality trends, cattle stock growth, and cattle stock mobility. Thus, we apply methodological tools from the income inequality literature. First, we focus on the spatial concentration of cattle production using Gini coefficients. Because the Gini indices may hide different spatial distribution of cattle stock, we present the Lorenz Curves. In addition, we investigate the dynamics of spatial concentration over time employing the Gini decomposition methodology.

Following Jenkins and van Kerm (2006) we decompose the change in the single Gini index – $G(v)$ – using the formulas below:

$$\Delta G(v) = R(v) - P(v), \tag{1}$$

where $$R(v) = G_0(v) - G_1^0(v) \tag{2}$$

and $$P(v) = G_1(v) - G_1^0(v). \tag{3}$$

where $G_1^0(v)$ is the generalised Gini concentration index for final year 2010, based on the ranking of the initial year 2000 $G_0(v)$. The value of $P(v)$ can be interpreted as a measure of the progressivity of cattle population growth, while the value of $R(v)$ can be interpreted as a mobility index based on re-ranking. Equation (1) expresses that inequality is progressive with an increase in the cattle population, assuming that it is not offset by simultaneous mobility. If the cattle stock increases between beginning and end periods, and the value of P(v) is greater than zero, implying that the cattle stock is more concentrated in the "poor" (smaller cattle stock) than the "rich" (larger cattle stock) units: this is called pro-poor growth. If *P(v)* is less than zero, then cattle growth is more strongly concentrated in "rich" than in "poor" units. In our case, when the cattle stock does not rise but declines, we identify an increase in the "poor" stock when losses are less concentrated among the "poor" territorial units compared to the "rich" ones.

Second, we employ Markov transition probability matrices to identify the spatial persistence and mobility of cattle stock between 2000 and 2010. A Markov matrix is a square matrix with all nonnegative entries, and where the sum of the entries down any rows is 1. A Markov matrix shows all possible states, and between states, and they show the transition rate, which is the probability of moving from one state to another per unit of time. We classify data into quartiles based on the size of cattle stock. Transition matrices show the probability of passing from one quartile to another between the starting year (2000) and the end year (2010). The diagonal elements of the Markov matrix show the probability that a particular cell at the start of the period will have the same status at the end of the period. The eigenvalues of a Markov matrix provide important information about the long-term behaviour of linear systems. The determinant of a Markov matrix can be interpreted as putting bound on how good the system is at preserving information about its initial state. The degree of mobility in patterns of cattle production can be summarised using different mobility indices from the income inequality literature. To check the robustness of our results we applied four different mobility indices for each country. These indices are functions of the transition matrix $P_{K\times K}$ between two time periods. Indices derived from the transition matrix combine the elements on the main diagonal (Shorrocks, 1978): they consider the average "jump" of income classes (Bartholomew, 1973); they account for the second-largest eigenvalues (Sommers & Conlisk, 1979) or the determinant of the matrix itself (Shorrocks, 1978). Higher indices imply higher mobility. The formulas for the mobility indices are as follows:

$$\text{M1 Prais (trace): } (K-1)^{-1}\{K-\text{trace}(P)\} \tag{4}$$

$$\text{M2 Bartholomew: } \{K(K-1)\}^{-1}\Sigma_i\Sigma_j\, p_{ij}\, |i-j| \tag{5}$$

$$\text{M3 Eigenvalue2: } 1-|\text{2nd largest eigenvalue} \tag{6}$$

$$\text{M4 Determinant: } 1-|\det(P)| \tag{7}$$

Finally, to investigate the spatial dimension of the cattle sector, different spatial autocorrelation measures are used for each country. Spatial autocorrelation measures provide information about the overall level of clustering in the cattle sector (i.e. global spatial autocorrelation, Moran's I, and local neighbour match test) and its spatial representation in the form of local clusters (i.e. local indicators of spatial association [LISA] cluster maps).

Global and local Moran's I indices were used to investigate the spatial distribution in terms of spatial association patterns, such as global spatial association and local spatial association. Global Moran's I index reveals the clusters or dispersion of a given variable in terms of space, describing the overall spatial characteristics of a variable across observation (LAU) units (Zhang et al., 2016). Global Moran's I index is defined as:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})^2} = \frac{\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S^2\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}} \tag{8}$$

where n denotes the number of LAUs; x_i and x_j are the natural logarithms of cattle population (heads) in LAUs i and j, respectively; and w_{ij} is an element of the spatial weight matrix (more specifically, a row-standardised queen contiguity weights matrix) and refers to an adjacent relationship between LAUs i and j. The elements of the matrix are calculated using the following rules (before row-standardisation):

$$w_{ij} = 1 \text{ if bnd(i)}\cap\text{bnd(j)}\neq\varnothing, \tag{9a}$$

$$w_{ij} = 0, \text{ if bnd(i)}\cap\text{bnd(j)}=\varnothing, \tag{9b}$$

where *bnd(i)* and *bnd(j)* denote the set of boundary points of units i and j, respectively. In other words, the queen contiguity matrix defines two LAU's as neighbours if they share a common edge or common vertex. Hence, queen contiguity is more permissive than the so-called rook contiguity matrix, which defines neighbours solely in terms of common edge. Spatial weight matrices can also be defined by other methods, e.g. based on distance. This latter option, however, is more appropriate in the case of point observation units (about spatial weight matrices see more in Zhou and Lin, 2008).

In our case, since we use a row-standardised contiguity matrix with all elements non-negative, the values of Moran's I range from -1 to $+1$. Negative values indicate negative spatial autocorrelation (dispersion), while positive values represent positive autocorrelation (clustering). Values close to zero, more precisely, values around $-1/(n-1)$, represent a random spatial pattern (Moran, 1950): while global Moran's statistics, as described above, are used to test the spatial autocorrelation for the whole sample, local Moran's I test and quantifies the partial autocorrelation for each observation unit. For the ith unit, local Moran's I is defined as (Anselin, 1995):

$$I_i = \frac{(x_i-\bar{x})}{{S_i}^2}\sum_{j=1}^{n} w_{ij}(x_j-\bar{x}), \tag{10}$$

where

$${S_i}^2 = \frac{\sum_{j=1}^{n}(x_j-\bar{x})^2}{n-1} - \bar{x}^2. \tag{11}$$

LAUs with positive local Moran's I values can be classified as spatial clusters. Two types of spatial cluster can be distinguished:

- high-high clusters (high value in a high-value neighbourhood),
- low-low clusters (low values in a low-value neighbourhood).

Negative local Moran's I values identify spatial outliers, including

- high-low outliers (high value in a low-value neighbourhood),
- low-high outliers (low value in a high-value neighbourhood).

Note, that the reference to high and low is relative to the mean of the variable and should not be interpreted in an absolute sense.

To check the change in spatial autocorrelation over time, differential Moran's I was used at both global and local levels. Differential Moran's I measures spatial autocorrelation to the variable $y_{i,t}-y_{i,t-1}$, where t and $t-1$ represent two different periods (i.e. the current year and base year). In other words, using differential Moran's I we measure the correlation of the change in a variable over time between a given spatial unit and its neighbours. For more details on differential autocorrelation, see Anselin (2019) and Ghodousi et al. (2020).

