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Hungary's Border Sections After the Schengen Opening: Integration Potential in the Context of Population Concentration and Urban Gravity

ABSTRACT

With Croatia's accession to the Schengen Area in 2023, followed by Romania's in 2025, Hungary's border regions have once again come to the fore. The expansion of the Schengen Area has created a new spatial context in which population concentration in border areas and the gravitational pull of nearby urban centers indicate varying levels of integration potential across different border sections. This study provides a bilateral comparative analysis of Hungary's border sections based on population concentration in border areas and the urban gravity of nearby centers. The analysis draws on NUTS 3-level population data, the Border Population Concentration Index (BPCI), and the gravitational weight of nearby urban centers located on both sides of the border. The results show that Hungary's border sections exhibit considerable differences in terms of integration potential: in regions with larger urban centers, denser opportunities for spatial linkages emerge, whereas along sections characterized by weaker urban networks and lower population concentration in border areas, the spatial conditions for integration are more limited. These differences suggest that the possibilities and anticipated directions of cross-border cooperation vary significantly across border sections. An important question for further research is which territorial and institutional instruments may help strengthen linkages in less favorably positioned areas.

Keywords: state border, border region, Hungary, urban gravity, population concentration, integration potential

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INTRODUCTION

In recent years, Hungary's Schengen border system has been expanded to include two new sections: the accession of Croatia (2023) and Romania (2025) has created a new spatial situation in Hungary's border regions (European Parliament [EP], 2022; European Commission [EC], 2024a). The enlargement of the Schengen Area necessitates a novel approach to the bilateral comparative analysis of border regions, particularly in cases where population concentration, transport linkages, and the spatial organizing role of urban centres vary significantly from one border section to another. An issue that deserves special emphasis is the rising prominence of the Hungarian–Romanian border, which has emerged as a zone of connectivity within the European Union [EU] as a result of spatial structural transformation processes in the Schengen Area (Horeczki & Szilágyi, 2025).

In the EU narrative, the concept of periphery may refer to macro-regional (Central and Eastern European) entities, remote, sparsely populated, rural (mountainous) areas, as well as internal peripheries, border regions, peri-urban zones, or less developed Member States (EC, 2024b; Kühn, 2015). Our previous analyses emphasize the co-existence of a variety of peripheries in Hungary. Dependency as an underlying condition and the issue of inequality are defining concepts in centre–periphery theories (Pike et al., 2011; Wallerstein, 1974). Regions undergoing peripheralization can be distinguished by their less favourable socio-economic situation and lower accessibility compared to neighbouring regions. Hungary provides an interesting study area due to its semi-peripheral position in the global economy, facing the classic dilemma of “catching up” (Arrighi, 2014; Molnár, 2021): fulfilling its role in the international division of labour, facilitated by the liberalization of trade and capital flows, or striving for central functions through comprehensive economic restructuring. Spatial polarization manifests itself in various forms in Hungary: between the capital and the countryside; between the western and eastern parts of the country; across different border sections; and between regional centres, small towns, and villages. This division is also apparent in the geographical characteristics of border regions. Throughout history, central places and areas have consolidated their economic base by attracting labour, knowledge, and thus entrepreneurial and innovation capital from other settlements (Nagy et al., 2022; Péntzes, 2013a).

The authors have analyzed border sections extensively, focusing on the socio-economic implications of the enlargement of the Schengen Area and the geographical fragmentation of border sections. Increased border permeability has strengthened everyday interactions and cross-border cooperation in a number of regions, as documented in the literature, but their intensity is decisively shaped by the specific location of the border region, its transport infrastructure, and the structure of the settlement network (Lados, 2005; Rechnitzer, 2005). The present study, while adhering to this strand of research, does not address the direct implications of open borders but rather focuses on the comparative characteristics of the newly emerging spatial situation. A study by Péntzes (2013b) modeled the cross-border catchment areas of the Hungarian–Romanian border region using the gravity method, based on different scenarios of border openings and road network development (Péntzes, 2013b).

Fragmentation is a dominant characteristic of European border regions, often acting as a barrier to integration. In Central and Eastern Europe, the systemic change and subsequent EU accession have promoted and reinforced horizontal, cross-border interactions both within and beyond the region, with access to EU funds serving as a powerful incentive (Péntes et al., 2024). Border regions are particularly affected by policies targeting the mitigation of development disparities and the catching-up of lagging regions. Importantly, borders are not depicted in the literature as simple dividing lines, but rather as spatial constructs shaping social, economic, and geopolitical relations (Van Houtum, 2005). This has inspired the investigation of cross-border aspects of regional integration, such as cooperation in governance (Perkmann, 2003), analyses in various geopolitical and retrospective contexts (Konrad et al., 2026), sustainability-related issues (Liu et al., 2021), as well as demographic perspectives (Gwiażdzińska-Goraj, 2026).

Drawing on the results of our previous analyses, which highlighted the vulnerability of border-area populations in the Central European region (Horeczki et al., 2025), this study examines the size of border-area populations and the gravitational pull of cities on border crossing points. The objective of this research is to explore the spatial disparities in population concentration and urban gravity along Hungary's Schengen borders, as well as the resulting integration potential across different border sections.

METHODS

The subjects of our analysis are Hungary's Schengen borders as of January 1, 2025, more specifically the country's state border sections shared with Austria, Slovenia, Slovakia, Croatia, and Romania. The present situation developed in three stages. On December 21, 2007, Hungary—together with Slovakia (679 km) and Slovenia (102 km)—joined the Schengen Area, which had already included Austria (356 km) for ten years, increasing the proportion of Schengen border sections from 0% to 50.6%. Croatia's accession (355 km) on January 1, 2023 further raised this proportion to 66%, which reached 86% with Romania's (453 km) accession on January 1, 2025.

The total length of the Schengen border sections (1,945 km) can be divided into two non-contiguous parts, as the Hungarian–Ukrainian (137 km) and Hungarian–Serbian (164 km) sections—external borders of the EU located in the northeast and southeast—interrupt the continuity of Hungary's Schengen borders. Together with the Hungarian–Slovenian border section, these represent the shortest external border sections of Hungary (Vukovich, 2022, p. 423).

