PHD THESIS, SUMMARY

Doctoral School of Earth Sciences

Methods of spatial analysis and spatial structure in economic geography. The interconnectedness of agricultural enterprises in Vas and Zala counties based on a small-sample-research, with particular regard to economic and urban geography networks

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ACTUALITY OF THE TOPIC

The actuality of the research on spatial theories today is unquestionable. The world around us has changed rapidly and dramatically in recent times.

First, the coronavirus epidemic beginning in spring 2020 has transformed every aspect of our everyday life, including work, economy and economic relations. Supply chains have been severely influenced: the temporary and partial closure of borders has highlighted the extent to which our daily lives and the functioning of the economy and economic organisations depend on cross border relationships.

Parallel to the epidemic, the effects of climate change are being felt more intensive. It became a central question, how individual actors – consumers, companies, institutions, governments – can reduce their emissions. In this context, for companies the main question is no longer how to maximise (or optimise) their profit; they also struggle to do business in a way that has a positive (or the least a less negative) impact on both society and the environment (Richardson 2020).

The third event that brings the spatial theories into focus is the Russian-Ukrainian war, that started in February 2022. The war highlighted how fragile and easily disrupted the supply chains formed in the 20th-21st centuries are: borders become impassable again, business relationships are broken, and previously stable flows of raw materials, energy, finished goods, food and labour are disrupted very rapidly.

All these contexts point in the direction that the role of local connections; direct, local partnerships and locally produced goods is enhanced: all three effects show that long-distance connections can be beneficial, but are also vulnerable precisely because of the long distance involved; and that long distances in business relationships in many cases contribute unnecessarily to environmental pollution.

The role of the study of economic space, the connections formed and maintained in the economic space, will be in the focus of research in the near future: more and more business and strategic decisions will have to take into account not only physical distance itself, but also other factors like environmental impact.

This dissertation contributes to this new understanding of spatial structures. On the one hand, it synthetizes theories describing and quantifying economic space. On the other hand, on the example from a narrow, specialised field – crop production – it uses empirical data to map the relationships between individual enterprises and, through these, the spatial structure and the geographic networks of settlements.

STRUCTURE OF THE THESIS

The theoretical part of the thesis summarizes the research on spatial structures. The summary is not exclusively geography-centered: spatial structure and its economic effects are also dealt with by economics and regional science. The literature review thus systematizes and presents models from these different scientific fields. Following a summary of the classic spatial theories, modern trends on the border areas of geography are presented: the thesis highlights the role of econometrics and network research in the study of spatial structures. The thesis also presents the main indicators and calculations used by these methods.

In the empirical part of the thesis, we try to map the economic relations of Vas and Zala counties in light of agrobusinesses by using different spatial models. Our aim is to investigate the models of several spatial theories on a given data set. The emphasis is again on econometrics and network approaches. By doing so, we will demonstrate the similarities and differences between the various approaches on a given empirical data.

RELEVANCE OF THE RESEARCH

The relevance and actuality of the research is clear: the choice of business locations has a large impact on the success of a business. Although there are many contexts and many disciplines that investigate the characteristics of business site selection, we are not aware of any analysis that meets the criteria of 1) investigating the real (questionnaire-based) relationships of existing business sites in Hungary, 2) not limiting the analysis to one method (or a few methods of a given discipline), and 3) focuses in its approach primarily on network structures.
The theoretical use of the research can be summarized as follows:

- It synthetizes theories of location theories,
- It brings together the metrics and methods used in the analysis of business locations,
- proves and examines different location theory approaches on the basis of empirical data,
- describes the economic and economic-geographical interrelationships of business locations in several contexts.

The practical use of the research can be summarized as follows:

- it sheds light on economic material flows that can only be understood through questionnaire surveys, using empirical data.
- It includes aspects of the analysis that have been neglected so far (e.g. the language skills of the manager of a given site).
- It can help businesses to optimize their economic relations, i.e. it can point out the context that should be taken into account when businesses choose a business location or introduce new services.
- When we know the spatial structures of existing enterprises, the results can be generalized and used when choosing locations for new enterprises: it can help – based on spatial structures and the relationship networks – to determine which factors should be taken into account when choosing the location for a particular type of enterprise.

