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Peripheries and centers – mapping the innovation potential in Hungary

Thesis of PhD dissertation

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1. INTRODUCTION

The policy makers of many countries and international organizations emphasize the importance of socio-economic resilience in the light of the COVID-19 pandemic, climate change, or even geopolitical structures – and the world economy – moving in a protectionist direction. In the age of innovation-driven economic growth, the key to "future-proof" regions may be the development of their innovative potential and the increase of their innovative activity. At the same time, although there are significant regional differences in the quality and process of innovation[1], the peripheral innovation potential in innovation geography remained an under-researched area for a long time. In this context, there is now a growing literature on the nature of various forms of innovation activity, for example in rural, peripheral contexts. In recent decades, scientific research has primarily examined the question of concentration (Eder, 2018 refers to Davies et al., 2012; Isaksen & Karlsen, 2016; Petrov, 2011; Shearmur, 2011; Shearmur, 2015), i.e. the spatial centers and nodes where innovation activity becomes denser (Chen et al., 2020; Katz & Wagner, 2014). However, several studies have shown that different clusters, agglomerations or growth centres are surrounded by a socio-economic space (Eder, 2018; Oláh & Alpek, 2021a, 2021b), where, despite the apparent lower activity, innovation processes are taking place. These innovation activities are linked to – and complementary to – the innovation production of the central areas (Mayer et al., 2016). Resilience to socio-economic crises may therefore depend to a large extent on the quality and characteristics of the local knowledge networks that emerge in a networking world (Pirisi, 2019), which we describe in our research as the "innovation hinterland". Exploring and learning about the innovation capabilities and processes taking place in this "hinterland" is important not only because of the lack of literature, but also in order to prevent the growth of regional differences and the formation of a dual economic structure in the long term (Józsa, 2019, Zsibók 2019, Csizmadia & Bareith, 2022, Vida, 2022). For policy, it is important to stimulate innovation activity, strengthen innovation potential and remove barriers to innovation generation, which in turn requires a territorial focus (Iammarino et al., 2017). The relevance of the research is increased by the fact that the literature investigating innovation factors – which, if not fulfilled, can be considered as factors hindering innovation or barriers to innovation – largely lacks a spatial approach, despite the fact that innovation is produced in different (economic, social, cultural) spaces. Therefore, the assessment of the innovation potential at the domestic, settlement level and the creation of a theoretical and empirical model for its investigation can be considered a current, relevant scientific and policy objective.

2. OBJECTIVES

The purpose of the research is to provide answers to the following research questions related to the Hungarian innovation potential. Our final goal is to examine the spatial structure of the innovation potential, its spatial differentiation and structure, based on the theoretical and empirical model we develop. The three main objectives of this research are presented in table 1.

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[1] Any **innovation** or change that increases a company's productivity, for example its output per capita, to any extent, even indirectly, is considered an innovation. **Innovation potential** is understood as a complex socio-economic environment – an ecosystem – that stimulates innovation and facilitates related activities. A possible tool for defining **rural semi-peripheries** and **peripheries** is the spatial atlas resulting from the analysis of the Central Statistical Office, which divides the map of Hungary into agglomerations, agglomerating areas, metropolitan agglomerations (and the remaining other areas). A possible approach is to call the latter "other areas", which are not characterised by any of the three formations, the "rural periphery" (the category of districts to be developed by complex program is also a possible definitional approach to the notion of rural periphery).

Table 1 – Research questions and hypotheses

1.	To **systematise** and **synthesise** the theories on innovation (in particular barriers to innovation) in order to have a spatially meaningful, integrated theoretical model of innovation generation (or spatial production) that also underpins measurement purposes.	**Target**
	• What are the main theoretical directions, concepts and theories describing innovation production? • What theoretical and empirical results have been obtained about the innovation characteristics of rural peripheries? • Is there innovation activity in areas with low innovation potential?	Question
	Compared to research on centres and agglomerations, research on the innovation characteristics of peripheral areas is significantly less emphasised in the literature, which may be due to the fact that peripheral innovation can be described by different characteristics than innovation activity in centres.	Hypothesis
2.	Based on the former, **to create an empirical model and measure** the innovation potential on the spatial structure of domestic settlements and districts. **To identify regional differentiating factors**, on a micro, meso and macro spatial structure, by exploring **local barriers to the innovation process.**	**Target**
	• Which variables best describe innovation potential? • What territorial patterns can be observed in the innovation potential in the case of Hungary based on the empirical model? • What innovation potential characterizes central and peripheral regions in Hungary? • What innovation barriers does our newly developed complex innovation potential index indicate?	Question
	In the domestic spatial structure, the innovation potential of cities is indeed significant, but the presence of innovation capacity can also be observed on the periphery. Innovation districts and "axes" are also emerging outside the centres.	Hypothesis
3.	On the basis of the empirical results, further aspects of innovation should be explored with case study-based, semi-structured interview investigations. The empirical, spatial econometric results should be **deepened in "practice" with company manager interviews.**	**Target**
	• What are the characteristics and innovation strategies of successful companies in peripheral regions in terms of innovation potential? • With what strategies can companies in peripheral regions become successful? • What obstacles to innovation do the interviewed domestic companies see? • Is geographical proximity the number one factor supporting corporate innovation?	Question
	Even in peripheral regions with below-average innovation potential, small and medium-sized enterprises are highly successful and adapt to the challenges of their location through a hidden, slow, "follower" innovation strategy.	Hypothesis