The statistical/computational significance of the global and local Moran's I and differential Moran's I were tested using permutation tests based on 999 permutations. By running 999 permutations, the pseudo p-value can be estimated with a precision of one thousandth (0.001). We reject the null hypothesis of spatial randomness if the pseudo p-value is equal to or less than 5 percent.

Two variables are used in the spatial autocorrelation estimation: cattle stock (number of heads) as a proxy of cattle farming, and average size of cattle farms (amount of cattle heads/number of cattle farms) as a proxy for farm structure.

The spatial clusters and outliers explored by local Moran's I and differential local Moran's I statistics are visualised by LISA-maps (LISA: local indicator of spatial autocorrelation). These maps display the different types of significant spatial clusters or outliers in different colours. Three LISA maps per country and per variable were produced using GeoDa and ArcMap software: one for 2000, one for 2010 and a differential map for changes between 2000 and 2010. To explore the multi-attribute similarity of adjacent spatial units, we apply the Local Neighbour Match Test based on cattle stock and average farm size following Anselin and Lin (2020). The match test assesses the extent of overlap between the k-nearest neighbours of a given spatial unit in geographical space and in the multi-attribute (multi-variable) space. We adjust the value of k-set as close as possible to the average number of neighbours defined by the spatial weight matrix used in Moran's I statistics. Considering that the average number of neighbours is 5.38 for Hungary and 5.22 for Slovenia, the appropriate k-set value is five. Euclidian distances were used to determine both the geographical and the multi-attribute neighbour sets. The significant overlap between each LAU's geographic and multi-attribute neighbourhood sets was tested using a 5 percent threshold for the p-value. We visualised the degree of overlap by a cardinality map, where each location indicates how many neighbours the two sets have in common. The number of common neighbours in the two sets is indicated on the maps by different shades of green (the darker the shade, the greater the number of common neighbours). Matched neighbours are also connected by a red line on the maps.

4. Results

Cattle stock in both countries declined during the period under analysis in Hungary from 805 thousand in 2000 to 682 thousand in 2010 (– 15.3%), whilst in Slovenia from 494 thousand to 470 thousand (– 4.9%). The cattle population stabilised in Slovenia after 2007 (Fig. 1).

The structure of the cattle sector is different in Hungary and Slovenia (Eurostat, 2020a, 2020c). In Hungary, large farms predominate, with the proportion of farms with 500 or more cattle heads being over 50%. In contrast, small farms are predominant in Slovenia, where the proportion of farms with fewer than 50 head of cattle ranged between 82 and 90 percent in the period considered. Despite the structural differences, similar structural transformations can be observed in both countries, although the scale of the latter is different. The distribution of farm size has involved an increase in middle-size farms in both countries. The share of farms with less than 50 livestock units and above 500 livestock units has declined, while the proportion of farms with a size of between 50 and 500 livestock units has increased.

Table 1 confirms decline in the cattle stock both in Hungary and Slovenia between 2000 and 2010. In Slovenia, however, we can observe an increase in the maximum size of cattle stock per municipality.

Our research question is how this farm-size structural transformation has translated into changes in the spatial distribution of the sector.

4.1 Spatial concentration in cattle sector

Spatial inequality is graphically illustrated with Lorenz-curves. Figure 2 shows that inequality has increased slightly in both countries. The shape of the Lorenz curves is rather similar in Hungary and Slovenia.

To analyse the dynamics of spatial concentration we use the Gini decomposition methodology (Tab. 2). The values of the initial (year zero = 2000) and final (year one = 2010) single-parameter Gini coefficients show that both the Hungarian and Slovenian cattle sectors were spatially concentrated in 2000, and that this inequality had further strengthened by 2010. The concentration coefficients increased despite the declining total cattle population. The growth ratios of Gini values were similar in both countries (7.6% for Hungary and 5.6% for Slovenia). There are significant

	Obs.	Mean	Std. dev.	Min.	Max.
Hungary					
Cattle in 2000	175	4,834.96	4,008.93	179	20,921
Cattle in 2010	175	3,985.59	3,646.96	51	18,673
Slovenia					
Cattle in 2000	192	2,475.47	2,134.91	22	11,365
Cattle in 2010	192	2,332.29	2,149.13	6	12,081

Tab. 1: Descriptive statistics of cattle stock in Hungary and Slovenia
Source: authors' calculations based on Hungarian Central Statistical Office (2022) and Statistical Office of the Republic of Slovenia (2022)

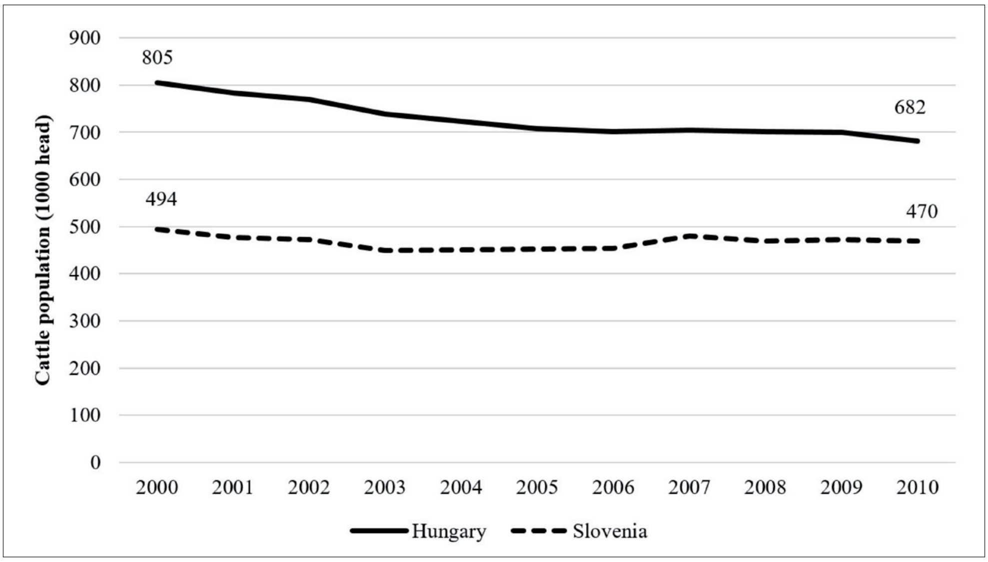

Fig. 1: Evolution of cattle stock in Hungary and Slovenia between 2000 and 2010
Source: authors' construction based on Eurostat (2020b)