AIMS

In the empirical part of the thesis, we analyze data, which was collected by a questionnaire from agricultural enterprises in Vas and Zala counties. The collected data – sales, purchases and services used – are analyzed using different spatial models. The analyses are carried out on a small, not random sample and the research is conducted in the context of a narrow geographical area in a specific economic sector.

The empirical research objectives of the thesis are:

- To identify the central locations in the sample by applying classical spatial theory models.
- Determining the central locations in the sample using gravity models.
- Using econometrical models (autocorrelation, Moran index) on the sample.
- Carrying out network analysis: identify nodes and central elements in the network under study.
- Comparing the results of the above mentioned different spatial analyses.
- To demonstrate that different central locations can be identified from the same data set using different models.
- We want to prove that in the context of the research (economic activities of agricultural enterprises) the centers of the spatial structure will not be large settlements (cities, county capitals), but those smaller settlements where the complex activity of an agricultural enterprise gives the settlement a central role.

The research will test the following hypotheses:

- H1: Based on different spatial models, different central places will emerge from the same data set.
- H2: Smaller settlements can also function as central nodes in the network of agricultural enterprises.

RESEARCH METHODS

A five-page, 14-question questionnaire was prepared in Hungarian and German. It was necessary to design the questionnaire in German because there are several entrepreneurs in Vas and Zala County who came to Hungary from abroad (e.g. Austria, the Netherlands, Germany) in the early 2000s and are not fluent in understanding/reading Hungarian.

The survey was conducted in 2019-2021. A non-random sampling – snowball sampling – was used to select the businesses. Our aim was to contact 100 farmers. We received 46 completed questionnaires in response to the inquiries, 10 of which were not completed from Vas and Zala counties, and 6 questionnaires were so incomplete that they did not allow the questionnaire to be processed.

The questionnaire could be completed on paper or online.

The first step in the data analysis was the cleaning of the received data. The data were then entered into MS Excel, where data processing could begin. During the data analysis we also needed to include secondary data, most of which came from the data of the Hungarian Central Statistical Office. During the analysis, various calculations and estimations were made on the basis of the information provided by the enterprises and on the secondary data from the Hungarian Central Statistical Office in order to obtain a more complex picture of the interconnections between enterprises and, through them, between settlements.

In addition to the information obtained from the questionnaire, we needed additional information from the farmers, so semi-structured interviews were conducted with 3 enterprises (in 2021) to obtain detailed information. The interviewees are the

managers of enterprises who also completed the questionnaire. Both large and small farmers are among the interviewees.

The purpose of the interviews was to gain a deeper insight into the processes, causes and context. For these reasons, the interviews are not analyzed separately, and the information obtained from the interviews is reported in the results of the questionnaire.

RESULTS

In the Results part of the thesis in a first step the agrobusinesses are introduced. In a second step the spatial theories are applied on the surveyed enterprises: the connections between settlements in Vas and Zala counties are investigated through business relations (purchases, sales, use of services) of agricultural (crop producing) enterprises. The following models were used:

1. Classic location theories
   a) Von Thünen model
      - the hypotheses of the model: distance from the market centre and transport costs are the determining factors
      - the results of the research:
        - distance and transport cost are no longer the primary determinants
        - from the companies, a significant proportion of the goods are sold to Austria and Italy
   b) Weber's location triangle
      - the hypotheses of the model: transport costs are the determinant, the spatial distribution of labour is given
      - the results of the research:
        - workers are mobile: migration, commuting
        - modern (4.0) technology requires specialized workforce
   c) Christaller's and Kluczka's central place theory
      - hypotheses of the model: cooperation between central places – municipalities; upper limit of the range, lower limit of the range
      - the results of the research:
        - upper limit of the range: higher values - from Hegyfalu (70% of the surveyed enterprises), Szombathely (41% of the surveyed enterprises), Bak (60% of the surveyed enterprises in Zala county) buy
        - lower limit of the range: difficult to interpret, larger farms do not produce for the local market, goods can be transported over longer distances
        - For purchases: Szombathely (72), Hegyfalu (33), Körmend (29), Zalaegerszeg (29), Nagykanizsa (23), Sárvár (20), Vasvár (12), Budapest (9) ... contact
        - Services: Szombathely (26), Zalaegerszeg (15), Nagykanizsa (10), Körmend (8), Sárvár (8), Győr (5) … contact

- Services (weighted by frequency of use): Szombathely (197), Zalaegerszeg (101), Nagykanizsa (60), Körmend (35), Sárvár (35), Güssing (Ausztria) (31) …
- Hierarchy of municipalities:
  - highest order places: Győr, Budapest
  - higher order places: Szombathely, Zalaegerszeg, Nagykanizsa
  - intermediate order places Körmend, Sárvár, Bük, Kőszeg, Őriszentpéter, Hegyfalu ...
  - lower order places: Egyházasrádóc, Lakhegy, Répcelak ...

d) Lösch model
- hypotheses of the model: economic space exists in addition to physical space – they follow different laws; market networks of different products organized around a single center
- the results of the research:
  - market networks of different products were represented in matrices and then combined
  - 26,73% of the produced goods are sold to Austria, 26,10% to Italy, 21,35% to Egyházasrádóc, Körmend, Vasvár
  - further sales cannot be traced

2. Theories that take into account transport costs and more complex site selection factors
- Krugman's model
  - hypotheses of the model: territorial concentration reduces transport costs, labour is more easily available, economies of scale - income increases, consumption increases
  - research results:
    - production is tied to arable land,
    - there is a shift towards cheaper labour, but less so than in other sectors because of the connectedness to land

3. Gravity model
- gives an estimate of the flow rate between two regions
- the results of the research:
  - significant flows: between Jákfa and Bük, Jákfa and Szeleste, Hegyfalu and Egyházasrádóc, Egyházasrádóc and Rádóckölked, Zalaegerszeg and Egervár, Uraiújfalu and Rádóckölked
  - weight influenced by trading partners
  - the weight of large area farmers influence results

4. Econometric models (Moran index) (Table 1.)
- spatial autocorrelation - Moran index: testing neighbourhood relationships, regularity of spatial distributions
  a) examination of the purchasing connections
  b) examination of the sales connections
  c) examining the relationship between purchasing and sales

	Purchasing relationships	Sales relationships	Purchasing and sales relationship
N	44	28	53
$\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}$	142	68	210
$\bar{x}$	1 112,55	2 203,93	2 087,97
$\sum_{i=1}^{N}\sum_{j=1}^{N}(x_i-\bar{x})(x_j-\bar{x})\times W_{ij}$	203 509 944,98	442 365 184,35	2 635 553 821,46
$\sum_{i=1}^{N}(x_i-\bar{x})^2$	159 559 854,16	253 305 859,86	740 664 011,91
I	0,395	0,719	0,898
I^*	-0,0232	-0,037	-0,019
Evaluation	positive spatial autocorrelation, medium neighbourhood ties	positive spatial autocorrelation, strong neighbourhood ties	positive spatial autocorrelation, strong neighbourhood ties

Table 1: Moran indices calculated by examining purchasing, selling and purchasing-selling relationships. Source: own ed.