The broader geographical scope of the analysis covers NUTS 3 units located on both sides of the Schengen border; however, the main focus of the research is the border zone defined by a 20 km straight-line distance. Within this 20 km border zone, 37 NUTS 3 units contain inhabited areas on both sides of the border (Hungary: 15; Croatia: 6; Austria: 6; Slovakia: 5; Romania: 4; and Slovenia: 1). According to the 2021/22 census, the combined population of these units exceeds 14 million people;

however, when narrowing the focus to the 20 km border zone, this figure decreases to nearly one-third (4.8 million inhabitants).

Table 1. Categories of the Examined Sample Sizes by the Population Intervals of NUTS 3 Units

Sample size	Country	Average population	Data source
Large unit size	Slovakia	674,000 (interval: 566,000 – 782,000)	Census Slovakia 2021, 2023
Average unit size	Romania	485,000 (interval: 330,000 – 650,000)	Rezultate definitive RPL 2021 – Recensământul Populației și Locuintelor, 2025
Average unit size	Hungary	447,000 (interval: 182,000 – 1,333,000)	Census database – Central Statistical Office, 2025
Low unit size	Croatia	133,000 (interval: 70,000 – 258,000)	Population, Households and Families by Statistical Region, Year and Measures
Low unit size	Slovenia	114,000 (one examined unit)	2025SODB2021 – Population – Basic results, 2025
Low unit size	Austria	99,000 (interval: 37,000 – 63,000)	STATcube – Log in, 2025

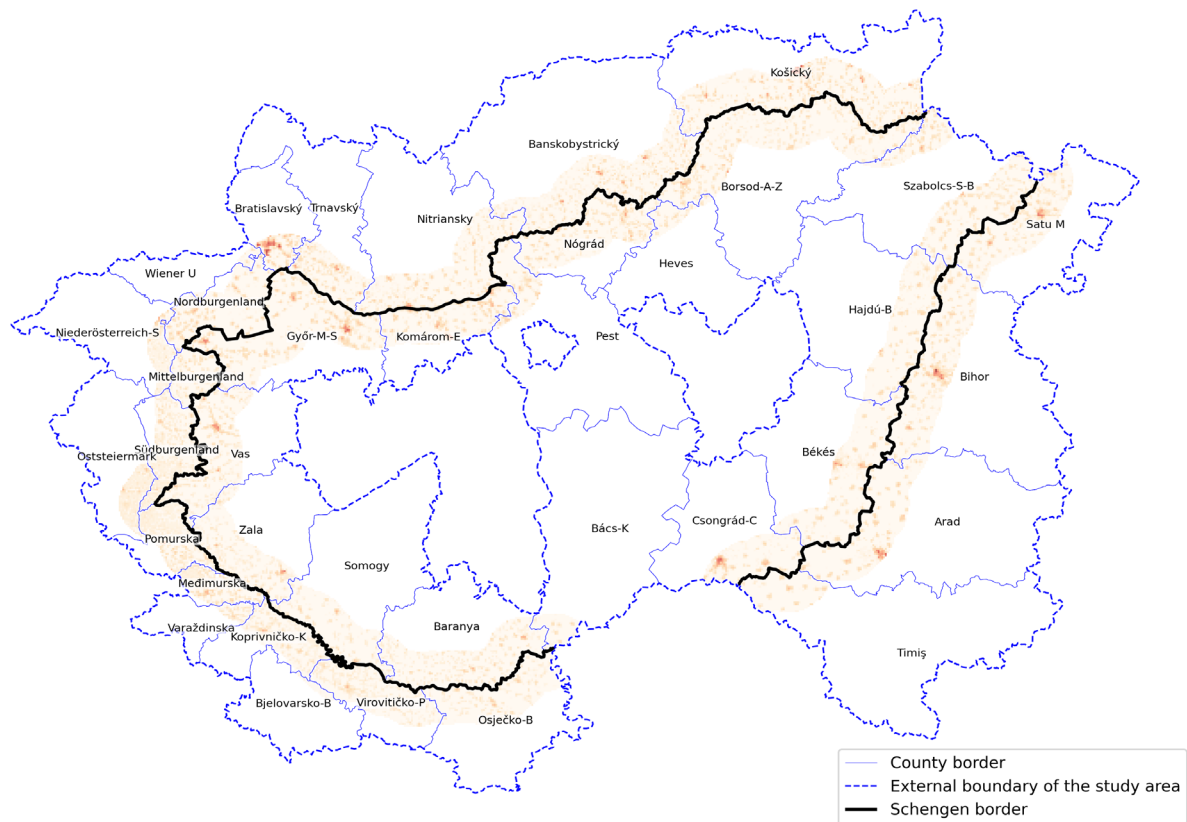
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Given the sometimes considerable variation in the size of NUTS 3 territorial subdivisions across the countries of the examined region, the sample was divided into two distinct groups (see Table 1): countries with large-sized units (Slovakia, Romania, Hungary) and those with NUTS 3 units of a smaller average population size (Croatia, Slovenia, Austria). The most common units of observation are counties; however, Slovenian and Austrian NUTS 3 level units do not perform administrative functions. In Austria, districts represent the administrative tier between the province and the municipality, and these may coincide with the NUTS 3 level (as in the case of Central Burgenland and the Upper Pula District). Within the selected sample, Central Burgenland in Austria represents the NUTS 3 unit with the smallest population, with fewer than 38,000 inhabitants.

Contrary to previous analyses in Hungary focusing on border buffer zones with a depth of 25–30 km, the present enquiry defines the study zone with a depth of 20 km. This is fully consistent with the 30 km threshold defined in the Local Border Traffic Regulation (1931/2006/EC), as well as with the 20 km “frontier worker” band applied to daily cross-border commuters (e.g. Italy–Switzerland) (Gazzetta Ufficiale, 83/2023.06.30). As indicated by previous Hungarian data, the majority of commuters from Hungary to Austria live within 20 km of the state border, with 40% residing in settlements adjacent to it (Hungarian Central Statistical Office [HCSO], 2015).

A 25–30 km radius would have enabled the inclusion of additional Hungarian and non-Hungarian NUTS 3 regions (e.g. Fejér, Tolna counties, Budapest), which, however, do not fall within the category of “border regions,” and their inclusion would have distorted the analytical focus. In several neighbouring countries, even a zone with a depth of 20 km may encompass entire small-sized NUTS 3 regions, as the size of statistical-administrative units implies different territorial scales across countries (Figure 1).