Note: own editing.

3. RESEARCH METHODS

The research is based on both primary and secondary sources (Figure 1).

Figure 1 – Summary of the methodological structure aimed at answering research questions
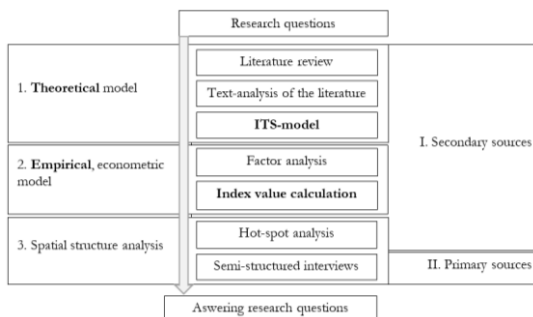
Note: source of data is own collection; own editing.

As for the analysis of literature, a database created by Google in 2011 was used. This allowed a deep, data-driven literature analysis. The dataset contains five million scientific volumes and 500

billion words, of which more than 72%, around 361 billion, are English. The method is used to investigate the occurrence of certain models of innovation, in particular the geography of innovation, and their basic concepts in the database. This is complemented by a traditional literature review to create a new theoretical framework describing the emergence of innovation in time and space, which is called the ITS model.

We then select 78 initial, economic, social, infrastructural variables from the TeIR (National Spatial Information System) database for the year 2016, all of which may be indirectly related to the phenomenon of innovation. These variables have been narrowed down to 16 final variables by factor analysis (varimax rotation method) (after having been found suitable for the application of the method), which have been separated into seven groups of factors by the data reduction methodology.

These variable groups represent different dimensions of innovation potential and the index developed to measure it. The resulting 16 variables can mostly be considered as proxies in the sense that innovation potential can in many cases only be inferred to, as opposed to innovation activity, for which there are many direct inputs and outputs in the literature. Thus the analysis is future-oriented, trying to measure the possibility of future innovative activities locally. The variables obtained by factor analysis (Table 2) were transformed where necessary (standardisation to 0-1 range, one-way adjustment) to create the complex regional innovation potential index. The former, newly developed theoretical ITS model was thus could be transformed and translated into the empirical domain in its several dimensions with our new empirical model.

Table 2 – Variable groups serving as the basis for indexing the spatial innovation potential

Dimension	Variable	Factor						
		1	2	3	4	5	6	7
Labor market potential - tight labor market	*He has been unemployed for more than 180 days compared to the permanent population*	0.928						
	Jobseekers in relation to the population	0.922	-0.127					
Networking potential - foreign relations	*Percentage of foreign ownership*		0.757	0.195				
	Export compared to sales revenue		0.750	0.244				
	Fixed assets compared to total balance sheet		0.629	-0.217				
Corporate potential – innovative companies with high added value	*Development (R&D) tax credit per company*			0.842				
	Wage costs for a company		0.299	0.760				
Availability potential – geographical proximity to centres	*In the case of time-based optimization, the length of the fastest route in minutes to the regional center [minutes]*				0.820			
	In the case of time-based optimization, the length of the fastest route in minutes to the county seat [minutes]				0.810			
Knowledge production potential - institutional learning	*Number of domestic patent applications submitted by Hungarian applicants (according to applicant share), pcs*					0.818		
	Higher education students in relation to the population (%)					0.799		
Social activity potential - social openness, creativity, relationship building	*Visitors to cultural events as a proportion of the population*						0.806	
	Visitors to informational events as a proportion of the population						0.798	
Industrial potential - high-tech industry	*IT company in proportion to all companies*							0.741
	Education company in proportion to all companies		0.105					0.608
	Professional, scientific, technical companies in proportion to all companies	-0.213			-0.136	0.101		0.503

Note: all variables refer to 2016, the source of the data is own calculation based on TeIR, own editing.