5. Network research
   a) network of purchasing relationships
      - 54 nodes, 84 edges; directed links
      - node degrees: Rádóckölked (15), Hegyfalu (12), Körmend (11), Egyházasrádóc (9), Bük (8), Nagyrákos, Sárvár, Szombathely (7), Szeleste (6), Csönge, Vasvár, Zalaegerszeg (5) …
      - β-index, intra-network connectivity index: 1.556 – more circuits in the network
      - γ-index, network connectivity index: 0.5385 – medium value
      - α-index, network connectivity index: 0.3010 – less complex network
      - number of communities: 10
      - modularity: 0.459 – communities are well separated from each other
   b) network of sales relations
      - 28 nodes, 37 edges; directed links
      - node degrees: Ausztria (7), Egyházasrádóc, Körmend (6), Csönge, Hegyfalu, Olaszország (5), Szeleste (4), Bük, Vép (3), Egervár, Vasvár, Szombathely … (2), …
      - β-index: 1.3214 – more circuits in the network
      - γ-index: 0.4744 – medium value
      - α-index: 0.1961 – less complex network
      - number of communities: 7
      - modularity: 0.484 - communities are well separated from each other

c) network of purchasing and sales relationships (Figure 1)
   - 62 nodes, 121 edges; directed links
   - node degrees: Rádóckölked (20), Hegyfalu, Körmend (17), Egyházasrádóc (15), Bük (11), *Ausztria*, Csönge, Szeleste (10), Szombathely (9), …
   - β-index: 1.9516 – more circuits in the network
   - γ-index: 0.6722 – medium value, moderately complex network
   - α-index: 0.5042 – moderately complex network
   - number of communities: 10
   - modularity: 0.429 - communities are well separated from each other
d) network of demand for services
   - 36 nodes, 56 edges; directed links
   - node degrees: Szombathely (11), Körmend (9), Hegyfalu, Zalaegerszeg (7), Egyházasrádóc, Nagyrákos, Rádóckölked (6), …
   - β-index: 1.5556 – more circuits in the network
   - γ-index: 0.5490 – medium value, moderately complex network
   - α-index: 0.3134 – less complex network
   - number of communities: 5
   - modularity: 0.478 - communities are well separated from each other
e) network of purchasing, sales and service use (Figure 2)
   - 72 nodes, 177 edges; directed links
   - node degrees: Körmend, Rádóckölked (26), Hegyfalu (24), Egyházasrádóc (21), Szombathely (20), Bük (16), Csönge (14), Nagyrákos, Szeleste (13), *Ausztria*, Zalaegerszeg (12) …
   - β-index: 2.4583 – more circuits in the network
   - γ-index: 0.8429 – medium value, complex network
   - α-index: 0.7698 – high value, complex network
   - number of communities: 10
   - modularity: 0.401 - communities are well separated from each other