Figure 1. The Examined Schengen Border Zone



Source: own compilation

When examining NUTS 3 units in Hungary, although several counties and Budapest do not directly border Schengen states, they may still be partially covered by the buffer zone (e.g. the northwestern corner of Heves County). Due to the smaller territorial extent of NUTS 3 regions on the other side of the border—particularly in Austria and Croatia—the 20 km zone in some cases not only includes but extends beyond border units. As a result, the size of the border-area population can also be calculated for units without direct adjacency to the Hungarian state border, such as Oststeiermark, Niederösterreich-Süd, or Wiener Umland/Südteil, as well as Croatia's Varaždin County ("behind" Medimurje) and, to a lesser extent, Bjelovar-Bilogora County.

To analyze the border sections, we used and modified 1:1 million-scale shapefiles from the EU GISCO database (Eurostat, 2021). The use of this dataset raises a methodological issue, as the total length of Hungary's border derived from this method is 2,000 km—approximately 10% shorter than the 2,246 km reported by the HCSO. For comparison, we also included the OpenStreetMap representation of Hungary's border (2,214 km), which closely approximates the official value.

This discrepancy can be attributed to the course of the boundary line, the resolution of the map, and potential vertical deviations; the GISCO-derived boundary can therefore be considered a simplified representation. The discrepancy is not uniform: borders following rivers and mountain ranges (i.e. natural borders) appear to be the most simplified, whereas smaller deviations occur along more

conventional, angular border sections (Table 2). This is important because the impact of border-length simplification on indicator values (such as the BPCI), which are relative to border length, may vary across different border sections.

Since meter-level accuracy of the state border line has no direct implications for the daily lives of inhabitants, the use of a simplified boundary was deemed justifiable for ensuring comparability across different types of border zones.

Table 2. Difference Between the Lengths of the Shapefile and the HCSO Border Line

Schengen border (km)	Austrian	Slovak	Slovenian	Croatian	Romanian	Total
HCSO	356	679	102	355	453	1945.0
GISCO	314	577.4	87.5	322	421	1721.9
Deviation, %	11.80	14.96	14.22	9.30	7.06	11.47

Source: own compilation

We refined the method for calculating the border-area population used in our previous comparative analyses of the Hungarian–Romanian and Hungarian–Croatian Schengen border sections (Horeczki & Szilágyi, 2025; Szilágyi, Rácz, & Horeczki, 2025). As a point of departure, we calculated the 2021 population by grid cell, while delineating the 20 km border zone based on centroids; that is, the inclusion of a given cell in the analysis was determined by the straight-line distance between the center of the grid cell and the border line. This refinement primarily concerns the treatment of cells “divided” across administrative boundaries or state borders.

We created a separate centroid layer from the GISCO 1×1 km population grid and then spatially linked these points to the NUTS 0 and NUTS 3 polygons (using the “within” predicate). As a result, the total population of a grid cell could be assigned to only a single territorial unit. The methodological justification for this step lies in the fact that border lines and administrative boundaries often intersect grid cells, and aggregation based on pre-stored territorial codes does not always allow for unambiguous classification. By contrast, centroid-based assignment ensures that a cell’s population is attributed to the unit containing its center, thereby preventing populations of cells split by borders from being counted on both sides (in extreme cases, multiple times). This adjustment directly affects the BPCI numerator, i.e. the N_d value representing the border-area population.

A separate control study was conducted to validate the calculation of the border-area population. A total of 4,991,405 people were counted within the 20 km zone on both sides of Hungary’s Schengen borders, while the estimated number was 4,990,734 when grid cell centers were matched with the examined NUTS 3 units using the centroid-based assignment method. The slight discrepancy between the two values (671 people) suggests that the centroid-based method can estimate the total size of the border-area population without significant distortion.

It should be noted that, when computing the BPCI, the absence of a border section implies that the indicator can only be interpreted for NUTS 3 units directly adjacent to the state border. A total of 30 such units were identified in the full sample, with a corresponding border-area population

of approximately 4,791,405 people. This indicates that, within the 20 km border zone, 199,329 people reside in eight NUTS 3 units that have a border-area population but no direct border section; consequently, individual BPCI values could not be assigned to them.

To address this issue, we did not apply a uniform solution but introduced adjustments tailored to specific spatial configurations. In cases where a NUTS 3 unit without a direct border section had infrastructural access to the state border via a single adjacent cross-border unit, its entire border-area population was added to the “intermediate” unit, thereby increasing the corrected BPCI value of the directly adjacent unit (e.g. the border-area population of Oststeiermark increased the BPCI of Südburgenland, while that of Varaždin County increased that of Međimurje County).

In situations where the border could be accessed via two alternative routes—that is, where two intermediate NUTS 3 units provided effective connections—the border-area population was distributed evenly between them (e.g. the population of Heves County was divided between Borsod-Abaúj-Zemplén and Nógrád). Cases in which a NUTS 3 unit was located along the Schengen border but lacked road crossings, and where significant natural barriers (in this study, rivers) hindered such connections, were treated as a separate category. This situation characterizes the Slovak border section of Szabolcs-Szatmár-Bereg County (Tisza River), as well as the Croatian border section of Bács-Kiskun County (Danube). In such cases, crossing the border required passage through another Hungarian NUTS 3 unit, implying a substantial detour.

As this disrupts the logic of the 20 km border zone measured as the crow flies, such grid cells were only partially assigned to the de facto connecting NUTS 3 unit, namely with half of their population (e.g. Baranya in the case of Bács-Kiskun, and Borsod-Abaúj-Zemplén in the case of Szabolcs-Szatmár-Bereg). Overall, the application of the halving rule reduced the population base used for calculating the BPCI: the total border-area population from which corrected BPCI values were derived amounted to 4,956,013 people.