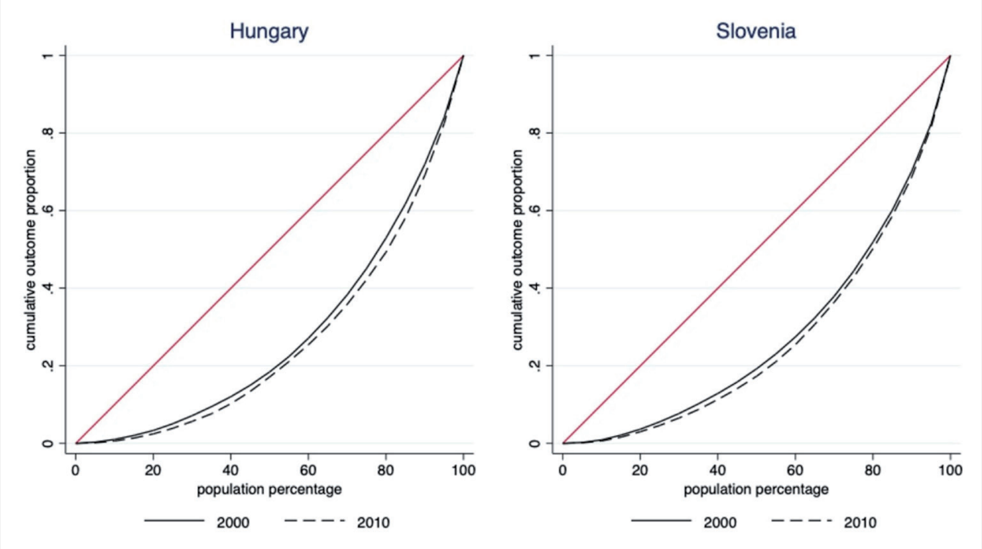

Fig. 2: Lorenz curves for the Hungarian and Slovenian cattle sector
Source: authors' calculations

differences in the nature and internal components of similar changes in concentration. In the case of Hungary, the positive value of the P-component indicates that the decline in the cattle population tended to affect 'richer' LAUs with a larger cattle herd in the initial period. Based on the P-component, spatial reallocation would therefore have essentially involved a 'pro-poor' inequality-reducing process. On the other hand, the value of the R-component eroded and even overrode this smoothing effect. The increase in concentration in Hungary was due to a high degree of reranking between LAUs. This suggests that the mobilisable resources of cattle farming have increased in some spatial units at the cost of other spatial units. In Slovenia, the reverse has happened: the smaller percentage of the R-component implies that the resources of cattle farming are less mobilisable, leading to smaller changes in concentration. On the other hand, the P-component is negative, which indicates a 'pro-rich' spatial transition. In other words, the LAUs with a small initial cattle population were the losers of the structural change, and the 'pro-rich' process intensified the increase in concentration in the Slovenian cattle sector.

The Markov transition probability matrices confirm the Gini decomposition results and their interpretation (Tab. 3). The diagonal elements of the Markov matrix are lower for Hungary than for Slovenia, indicating that there is a lower probability that each regional unit will remain in the same size category at the beginning of the period and at the end of the period. This implies that cattle farming in Hungary has been characterised by significantly higher spatial mobility. Specifically, a shift in the position of LAUs was observed between the two middle (Q3 and Q4) quartiles, in contrast to the quartiles with the largest (Q4) and smallest (Q1) stock. It is possible that in the former areas, path-dependency and resource constraints were less limiting for spatial mobility, opening the possibility of regional competition for resources, which eventually led to an intensive territorial re-ranking process.

For Slovenia, the Markov matrices show lack of mobility and strong long-term territoriality of cattle farming. The spatial units in the lower quartiles changed position less frequently than in Hungary. There has been some degree of reallocation between Q3 and Q4 – which initially had a larger cattle stock – consistently with the pro-rich nature of spatial concentration in this country.

The mobility indices reveal that the spatial mobility of the cattle sector is greater in Hungary than in Slovenia regardless of the indicator considered (Tab. 4). All mobility indices confirmed the higher values for Hungary than for Slovenia. This is consistent with the greater spatial cattle mobility in Hungary *vis-à-vis* the lesser mobility and stronger persistence of the cattle-stock spatial distribution in Slovenia.

4.2 Spatial association of cattle distribution

Finally, we investigate the spatial association of the cattle stock distribution. The values of Moran's I are quite low but significant in both countries and periods, revealing the existence of weak

Components	**Hungary**	**Slovenia**
Initial Gini	0.442	0.444
Final Gini	0.476	0.469
Change	0.034	0.025
R-component	0.046	0.009
P-component	0.012	− 0.016
Change of R and P-component as percentage of the initial Gini		
Gini	7.6	5.6
R-component	10.4	2.1
P-component	2.7	− 3.5

Tab. 2: Gini decomposition of change in spatial concentration between 2000 and 2010. Source: authors' calculations

		Hungary		
Quartiles	Q1	Q2	Q3	Q4
Q1	0.80	0.20	0.00	0.00
Q2	0.16	0.61	0.23	0.00
Q3	0.05	0.18	0.61	0.16
Q4	0.00	0.00	0.16	0.84
		Slovenia		
Quartiles	Q1	Q2	Q3	Q4
Q1	0.83	0.17	0.00	0.00
Q2	0.15	0.75	0.10	0.00
Q3	0.00	0.08	0.81	0.10
Q4	0.02	0.00	0.08	0.90

Tab. 3: Markov transition probability matrices: mobility of cattle stock among the LAUs in Hungary and Slovenia (2000–2010)
Source: authors' estimations

	Hungary	**Slovenia**
M1 Shorrock/Prais	0.380	0.236
M2 Bartholomew	0.099	0.063
M3 Second largest eigenvalue	0.372	0.226
M4 Determinant index	0.803	0.575

Tab. 4: Mobility indices of Hungary and Slovenia
Source: authors' estimations

spatial dependence in cattle distribution (Tab. 5). The values of Moran's I suggest that spatial dependence is somewhat higher in Hungary. This can be explained mainly by the larger farm size and technological differences: in Hungary, cattle farming is dominated by large-scale, industrial, and equipment-intensive dairy production, whereas in Slovenia, the smaller average farm size is accompanied by a higher proportion of pasture-based, extensive cattle farming (Bojnec & Fertő, 2021; Fertő et al., 2021).

Our results highlight two key points. First, the degree of global autocorrelation changed in both countries to the same extent (about 12%), but in the opposite direction during the analysed period. Again, the reason for this lies in technology. In the Hungarian cattle sector, there are fewer constraints to the geographical movement of sectoral capital. The Hungarian cattle sector is dominated by technology-intensive dairy farms. The growth of cattle stock in intensive dairy farms is less constrained by available land, the rotation rate of breeding animals is higher and the withdrawal of capital from production is easier than, for example, in the case of grazing farms. As a result, the concentration of farm structure is due to the establishment of new, or expansion of, existing dairy farms within the neighbourhoods with initially smaller cattle populations. This result is also consistent with the re-ranking nature of the spatial transformation.

During the restructuring process, due to the high degree of mobility of resources, some spatial units were able to significantly increase their relative position in the sector, thereby weakening the impact of old spatial clusters. Another reason for the reduction in spatial dependence is the sharp decline in Hungarian cattle stock which also led to a reduction in the clustering potential. In turn, the increased spatial-association dependence of Slovenian cattle farming is in line with the pro-rich nature of spatial concentration in this country. The presence of grassland-based extensive systems has resulted in less spatial mobility of cattle farming. Consequently, the concentration of farm structure has naturally been accompanied by an increase in the spatial dependence and clustering of the cattle stock.