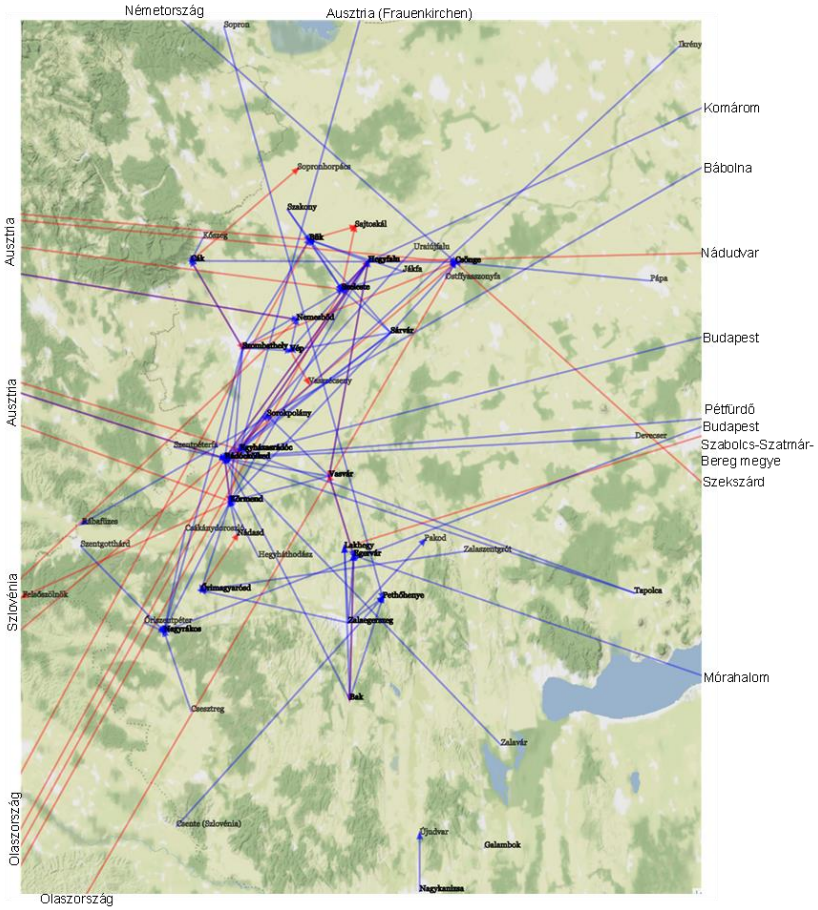

Figure 1: Map showing the network of purchasing and sales relationships, weighted by the number of relationships.
(blue - purchasing contacts, red - sales contacts)
Source: own editing, source of the background map: https://leafletjs.com.

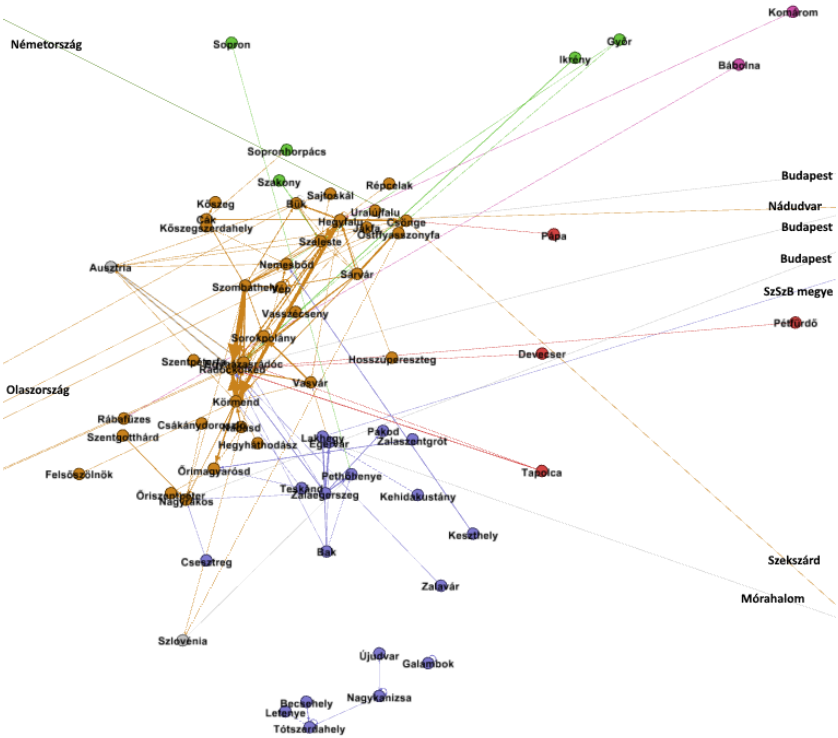

Figure 2: A network representing the network of purchasing, sales and service use relationships, weighted by the number of relationships, colored according to county.
Source: own editing, using Gephi version 0.9.7.

H1: Based on different spatial models, different central locations are drawn from the same data set.

Based on the analyzed models and the calculations with the selected models, we can say that different models represent the spatial structure in different ways. In spatial structure research it can therefore be important to use several models from different disciplines at the same time and to draw conclusions by comparing the results. In spatial structure analyses, therefore, an inter- or multidisciplinary approach cannot be avoided: only a combination of different methods can map real spatial relationships.

H2: Smaller settlements can also function as central nodes in the network of agricultural enterprises.