To determine the relative proportion of the border-area population, we used the Border Population Concentration Index (BPCI). This indicator cannot be substituted by the conventional population density of the 20 km border zone. Population density is an areal indicator that expresses the size of the population relative to the area of the examined zone (people/km²) and does not treat the border line as an independent factor. In this study, however, the length of the border section (L) is the key variable. The emphasis is therefore not on the general “density” of the border zone, but rather on the concentration of the border-area population along different Schengen border sections, relative to border length. This highlights the nature of the BPCI as a linear concentration indicator: it expresses the number of inhabitants within a border zone of width $d = 20$ km per kilometre of the examined (NUTS 3) border section; its formal unit of measurement is therefore people/km.

$$\text{BPCI} = \frac{N_d}{L}$$

where

N_d is the total population (people) of the border zone with a depth of $d = 20$ km

L is the length of the given land border (km).

A higher BPCI value indicates a greater share of the border-area population and a stronger linear population concentration, which—within the logic of this study—can be interpreted as a spatial precondition for cross-border linkages; however, it does not measure the intensity of actual interactions. The N_d values used for calculating the BPCI were derived and adjusted as specified above. The term “corrected BPCI values” refers to those cases in which the spatial allocation of the border-area population (particularly for units without a direct border section) was carried out using the method presented here.

This approach is not without historical precedent. In the 1930s, András Rónai applied a ratio linking population and border length, motivated by geopolitical considerations; his objective was to determine the “external” demographic pressure exerted by populations on the other side of the border, with higher values interpreted as indicators of a state’s geopolitical vulnerability (Rónai, 1933)⁴. By contrast, the BPCI applied in this study does not express external pressure, but rather internal pressure, more specifically the share of the border-area population along a given border section.

In line with our initial assumption that the concentration of cross-border populations constitutes an important spatial condition for cross-border linkages—and that the BPCI can therefore be interpreted as a proxy for interaction potential—it is reasonable to assume that nearby large cities function as potential organizing hubs for such linkages (Hardi, 2009). The analysis of urban gravity highlights the higher integration potential of major urban centres along different border sections and their role as organizational hubs shaping the directions of cooperation.

Border cities are popular destinations for shopping tourism (Rechnitzer, 2005) and for tourism more generally (Pirisi & Reményi, 2009). Within the Schengen Area, firms from the opposite side are free to establish themselves in industrial parks; similarly, cultural and educational institutions may extend their reach “beyond the border” (EduCultCentre project). In addition, the suburban zones of nearby large cities often extend across national borders (Balizs & Somogyi, 2024).

These asymmetrical processes—for example, the emergence of cross-border educational catchment areas—tend to benefit Hungarian secondary and higher education institutions, while suburbanization typically contributes to the growth of non-Hungarian centres (e.g. Bratislava, Košice, Oradea, and Arad). Whereas population concentration in border areas creates the (random) possibility of interactions, the presence of urban centres introduces rhythm and regularity into these processes. Therefore, it is worthwhile to examine these two components in parallel.

We analyzed the spatial organizing effect of cities on border crossings using a gravitational model. This study does not aim to measure actual traffic volumes, but rather to identify potential linkages shaped by the population concentration of cities and the accessibility of border crossings. The analysis draws on Newton’s law of gravity, where m_1 represents the population of a given city and m_2 the border crossing point; in the absence of population data for the latter, a value of 1 is uniformly assigned. G denotes the gravitational constant, which is commonly used as a weighting factor in similar studies; for the purposes of this analysis, its value is set to 1. Finally, r denotes the distance

⁴ Zoltán Hajdú noted the significance of this historical precedent.

between the city and the border crossing point, calculated here as travel time for passenger vehicles, measured in minutes.

$$F = G \frac{m_1 m_2}{r^2}$$

To apply the above formula, a database of Hungary's Schengen border crossings and the identification of the study cities were required. The analysis included border crossing points that facilitate the uninterrupted passage of road vehicles; accordingly, ferry crossings, as well as those intended exclusively for pedestrians, cyclists, or horseback riders, or lacking a paved surface, were excluded. The finalized database comprised 107 crossing points, of which 38 provide access to Slovakia, 28 to Austria, 22 to Romania, 11 to Slovenia, and 8 to Croatia.

Delimiting the scope of cities under study proved to be more challenging. Ultimately, all settlements with city and town status (regardless of population size) located within the 20 km zone of the Schengen border area (on both sides of the border) were included in the analysis. The seats of NUTS 3 units located within the border zone were also considered among the selected settlements, including those not directly adjacent to the state border (e.g. Eger).

In addition, three capital cities—Bratislava, as well as Budapest and Vienna (the latter two not located within the border zone)—and Graz were included in the database. However, in Bács-Kiskun County, Baja was selected instead of Kecskemét. The final database comprises 187 settlements with city status.

A critical aspect of the study was the identification of an appropriate methodology for calculating urban population. The analysis was conducted using the most recent census data from 2021 (2022 in the case of Hungary) (HCSO, 2025). It should be noted that Austria (Statistik Austria, 2023) and Slovenia (Žnidaršič & Miklič, 2022) did not conduct traditional, comprehensive censuses; instead, they relied on register-based censuses (using institutional data), which differ methodologically from those conducted in other countries (Rezultate definitive RPL 2021 – Recensământul Populației și Locuințelor, 2025; Census Slovakia 2021, 2023; Statistički sustav Republike Hrvatske, 2023).

Due to administrative structural specificities in neighboring countries, the population of the urban core and that of the municipality (as defined within LAU boundaries) show significant divergence in Croatia (e.g. 75,535 vs. 96,313 inhabitants in Osijek), a somewhat smaller difference in Romania, while in the remaining countries municipal and administrative boundaries largely overlap. Ultimately, population data for administrative units were used in the analysis.

An alternative approach could have involved incorporating agglomeration and conurbation areas; however, this option was not pursued.