During the spatial structure analysis, "hot spots" and "cold spots" of the innovation potential were also identified, which were explored with the help of local G_i^* statistics (Getis & Ord, 1992):

$$G_i^* = \frac{\sum_{j=1}^{M} w_{ij} d_j}{\sqrt{\frac{\sum_{j=1}^{M} d_j^2}{M}} \sqrt{\frac{M \sum_{j=1}^{M} w_{ij}^2 - (\sum_{j=1}^{M} w_{ij})^2}{M-1}}},$$

where M – is the number of units of area under consideration, w_{ij} – is the jth element of the i-th row of the neighborhood matrix, d_j – is the distance between the attribute values of the properties. The investigation and detection of the phenomenon of territorial autocorrelation was done by calculating the global and local Moran's I statistics regarding the spatial structure of the innovation potential. The global Moran's I statistic was determined using the following formula (Moran, 1948) :

$$I = \frac{n}{2A} * \left(\frac{\delta_{ij} * \sum_{i=1}^{n} \sum_{j=1}^{n} (y_i - \bar{y}) * (y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \right),$$

where n is the number of observations, y_i is the value of the variable of interest for observation i, $\bar{y}i$ is the average of the examined variable, A is the number of neighborhood relationships (adjacency links), and δ_{ij} is 1 if i and j are adjacent, otherwise 0.

The local Moran's I statistic was determined using the following formula (Getis & Ord, 1996):

$$I = \frac{(y_i - \bar{y})}{S_y^2} * \sum_{j=1}^{N} [W_{ij} * (y_j - \bar{y})],$$

where y_i is the value of the variable of interest for observation i, $\bar{y}i$ is the mean of the variable of interest, y_j is the value of all territorial units outside i, S_y^2 is the standard deviation of the values of the variable of interest, and W_{ij} is the weighting factor for the distance between points i and j. Finally, the fixed distance procedure was chosen for the spatial weights matrix to identify the micro, meso and macro spatial structure elements.

In addition, we conducted semi-structured interviews with companies selected from the annual SME TOP 100 publication. In this way, we selected the top one percent of all Hungarian SMEs, including the top thousand. The principles of the rating are shown in Figure 2. All TOP100 surveys published since the launch in 2016 were taken into account in our research. From the total number of companies ever awarded, we selected all those operating in municipalities with an innovation potential index value below the national average. This represented a total of 88 companies, all of which were approached by e-mail. Of these, five responded in the first instance and were interviewed in depth.

Figure 2 – Basic principles of selecting companies
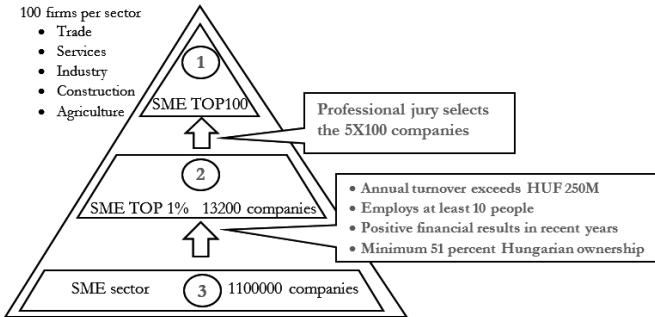
Note: the source of the data is KKV TOP100 publications.

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The various auxiliary calculations, database operations, and the calculation of the innovation potential index and its sub-dimensions were performed using MSExcel 2019 and IBM SPSS Statistics 23.0. ArcMap 10.4.1, QGIS 3.16.1 and GeoDa 1.16.0.12 software were used for the geospatial calculations and visualisation.