Second, the values of differential Moran's I for both countries show that the change in the cattle stock of LAUs is weak but significantly related to the change in the stock of neighbouring areas. This is of interest because differential spatial autocorrelation over time is less likely to be driven solely by geography than the static spatial autocorrelation discussed above. Thus, based on the significant differential Moran's I for cattle stock, we can hypothesise that socio-economic factors (such as technological and knowledge spillovers, ownership overlaps, resource pools, sales, and procurement cooperation) are relevant in the background of spatial clustering.

Country	**Global Moran's I**		**Differential Global Moran's I**
	2000	2010	2000–2010
	Cattle Stock		
Hungary	0.287***	0.252***	0.148***
Slovenia	0.201***	0.224***	0.152***
	Average farm size		
Hungary	0.225***	0.145***	0.072
Slovenia	0.151***	0.283***	0.045

Tab. 5: Global Moran's I indices cattle stock at the LAUa level
*Note: a Local administrative unit (LAU); *** The significance level (pseudo p) of I is 1%. Source: authors' estimation*

Country /Period	**2000**	**2010**
Hungary	0.331***	0.410***
Slovenia	0.290***	0.288***

Tab. 6: Pairwise correlations between cattle stock and average farm size at Local Administrative Unit level
*Note: *** The significance level (p) of Pearson's r is 1%*
Source: authors' calculations

For the average farm size, our global autocorrelation estimates are consistent with the results for the cattle stock, except for the differential Moran's I statistic, which is not significant. Thus, the change in the spatial distribution of the average farm size does not show spatial clustering, so that, in contrast to the evolution of the cattle stock, geographical proximity or spatial spillover does not play a role in the temporal dynamics of the farm structure.

Table 6 shows that the cattle stock and the average farm size at LAU level are weakly and positively correlated. The positive correlation indicates that there are more cattle heads where farms are larger and less cattle heads where farms are smaller. Small farms can be equally spatially concentrated but not enough to counteract this the positive correlation. These statements are also supported by the fact that in both periods we estimated higher coefficients for Hungary than for Slovenia.

4.2.1 Spatial changes in the Hungarian cattle sector

Now we turn to the investigation of local autocorrelation to identify clusters within the global pattern in Hungary using LISA cluster maps. Figure 3 shows that high-high clusters of cattle farming are primarily found in the plain areas of Hungary, while low-low clusters are concentrated in the hilly/mountain regions.

In the initial period (Fig. 3a), two larger high-high cluster cores can be distinguished: one in the eastern and south-eastern part of the country, in the Southern Great Plain region, and the other in the north-western part. In addition, there are two other non-contiguous cluster-core LAUs in the central part of the country.

Looking at the final period (Fig. 3b) and the differential map (Fig. 3c), it is clearly visible that the cluster area in Central Hungary, which was previously of negligible importance, has grown significantly. The region's unique advancement can be explained not only by its flat topography and excellent soil conditions, but also by its excellent transport infrastructure, as well as its proximity to the capital (Budapest) as a receiving market and as a technology or as knowledge transfer centre.

Large Low-Low clusters are mainly found in the north-north-eastern mountains of the country (Figs. 3a and 3b). In these regions, the potential for intensive dairy production is limited, especially due to the high costs of feed supply and manure spreading. However, by 2010, the extent of this Low-Low cluster had decreased slightly, and a High-Low outlier appeared in the mountains. This shows that geographical constraints can be overcome to some extent in the cattle sector. In summary, in Hungary the most important driver of spatial clustering is the topography and the related economic geography (e.g. soil quality and the presence of large contiguous agricultural areas). At the same time, the results of the dynamic (cross-time) analysis of spatial autocorrelation show that during the period of structural transition, agglomeration benefits and spillover effects known from the new economic geography theory have become also important drivers of clustering (Krugman, 1991; Chandra, 2022). The emergence of new cluster areas is also a sign of the exploitation of previously under-utilised local resources.

Figure 4 shows that the location of the High-High and Low-Low clusters of average farm size overlaps only marginally with the same cluster types of cattle stock, despite the positive correlation between the two variables. The explanation is that in the western part of Hungary, with its more fragmented topography and settlement structure, economies of scale in the farm level are more important. As a result, LAUs in this region contain a small number of farms with a size that is a positive outlier compared

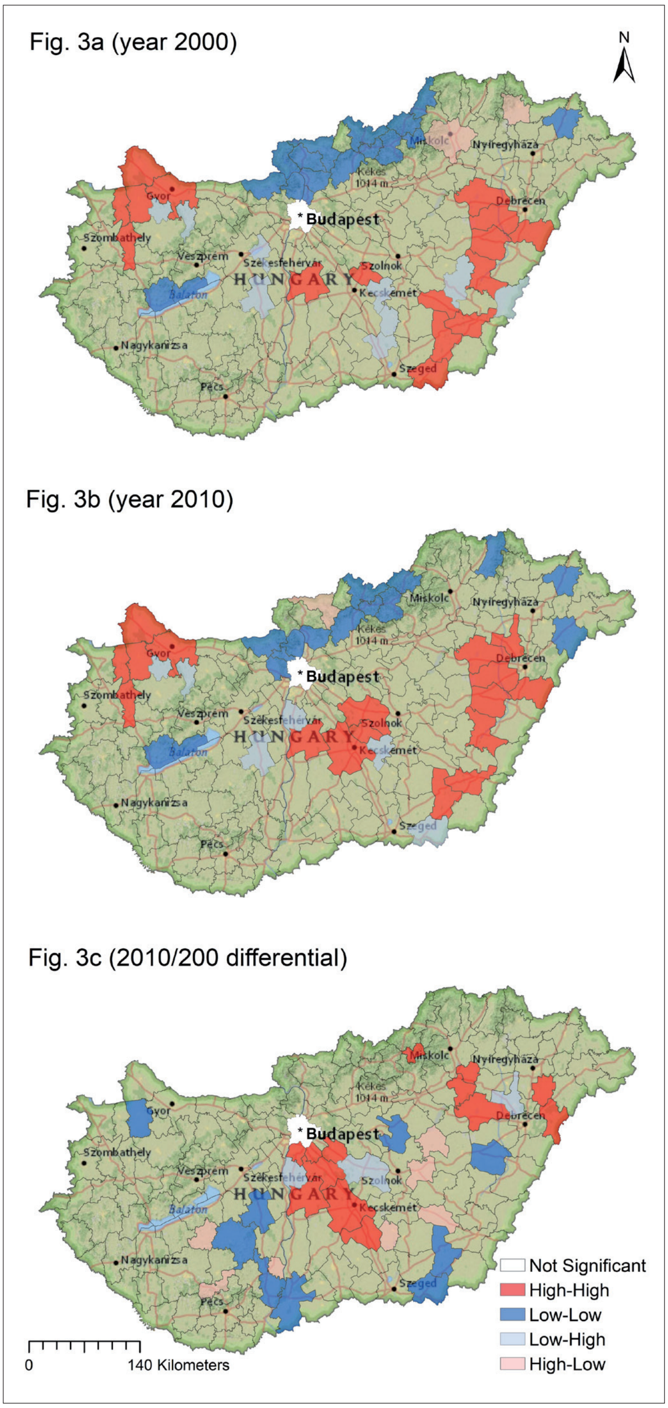
Fig. 3a (year 2000)