Purchasing relationships	Sales relationships	Purchasing + sales relationship	Services	Purchasing + sales + services
Rádóckölked (15)	*Ausztria* (7)	Rádóckölked (20)	Szombathely (11)	Körmend, Rádóckölked (26)
Hegyfalu (12)	Egyházasrádóc, Körmend (6)	Hegyfalu, Körmend (17)	Körmend (9)	Hegyfalu (24)
Körmend (11)	Csönge, Hegyfalu, *Olaszország* (5)	Egyházasrádóc (15)	Hegyfalu, Zalaegerszeg (7)	Egyházasrádóc (21)
Egyházasrádóc (9)	Szeleste (4)	Bük (11)	Egyházasrádóc, Nagyrákos, Rádóckölked (6)	Szombathely (20)
Bük (8)	Bük, Vép (3)	*Ausztria*, Csönge, Szeleste (10)	Bük, Tótszerdahely (5)	Bük (16)
Nagyrákos, Sárvár, Szombathely (7)	Egervár, *Szlovénia*, Szombathely, Vasvár … (2)	Szombathely (9)	Csönge, Nemesbőd, Sorokpolány (4)	Csönge (14)
Szeleste (6)	Bak, Lakhegy, Sorokpolány, *Sz-Sz-B. megye*, … (1)	Nagyrákos, Sárvár, Vasvár, Vép (7)	Egervár, Nagykanizsa, Sárvár, Szeleste (3)	Nagyrákos, Szeleste (13)
Csönge, Vasvár, Zalaegerszeg (5)	-	Egervár (6)	*Ausztria*, Cák, Győr, Lakhegy, Őrimagyarósd, Őriszentpéter (2)	*Ausztria*, Zalaegerszeg (12)

Table 2: Links between settlements identified by network research methods on the basis of the connections of the enterprises (sorted by size, only the first eight are shown)
Source: own editing.

By calculating values and structures by the different methods, our aim was to show that the chosen method and approach influences which settlement is central.

Based on the models and the calculations with the selected indicators, we can say that the different models that can be used to study spatial structure represent the spatial structure in different ways. In spatial structure research, it can therefore be important to use several models from different disciplines at the same time and to draw conclusions by comparing the results. Therefore, inter- and multi-disciplinary approaches cannot be bypassed in spatial structure analysis: only a combination of different methods can map real spatial relationships.

The research suggests that network methods are the ‘closest’ to the geographical thinking and geographical approach, as they are able to analyze spatial structure in a complex way, taking into account many aspects, in a way that can be easily understood without specialized knowledge (e.g. econometry) (cf. e.g. Barthélemy 2011). In the case of economic geography, the network approach is also suitable because network studies and the networked understanding of economic actors and activities describe economic processes precisely (cf. Easley – Kleinberg 2010).

SIGNIFICANCE OF THE RESEARCH

The results and the identified centers – as can be seen in the thesis – vary. Several methods have shown however that cities (centers of counties) are not, or only partially, considered centers in the analyzed context. This result suggests – from the point of view of the network approach – that spatial structure consists of complex sub-networks where the structure and organization of each sub-network may differ substantially from the structure and organization of the network as a whole. While large cities (such as Szombathely) would play a central role in most analyses (transport, industry, education, etc.), network structures exist, where their have only a subordinate role.

Thus, based on the network analysis and literature, geographical spatial structure can be considered from an economic point of view as a multiplex network where many different connections between the same points may exist, and the emerging spatial structure is influenced by the structure of the sub-networks, and where the role and function of the settlements varies from sub-network to sub-network. That is, different settlements in the spatial system have different (central or less central) roles, depending on which sub-network of the complex networked system is being analyzed. In the case of the agricultural economic network, such a settlement may have a central role which would not have even a subordinate central role in any other network. The reasons for this are twofold: on the one hand, the location of agricultural sites and hence of production is physically given (and cannot be changed) and, on the other hand, the established agricultural supply chain structure – with centres located further away from large cities – defines these centres.

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