4. RESULTS

4.1. First group of questions: theories of innovation geography and theoretical modeling

The theoretical research used big data text analysis tools to examine which main trends it can fit into, and which theoretical processes can provide a foundation for the territorial analysis of innovation. In this context the research:

- Found that before the twentieth century, we do not find a significant occurrence of terms referring to the connections between innovation and regional sciences in the English-language literature.
- Showed that the theory of industrial districts was "replaced" by the theory of growth poles by the middle of the twentieth century.
- Pointed out that since the 1990s theories marked by the terms innovation system, learning region or innovative milieu have advanced.
- Proved that the spatial production and diffusion of innovations has turned from an unresearched topic into one of the most important issues in the field of science in a century.
- Revealed that in innovation geography, we consider the production, spatial diffusion and characteristics of knowledge and its various forms to be one of the most important research issues of the first decade of the 21st century.
- Showed that the neoclassical agglomeration and location theories were somewhat repressed in the second half of the twentieth century in relation to the growth pole theory and the Keynesian regional planning school. However, in many cases these latter theories still imagined the analysis of social space and the creation of innovation in a spatial "black box".
- Showed that the new industrial geography *introduced* a new theoretical cornerstone with the trinity of organization, evolution, and interaction, from which the examination of knowledge networks also emerged, giving inspiration to evolutionary or innovation system trends. In the last third of the twentieth century, socio-economic networks and the learning processes embedded in networks enjoyed a growing popularity in the analyzed segment of literature.
- Showed that the long-established industrial district theory, integrated with new trends, was able to gain renewed popularity and save itself with technological-research parks and clusters.
- As one of the main changes, innovation production transformed from local to networked, and the flow of knowledge and information started to play a special role as the main focus.

The theoretical examination of the relationship between innovation and peripheries has shown that:

- It follows from the mainstream theory of the production of innovations that the locations for the creation of innovations are urban centers and agglomerations.
- Regarding the process of innovation, the vast majority of research examines the centers, even though it can be found in the semi-peripheries and peripheries as well, but the innovative activity of the latter is in many cases slow, hidden and often based on local traditions and conditions ("traditiovation").

- We should understand innovation not as a binary variable, but as a variable that has a continuous density in space, thus innovation is concentrated in the centers, but it is also definitely present outside of them.
- However, innovation is less visible in semi-peripheral and peripheral areas, because the end of the innovation process is mainly linked to the cities. The end of the innovation process's "pipeline", which runs through the whole economy and space, is mostly located in cities.

The literature analysis of innovation peripheries for Hungary reveals:

- So far, Hungarian regional innovation research has focused less on the characteristics of SMEs' innovation activity with a geographical focus. To the best of our knowledge, there has also been little research in the literature on firm-level barriers to innovation in comparison between domestic peripheries and centres.
- In many cases, the focus in the domestic literature is on the municipality as the unit of analysis, or on social and community innovations and the individuals who create them, rather than on entrepreneurs.
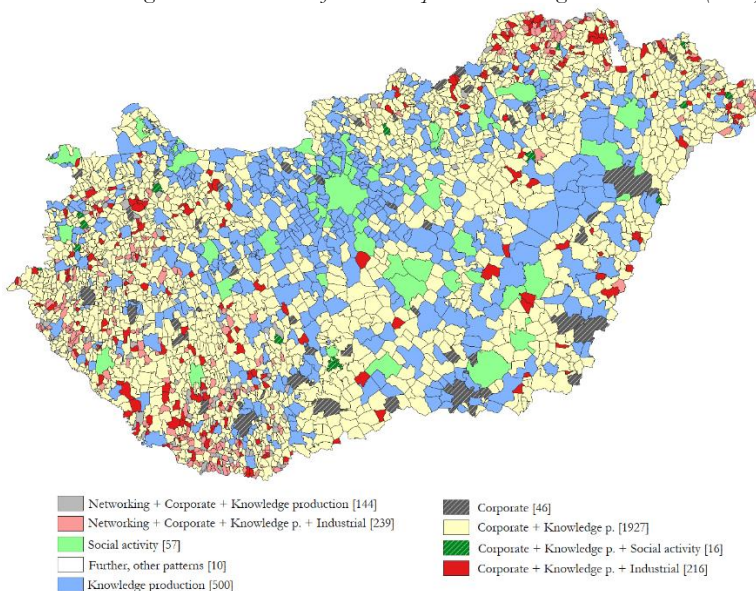
4.2. Second group of questions: empirical modeling and spatial structure analysis

The dissertation created a theoretical, then an empirical model to describe innovation potential, which revealed:

- The dimensions of the empirical model obtained by factor analysis (different innovation potential factor groups) cover the thematic areas of our theoretical "ITS model" on innovation barriers, can be considered as interdependent and reflect the theoretical schools of the past decades of innovation geography and their main concepts as well.
- An empirical measurement of the complex, municipal level innovation potential can be based on the separation of the seven dimensions of innovation potential: accessibility, labour market, social, knowledge creation, networking, firm and industry potential.
- The model can be used to draw a spatial structure landscape of local innovation endowments (resources) and potential in the country and to identify the main drivers (the seven components of innovation potential) that explain this spatial structure.
- As regards the distribution of the main index, the relative weight of cities increases significantly among municipalities with a higher index value. Even the city with the lowest index value has an innovation potential higher than 85.9% of all municipalities, which confirms the findings of several studies describing the agglomeration and multiplier effect mechanisms creating innovations in cities.
- In terms of innovation, the direct role of cities and urbanized areas and their indirect, dynamizing effect on their environment are clear (the relative weight of cities is significantly higher among settlements characterized by higher innovation index values).
- However, in a broader range of municipalities in Hungary, a well-developed innovation environment can be identified, with innovation corridors and zones with a potential present but less urbanised (such zones can also be identified in peripheral areas).
- The spatial differentiation of the factors influencing the dispersion of innovation potential values varies considerably at national level. The highest impact on the spatial pattern has networking potential, followed in turn by accessibility, labour market, industry, social activity, enterprise and knowledge production potential.

- The role and relative importance of the social activity potential in peripheral and semi-peripheral areas was found to be particularly high in terms of the innovation environment, and thus social activity can be seen as a potential resource for unlocking the innovation potential of rural areas.
- A similar resource can be identified for cities, which lies in local entrepreneurship, the community of entrepreneurs.
- The relative position of cities in terms of their innovation potential depends crucially on the degree of development of local knowledge production and the business environment.
- However, each sub-dimension does not contribute to innovation capabilities in isolation, but interacts with each other. The strongest co-movement is observed between knowledge creation and business potential, closely followed by the relationship between business and industry potential.
- In the case of bottlenecks (Figure 3), in most cases the barrier dimensions appear in a combined form, in more than 80% of the surveyed territorial units. In 60% of the municipalities the barrier is the combination of business and knowledge production potential.

*Figure 3 – Bottlenecks of innovation potential in Hungarian settlements (2016)*

▨ Networking + Corporate + Knowledge production [144]	▨ Corporate [46]
▨ Networking + Corporate + Knowledge p. + Industrial [239]	▨ Corporate + Knowledge p. [1927]
▨ Social activity [57]	▨ Corporate + Knowledge p. + Social activity [16]
▨ Further, other patterns [10]	▨ Corporate + Knowledge p. + Industrial [216]
▨ Knowledge production [500]	

Note: Own calculation based on TeIR data. Data managers: ITM, KSH, NAV, SZTNH, GeoX Kft.

The examination of the empirical model and the territorial index also revealed:

- Looking at the macro- and meso-spatial structure, zones, peripheral and semi-peripheral zones with significant capabilities in innovation potential can be identified (Figure 4).

- The core of Hungary's innovation spatial structure is formed by three connected areas with high innovation potential:
  - the junction emerging with the Pécs-Szekszárd axis in Southern Transdanubia,
  - in Eastern Hungary, covering two regions including Northern Hungary and the Northern Great Plain, a territorially interconnected zone on the Debrecen-Miskolc line,
  - and the largest space segment running from Hungary's northwestern border section through Budapest to Szeged.
- The other extreme is formed by border and internal innovation peripheries, which are largely located in districts to be developed with a complex program. Thus, the research confirmed that the districts to be developed with the complex program are indeed in significant need of development, also in terms of innovation.
- An extensive zone of this kind runs:
  - along the south-west, north and north-east border sections – particularly strongly connecting to Zala and Nógrád counties (almost all of these counties) –,
  - in some areas of Bács-Kiskun county,
  - and on the border of Békés and Hajdú-Bihar counties.
  - an indexable internal innovation periphery can also be found in Jász-Nagykun Szolnok county.
- In connection with the above two types of areas, two additional types appear: the range of settlements with a lower index, typically located on the outskirts of centers with high innovation potential, and the group of local settlements with a higher index that fit into an environment with a low innovation potential.