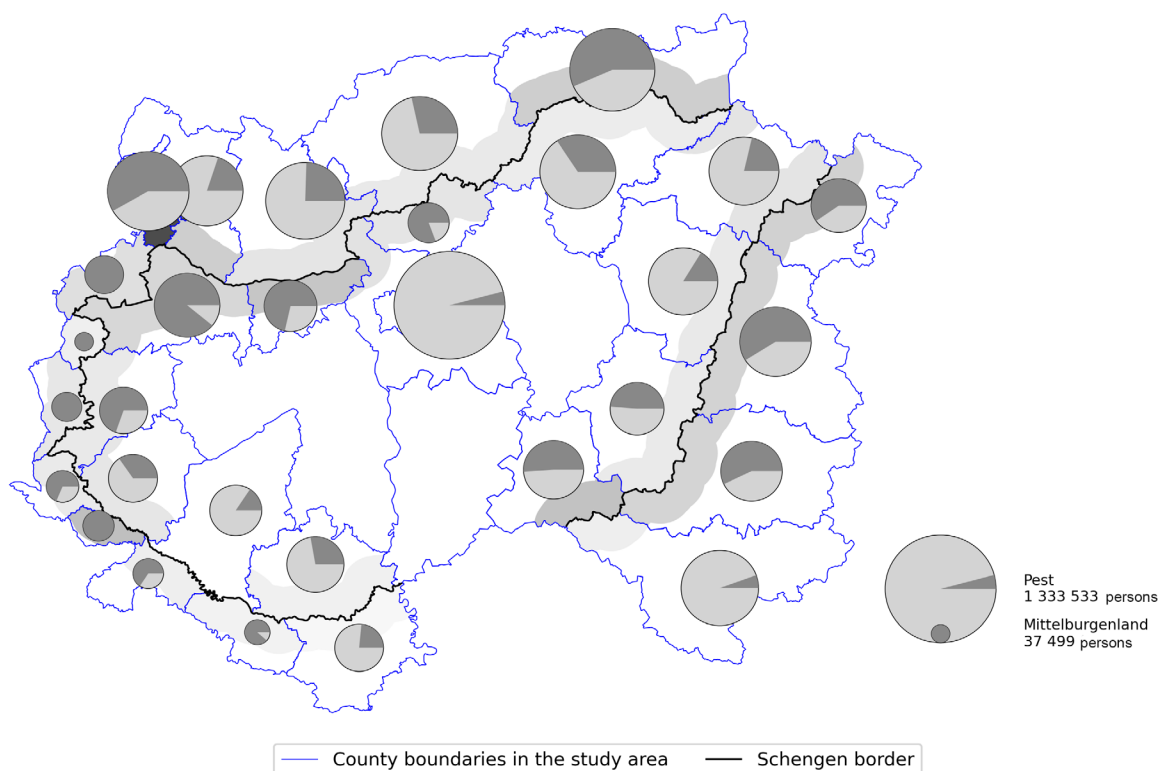
RESULTS

Analysis of the Border-Area Population

Within the 37 NUTS 3 units adjacent to Hungary's border zone, the average proportion of the border-area population is 42.4% (Figure 2), with values ranging from 0.1% to 100% (e.g. Central Burgenland). This may result in an apparent anomaly whereby, in certain units (e.g. Central Burgenland), the proportion of the border-area population appears to exceed the total population; however, this ratio does not affect the calculation of the BPCI. The main justification for excluding the proportion of the border-area population within NUTS 3 units from further analysis is that Slovenian and Austrian census data (register-based census) rely on methodologies that differ from those applied in other countries (Population Census, 2025), which constitutes one of the limitations of the present study.

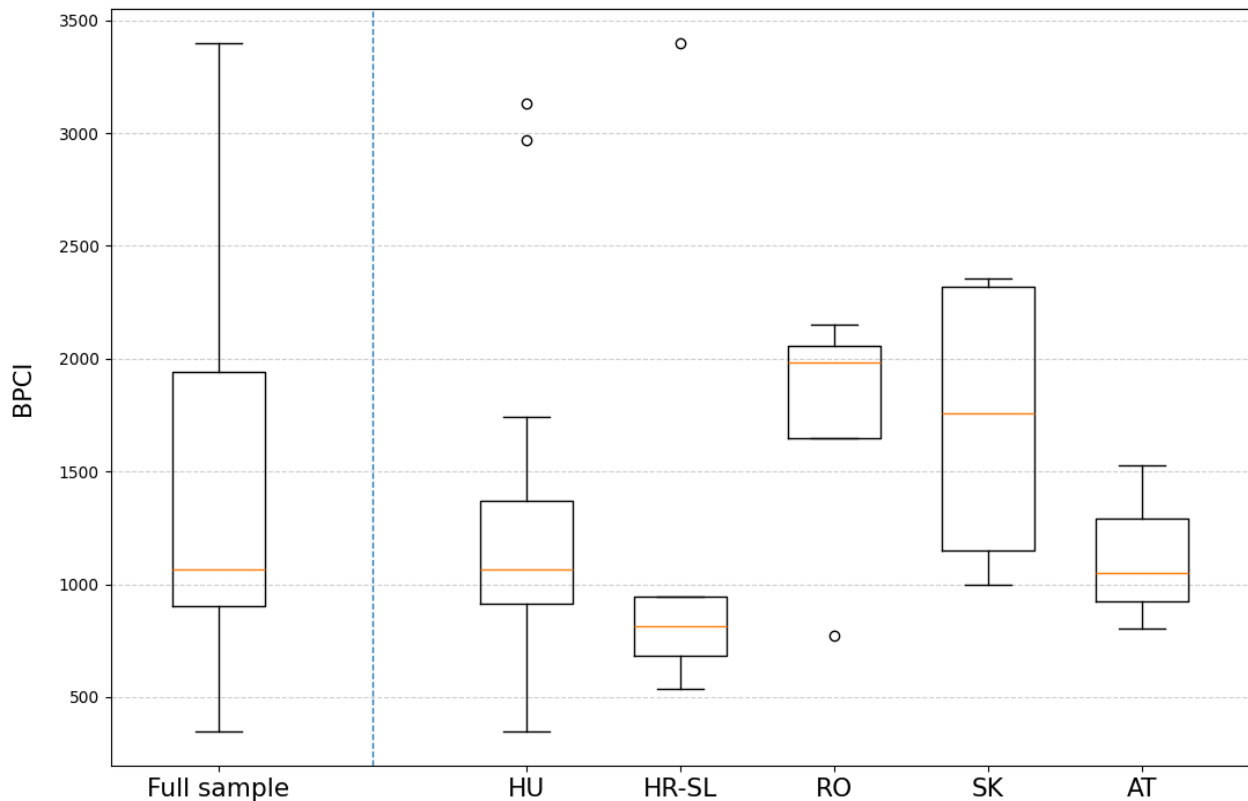
A boxplot analysis of BPCI values identifies a single upper outlier, namely Bratislava County. Excluding this case, the median for the entire sample is 1,064 people/km, while the interquartile range lies between 906 and 1,940 (Figure 3). Based on the regional distribution of the adjusted BPCI values, Hungarian counties (N = 13) have an average value of 1,341 people/km, with an approximately ninefold difference between the extremes: Somogy (347 people/km, the lowest value in the sample excluding Bratislava) and Csongrád-Csanád (3,129 people/km).