Fig. 3b (year 2010)

Fig. 3c (2010/200 differential)

Fig. 3: Univariate and differential LISA cluster maps for Hungarian cattle stock, 2000 and 2010
Source: authors' elaboration

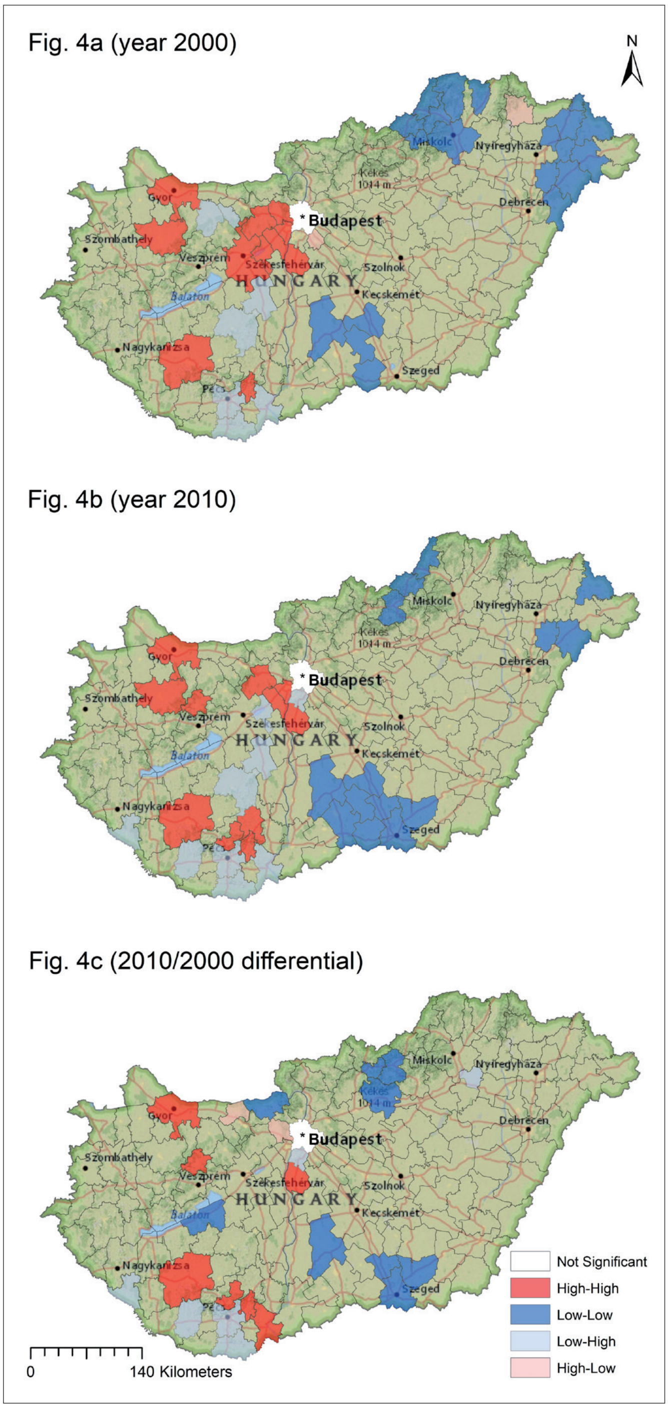
Fig. 4a (year 2000)

Fig. 4b (year 2010)

Fig. 4c (2010/2000 differential)

Fig. 4: Univariate and differential LISA cluster maps for Hungarian average cattle farm size, 2000 and 2010
Source: authors' elaboration

to the average. The Low-Low clusters on the eastern side of the country overlap with Natura 2000 sites and/or nature reserves. The special regulation of these areas leads to the trend towards smaller farm sizes in livestock farming.

Finally, we present the local neighbour match test (Fig. 5). The test essentially answers the question whether the geographically neighbouring LAUs are also "neighbours" in terms of the multivariate cattle farming profile (based on cattle stock and average farm size). On the maps, the dark green colours indicate LAUs that have neighbours with similar profiles. The darker the colouring of the LAU, the greater the number of neighbours with similar profiles. The test results show that in both periods, over a quarter of LAUs have neighbours with similar profiles. These areas are in different areas of the country. Again, these results show that geographical proximity and neighbour-neighbour relationships influence, albeit to a relatively small extent, the spatial structure of cattle farming in Hungary.

4.2.2 Spatial changes in the Slovenian cattle sector

Figures 6a and 6b shows that the Slovenian High-High clusters of cattle stock are located rather in the central part of the country (Inner, Upper and Lower Carniola). These clusters cover the flat valley corridors, but also extend to the mountainous areas around the valleys. These areas are home to both intensive dairy production and extensive, mountainous cattle farming. The cluster areas are also characterised by their geographical proximity to the receiving market and agglomeration zones (e.g. Ljubljana) and their relative proximity to major roads. The clusters of stock change shown on