Figure 4 – Innovation hot spots and cold spots in Hungary (2016)
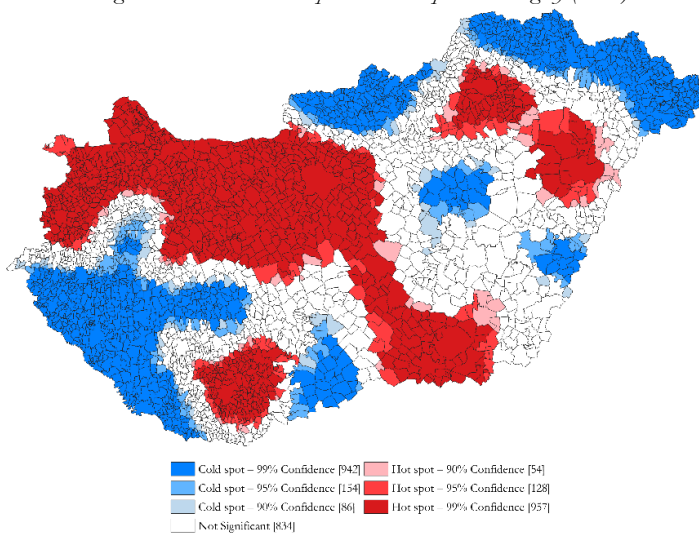
Note: Own calculation based on TeIR data. Data managers: ITM, KSH, NAV, SZTNH, GeoX Kft.

4.3. Third group of questions: lessons learned from semi-structured corporate interviews
Econometric empirical results were expanded with semi-structured interview research, so it was revealed that:

- The majority of respondents felt that their company's development was not thwarted by its geographical location and that it had access to the right knowledge base from which to innovate.
- In terms of internal barriers, no obstacles were perceived in terms of business potential or financial potential.
- The ability to build relationships was not perceived as a crucial barrier, with the role of trust issues being emphasised by many firms.
- In one case, the weakness of the local industrial potential was highlighted, in two cases accessibility problems were highlighted, but social potential was not perceived as a bottleneck, nor was labour market potential.
- One company highlighted the limitation of the market potential, i.e. the size of the domestic market, which may contribute to the fact that many companies innovate with a "first among followers" strategy and their innovations can not be measured by patents.
- The source of innovation is usually market demand, monitoring of partners, analysis of foreign market trends, manager's intuition, ideas of the firm's employees or results of the firm's suppliers.
- University or research institute cooperation is not the direct source of the new idea, but a part of the innovation process.
- Firms can be seen as a focal point in the socio-economic space that brings ideas that are forming in hidden societal networks to the surface: sometimes external actors bring their ideas to the firm.
- There are examples of successful companies in regions with low innovation potential in their home country being the first to bring certain innovations to market, not only at national level but also at European level, and this is a successful and feasible strategy, which requires intellectual employment and openness to development, but not patents or radical innovation.
- The majority view is that semi-peripheral or peripheral location does not mean today that success can be achieved at low cost, sheltered from market trends and relying on local market power, so it is far from being a shorter route to success: companies in peripheries are also competing internationally.
- There are examples of business leaders who do not recognise the role of geography in economic and innovation success. However, when a company manager reports economic difficulties and barriers to innovation, geography is more likely to be mentioned.
- The firms interviewed are flexible in taking advantage of the few perceived benefits of location and compensating for its disadvantages. The managers of the surveyed companies can imagine that the rural location can result in a more loyal workforce, lower turnover, calmer, more closed, and safer developments, and if appropriate, it can provide company managers with a quiet place for strategy creation and retreat.
- The semi-peripheral or peripheral location was perceived by firms as neither an advantage nor a significant disadvantage, as they can overcome it with several strategies. The majority of respondents build up their market relations and strengthen their domestic network

through online contacts, a combination or one of the systems of regional representatives, logistics bases, sites.

- Results also depend on the industry of the firm, but incremental innovation may be the more typical path for peripheral regions.
- At the same time, there is a combinative strategy of rural headquarters-Budapest development as well as the opposite. So Hungarian SMEs may separate the processes of the innovation value chain in geographical space.

In light of the above, we can verify and confirm our hypotheses in all three groups of research questions.

LIST OF PUBLICATIONS RELATED TO THE TOPIC OF THE THESIS

György, L. & **Oláh, D.** (2022). The Hungarian economy (politics) passed the stress test. In Parragh, B. & Báger, G. (Eds.), *Crisis management of the stimulus state II.: The successful economic restart.* Ludovika University Publishing House.

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Alpek BL & **Oláh, D.** (2021). Dimensions of the innovation potential of Hungarian settlements. Regional Statistics (Economics: **Q3** , Geography: **Q3**), 61(6), 712–738.

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Oláh, D. (2018). Neoliberalism as a Political Program and Elements of its Implementation: A Narrative in Theoretical History. *Public Finance Quarterly* , 2018/1, 96–112. (Finance: **Q4** , Public Administration: **Q4**).