Figure 2. Proportion of the Population Living in the Schengen Border Area (20 Km) (Dark Gray) as a Share of the Total Population of the NUTS 3 Unit



Source: own compilation

Figure 3. Boxplot Analysis of BPCI Values (Excluding the Bratislava Outlier (BPCI = 53,842))



Source: own compilation

The Croatian–Slovenian group ($N = 5$) has an average of 1,276 people/km and a median of 815 people/km, with the maximum value of 3,398 people/km recorded in Međimurje and Varaždin, while the remaining values typically fall within the lower range (538–943 people/km). Within this group, Prekmurje (943) exhibits one of the higher values, although it still falls within the range defined by the Hungarian and Croatian data.

The Romanian side of the border region (Arad, Bihor, Satu Mare, Timiș) shows a higher median (1,721 people/km) and a relatively narrower range (770–2,151 people/km), indicating a more uniform yet higher-density border zone. With the exception of Timiș, all values fall within the upper range, with Arad, Bihor, and Satu Mare each exceeding the overall sample median.

On the Slovak side, Bratislava significantly skews the results; however, even when excluded ($N = 4$), the group average remains high (1,717 people/km), roughly equivalent to Romanian values and higher than the averages observed in Hungarian, Croatian–Slovenian, and Austrian border regions. Within this group, the only lower outlier is Banská Bystrica County (998 people/km). The extreme value of 53,842 people/km for Bratislava County can be considered an outlier for the entire sample.

Finally, Austrian (Burgenland) units exhibit moderate values, with an average of 1,127 people/km, indicating a relatively balanced population concentration along the border.

As indicated by the corrected BPCI values, the examined Schengen border zones do not form a homogeneous area. Even when excluding Bratislava as an outlier, the greater demographic weight of units along the northwestern border, as well as along the Romanian border sections, is clearly observable. At the same time, the Croatian border area and certain southern and peripheral sections of the Hungarian border exhibit lower linear population concentration.

These findings point to pronounced differences in the population geography of Hungarian border zones affected by the opening of Schengen borders and, consequently, to significant variation in the density of opportunities for spatial linkages across different border sections. This result is consistent with earlier analyses of Hungarian border regions conducted by Tagai and his collaborators approximately one and a half decades ago (Tagai et al., 2009).

The Gravitational Attraction of Cities on Schengen Border Crossing Points

The combined population of the 187 cities in 2021/22 is 8.6 million: 3.9 million in 110 cities in Hungary; 2.3 million in 15 cities in Austria; 1.17 million in 28 cities in Slovakia; 0.8 million in 16 cities in Romania; 0.32 million in 15 cities in Croatia; and 40,000 in three urban settlements in Slovenia. The two extremes are Vienna (1.926 million inhabitants) and Pálháza (977 inhabitants), with an average city size of 46,000 and a median of 8,900.

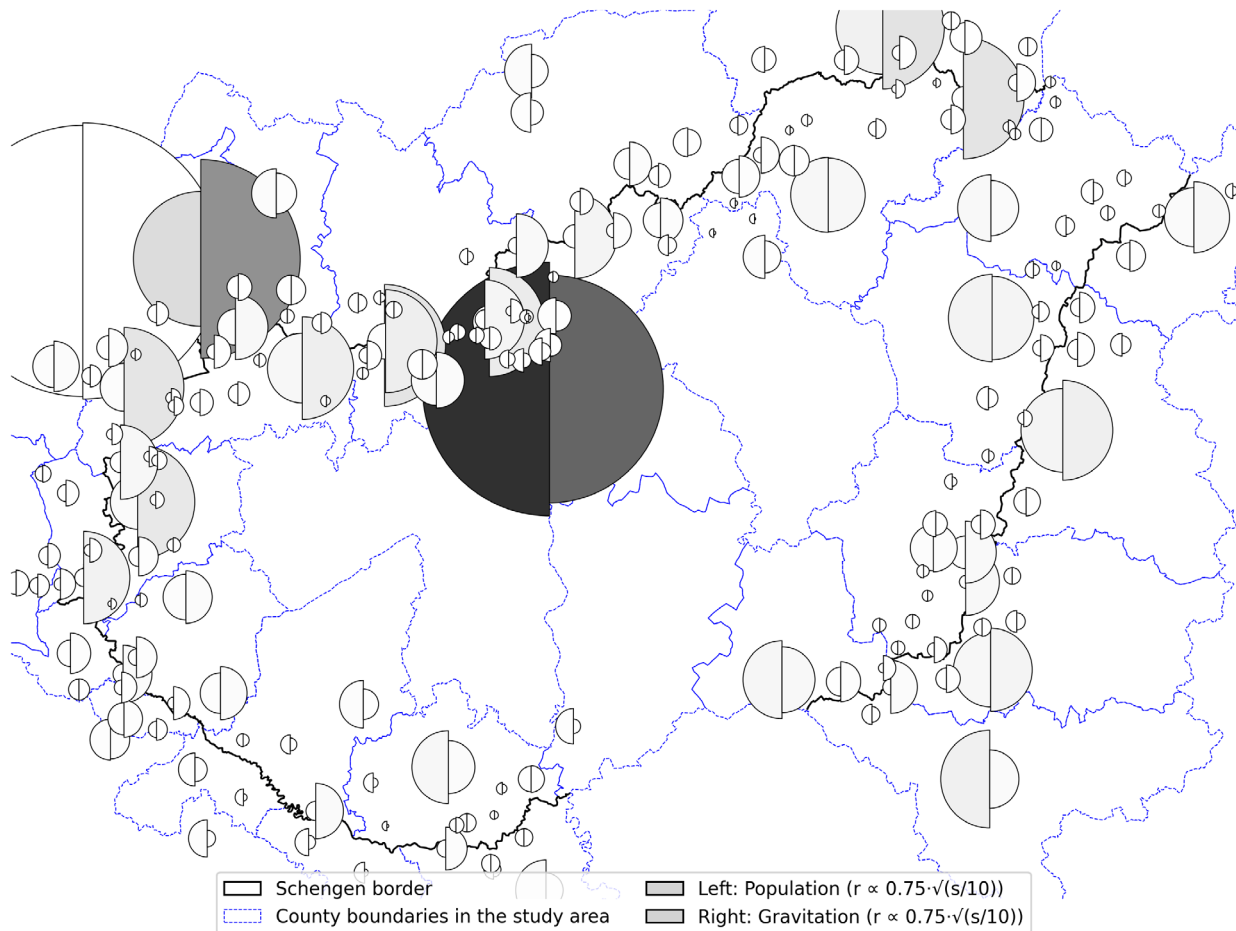
In terms of average values, Austria stands out due to the presence of Vienna (approximately 157,000 inhabitants), while Hungary occupies an intermediate position (35,500) between the upper cluster comprising Romania and Slovakia (50,000 and 42,000, respectively) and the lower group formed by Croatia and Slovenia (21,000 and 13,000, respectively). Half of the cities (93) fall within the 5,000–20,000 population range, one quarter (46) have fewer than 5,000 inhabitants, and one sixth (34) have populations between 20,000 and 100,000. A total of 14 cities with populations above 100,000 were identified in the study area.