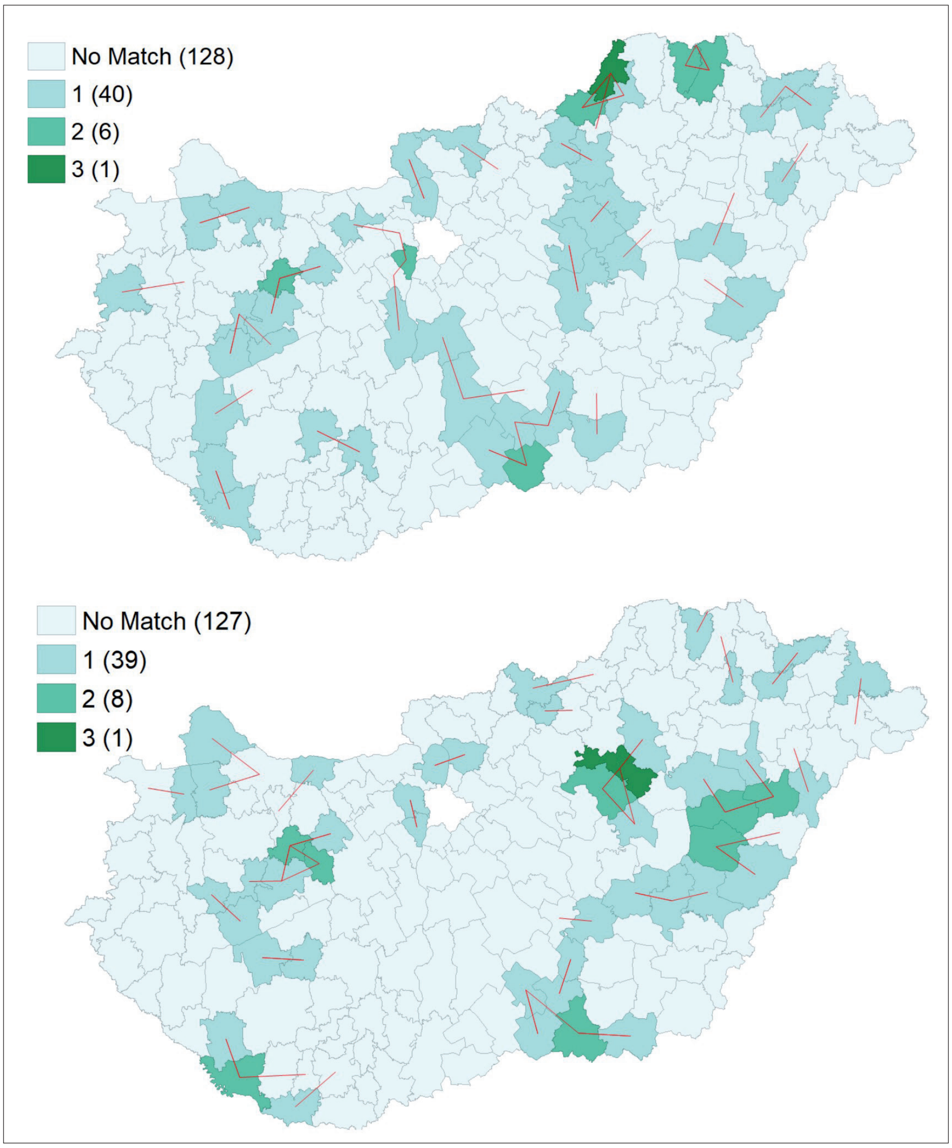

Fig. 5: Matching local neighbours by cattle stock and average farm size in Hungary in 2000 (above) and 2010 (below)
Note: The red lines represent the matched neighbours. Source: authors' elaboration

the differential map (Fig. 6c) have similar characteristics: they cover valley-mountain systems, are relatively close to the two largest cities in the country (Ljubljana and Maribor), and are crossed by major roads. In contrast to Hungary, the location of clusters has remained virtually unchanged during the structural transition. The structural shifts and concentration processes in the country's cattle sector did not essentially affect the spatial pattern and spatial dependence of the cattle stock. In addition, this may partly be explained by the fact that Slovenia has a larger proportion of extensive, pasture-based beef and dairy farming systems. This finding is in line with conclusions of Hinojosa et al. (2016) regarding place attachment as a factor of mountain farming permanence in the French Southern Alps, and to a lesser extent with Pecher et al. (2017) regarding agricultural landscapes between intensification and abandonment in a central-Alpine cross-border region. The land dependency of extensive farming systems and the immobility of resources result in the preservation of the spatial distribution of farms and livestock.

The High-High clusters of average farm size only become visible in Slovenia with the rise in farm concentration by 2010 (Fig. 7b). This shows that structural change has a spatially distributional impact on the farm structure of Slovenian cattle farming. The spatial intensity of the increase in farm size (Fig. 7c) was clearly highest in the eastern, flat part of the country (Podravska and Pomurje regions). Along the Italian border, a large Low-Low cluster is visible (Figs. 7a and 7b), which remains unchanged over time. The economy of the two most affected border regions (New Gorizia and Coastal-Karst) is mainly determined by the tertiary sector, including tourism. Within the emerging Low-Low cluster, mountain livestock farming is almost exclusively characterised by grazing livestock, which is naturally associated with smaller farm sizes. In the southern lowland areas, the mixture with the Mediterranean climate is more favourable to fruit growing, so that cattle farming does not have a high concentration of farm sizes.

Regarding the effect of geographical proximity on the similarity of the cattle herding profile in Slovenia (Fig. 8), results are like Hungary: almost 30% of LAUs have neighbours with similar profiles. Examples of the profile-shaping effect of geographical proximity can be found in different parts of the country, regardless of topography.

5. Discussion and implications

We investigated the spatial concentration and spatial mobility of cattle stock in Hungary and Slovenia between the 2000 and 2010 censuses of agricultural holdings. Mobility and clustering effects were identified. The Gini decomposition, Lorenz curves, and other concentration measures were used to study the spatial

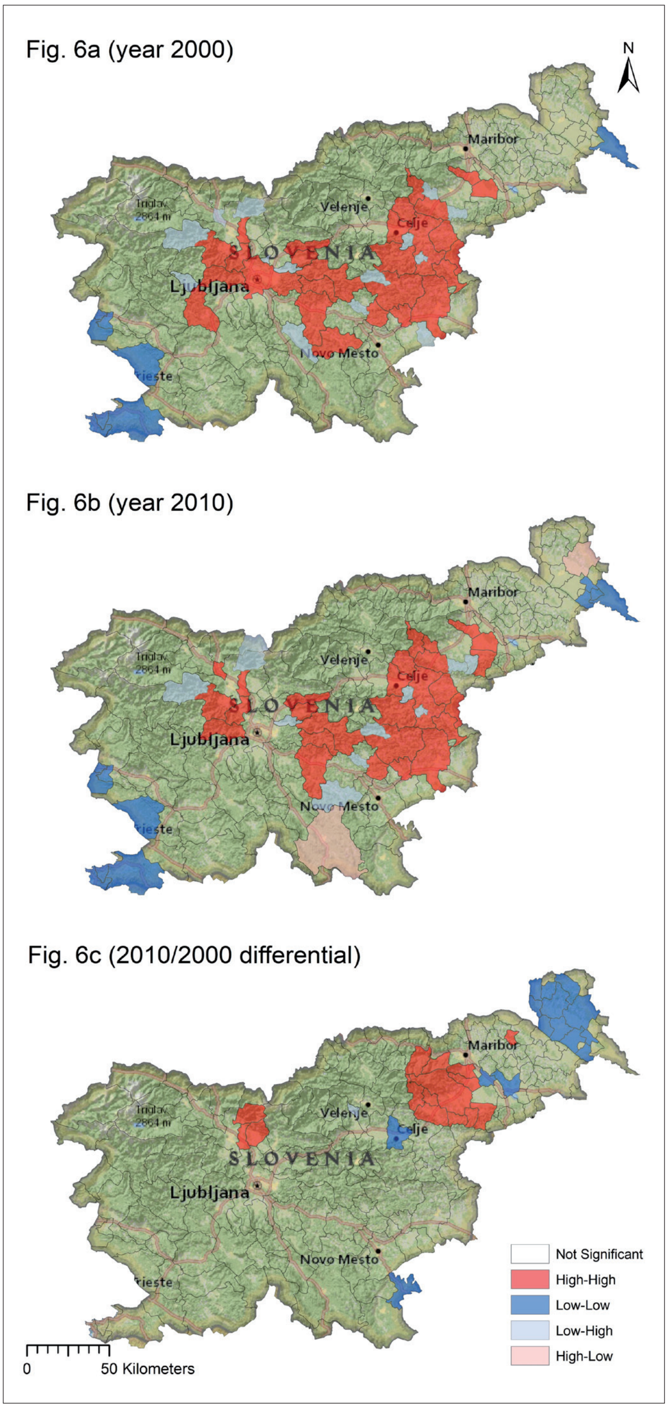

Fig. 6: Univariate and differential LISA cluster maps for the Slovenian cattle stock, 2000 and 2010
Source: authors' elaboration