To determine the gravitational attraction of the selected cities on the border crossing points included in the database, the shortest travel time had to be calculated, which proved to be the most challenging aspect of the analytical procedure. Rather than pre-filtering cities based on a presumed measurable gravitational influence—an approach deemed excessively time-consuming—we performed queries for the full set of combinations. Identifying all possible pairs of the 187 cities and the 107 border crossing points required a total of 20,009 queries, which were executed automatically in Python using the OpenStreetMap (OpenStreetMap, 2025) Overpass API (Overpass Turbo, 2025).

Within the primary dataset containing approximately 20,000 records, we calculated the gravity coefficient for each city–border crossing pair using the Python pandas library, applying the squared distance factor, which has been shown to preserve the relative importance of dominant centers, although calibration may further refine the analysis (Dusek, 2016). Records with very low values (below 1) were subsequently removed. As a result of this filtering process, 77% of the observations

were eliminated, while only 4% of the total gravitational weight was lost. The resulting reduced (secondary) database contains 4,634 relevant city–border crossing combinations.

Figure 4. Population Size (Left) of the Examined Cities and Their Gravitational Weight (Right) on Border Crossing Points

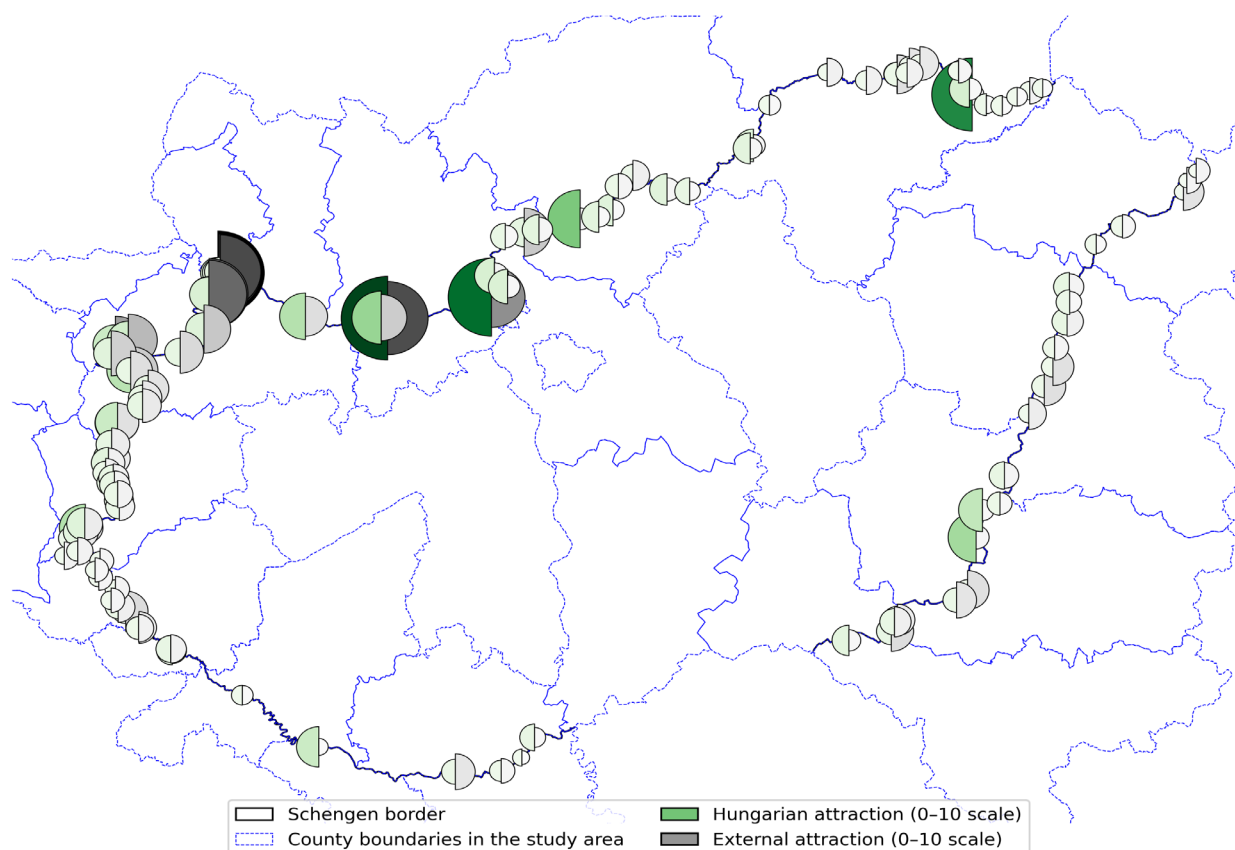


Source: own compilation

When aggregating gravity coefficients at the city level, 16% of the total corresponds to Vienna, 11% to Budapest, over 8% to Bratislava, 5.4% to the twin border cities of Komárom, and approximately 3% each to Sátoraljaújhely and Sopron (Figure 4). The combined share of the 94 cities in the lower segment of the ranking is less than 5%.