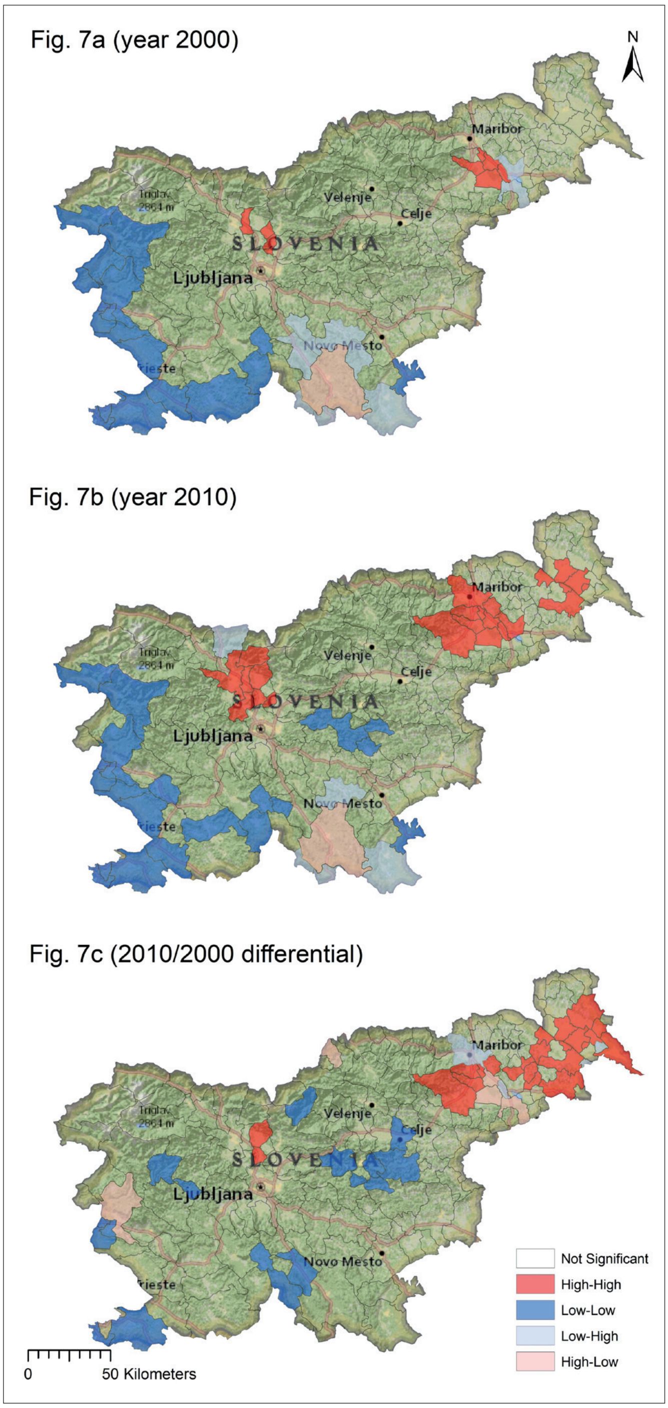

Fig. 7: Univariate and differential LISA cluster maps for the Slovenian average cattle farm size, 2000 and 2010
Source: authors' elaboration

concentration of cattle stock. They confirmed that cattle stock is spatially concentrated. The Markov transition probability matrices and mobility indices showed that cattle-stock spatial mobility in Hungary is greater than in Slovenia irrespective of the measures applied. One reason for these development patterns is the more rapidly declining cattle stock in the former than in the latter country. Finally, LISA/local Moran's I cluster maps clearly confirmed the strengthening of clustering effects, that are more robust for the Slovenian than for the Hungarian cattle stock.

These findings are relevant for science, policy, and practice. Regarding the science, we showed how applied spatial methods can be used to detect relevant spatial economic, social, and other spatially distributed phenomena. Regarding policy, based on the empirical results the study allows one to draw implications regarding the complex story of the restructuring of the cattle sector in terms of land-cover and land-use changes (see also Fuchs et al., 2015). Finally, there are practical implications for cattle and dairy farm businesses and rural areas.

Before EU accession in 2004, the cattle sector in Hungary and Slovenia was declining; it has been later declining further in the former and stabilising in the latter country with the introduction of CAP measures. In Slovenia, cattle with dairy on small- and medium-size family farms are the most important forms of livestock production specialisation and some of the most important farming activities (Bojnec, 2017). A striking finding is that the cattle sector in Slovenia shrank in plain areas where crop production is dominant and persisted in less-favoured hilly areas with grassland pasture during the grazing period and hay from

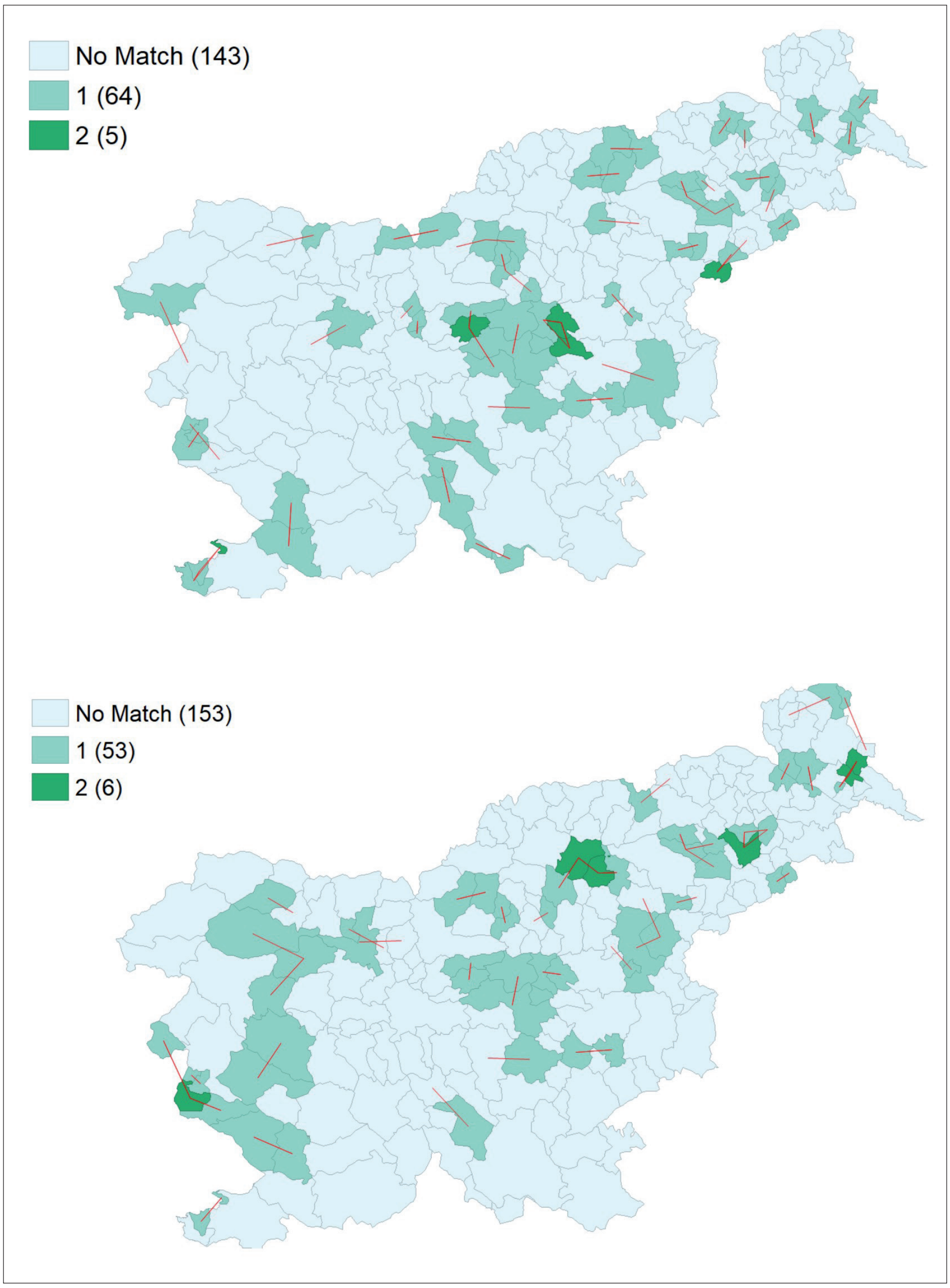

Fig. 8: Matching local neighbours by cattle stock and average farm size in Slovenia in 2000 (above) and 2010 (below)
Note: The red lines represent the matched neighbours. Source: authors' elaboration

meadows and grass, maize, and similar silage in the non-grazing period (Greenwood, 2021). On the other hand, the cattle sector in Hungary in general, as well as its spatial distribution and changes, were more volatile, with a different distribution of cattle stock by farm-size category, and a declining role for large-size commercial farms with more than 500 livestock units. Unlike the different farm-size and spatial distribution, the patterns of development are similar in the two countries, with a decline in small- and large-size farms and an increase in medium-size farms between 50 and 500 LSU. Despite similar farm-size patterns (an increase in medium-size cattle farms), the size gaps between LAUs remained large, and the spatial changes are geographically different. This spatial heterogeneity may be an issue for later research that seeks to explain the drivers of spatial transformation and changes in the cattle sector.

The results are in line, however, with those of Neumann et al. (2009), who argue that the spatial dimension of cattle farming reveals new socio-economic and environmental linkages that are important for rural regions. It has been argued on the spatial patterns of production linkages between the developments of rural regions and rural firms/farms. These linkages can be important for the local economy in small towns. In addition, the role of small and medium-sized industrial towns and their manufacturing can be important in rural transformation developments (Courtney et al., 2008; Bole et al., 2020; Ženka et al., 2021). These village-town linkages and their spillover effects can explain the decline in the number of cattle and dairy farms in both in Hungary and Slovenia, particularly due to the exit of smaller cattle and dairy farms and the substitution of cattle and dairy farming with crop farming. Interestingly, this process has been more frequent in plain geographical areas where there are better opportunities for a substitution of labour with mechanisation in crop production.

Moreover, our study confirms the relevance of clustering effects and spatial externalities in cattle industries undergoing major structural change in the CEE region. This means that the findings about the spatial dynamics of cattle farming in the USA and EU-15 countries (Weersink et al., 2005; Neumann et al., 2009; Ievoli et al., 2017) can be further developed and extended to countries with a transforming and restructuring agriculture. In contrast to previous studies, our research also reveals that spatial dependence are stronger in areas with a higher proportion of intensive cattle farming systems. In such locations, spillover effects may also be significant even in livestock sectors assumed to be relatively immobile. This finding is also in line with the finding of Hruška and Píša (2019) for Czechia, that there are winning and losing rural localities following post-socialist economic restructuring.

In accord with Santeramo (2020), Peyraud et al. (2020), and Hercule et al. (2017), our research suggests that the environmental regulation of the cattle sector should have different content from country to country, and regional strategies consider the spatial clusters associated with the industry are required to adequately address the environmental disadvantages and benefits of the sector. In countries with a more static spatial pattern of cattle farming (such as in Slovenia) greater emphasis should be placed on land-oriented regulatory instruments (e.g. greening measures). In countries with a more spatially mobile cattle farming sector, like Hungary, animal-based measures are essential. This can be a challenging issue for the development of cattle and dairy farming in some peripheral and remote areas (Pénzes & Demeter, 2021). While the intensification of conventional livestock farming has caused environmental degradation and animal welfare problems, building diversity and resilience through farm multifunctionality is also possible (Tamásy, 2013). A greening policy orientation has been also supported by CAP measures, such as agri-environmental schemes (Unay-Gailhard & Bojnec, 2015, 2016), with attendant side effects on the creation and maintenance of farm and rural employment (Unay-Gailhard & Bojnec, 2019) and farm and rural entrepreneurship, particularly involving young women on family farms (Unay-Gailhard & Bojnec, 2021). Understanding spatial changes in the cattle sector, along with their employment and other socioeconomic, land use, and environmental implications, is an issue for research in the future.

6. Conclusion

This article contributes novel empirical findings to the applied geography literature with its focus on spatial transformations in the cattle sector in Hungary and Slovenia. The cattle and dairy sector is important for both the supply and demand side of local rural economies and contributes to local employment and the cultural landscape. Interestingly, the cattle stock and number of cattle farms shrunk more in the plains of Hungary and plain areas in Slovenia, whilst its survival potential was identified in specific hilly areas in Slovenia with extensive cattle stock, increasing the clustering of cattle-stock concentration. Changes in cattle stock were linked to cattle-farm growth from small-size to medium-size in Slovenia and cattle-farm decline from large-size to medium-size in Hungary. The relatively stronger variation in the Hungarian cattle stock was confirmed with mobility and concentration measures. Despite the cattle-stock and cattle-farm transformation trends towards an increase in medium-size farms, it is unrealistic to expect strong convergence in cattle and dairy farm-size between the countries.

Farm size, in association with farm ownership and operation (the prevailing family farming in Slovenia and corporate farming in Hungary), and dairy processing, may be among the crucial drivers of the cattle-sector transformation and be responsible for the intensive clustering effects. In addition to geographical, farm-size, and operational farm and dairy processing structural characteristics, the specific nature of cattle concentration and clustering may also be linked to CAP measures for cattle and dairy. When new 2020 census data become available, the latter may be an issue for research as CAP support may have implications for farming in less favoured ‘disadvantaged’ areas (such as the farms typical of Slovenian mountain and hilly areas, and partly for Hungarian Less Favoured Areas), and for the competitiveness of farming in flat areas that are more common in Hungary but also exist in Slovenia. An additional opportunity would be to use the most recent 2020 agricultural census data, where available, and combine them with different potential drivers of the spatial transformation in the cattle and diary sector.

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