The aggregate coefficient calculated for border crossing points again highlights the pre-eminence of the northwestern region: the three Rajka crossing points account for 8.3% of the total gravity coefficient; the two crossings at Komárom account for 4.8%; the two at Hegyeshalom also represent 4.8%; and the Esztergom crossing point accounts for 4.4%. This value can also be disaggregated into Hungarian (“internal”) and foreign (“external”) components (Figure 5), and the gravitational force can be interpreted as having a directional (vector) component.

Figure 5. Aggregated Gravitational Coefficient for Border Crossing Points (Left: “Internal” Coefficient Generated by Hungarian Cities; Right: “External” Coefficient)



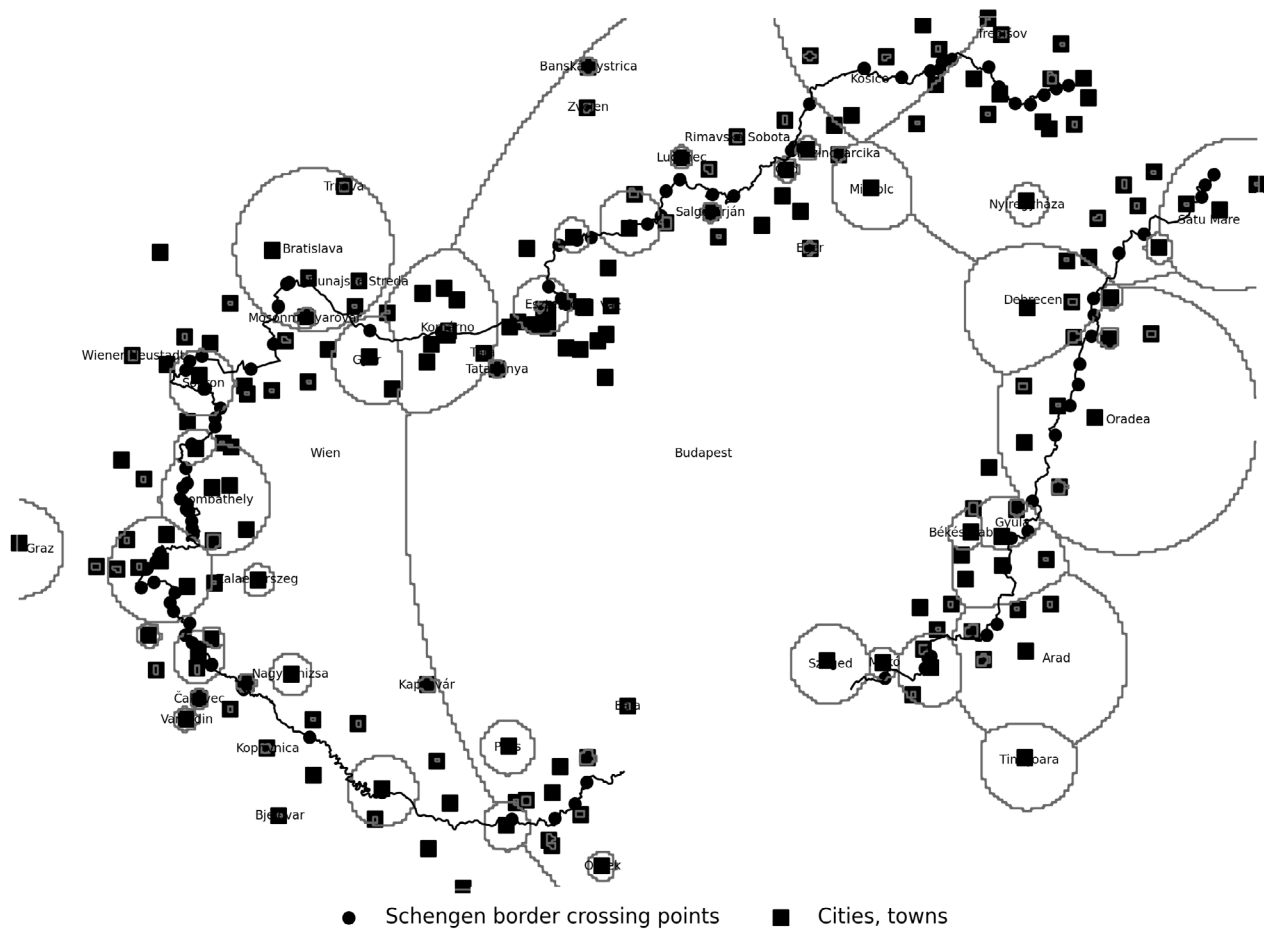
Source: own compilation

We constructed the gravitational dominance map of the examined border crossing points in a Python environment by integrating the two databases. After assigning the aggregated mass (GRAV) and centroid coordinates of the settlements to a GeoDataFrame, we calculated a Newtonian potential function (mass/distance) for each point of a regular grid. Based on the GRAV values assigned to the grid points, each cell was attributed to the settlement with the highest mass, and zones of dominance were delineated by generating square polygons from these dominant cells.

The resulting structure is hierarchical: at the macro level, the territory is divided between Budapest and Vienna, separated by a north–south axis running through central Transdanubia. The gravitational pull of these macro-centres is particularly strong along border sections lacking dominant local centres at the meso- or micro-level.

The Hungarian–Romanian border section is almost exclusively dominated by local centres: at the meso-level, Oradea, Arad, Satu Mare, and Debrecen; and at the micro-level, the spheres of influence of Szeged, Makó, Nagylak, Gyula, and Nagykároly extend to specific border sections.

Figure 6. Gravitational Dominance Map of Hungary's Schengen Border Zones



Source: own compilation

The Hungarian–Slovak borderland is characterized by the dominance of meso-level centres such as Sátoraljaújhely and Košice in the east, while Bratislava, Győr, and the twin border cities of Komárom occupy a similar position in the west. In the central section dominated by Budapest, however, the gravitational influence of micro-centres—such as Esztergom, Ipolyság, Balassagyarmat, Salgótarján, and Ózd–Putnok—extends only to smaller, localized border segments.

Vienna's influence prevails along the Austrian and Slovenian border areas, although it is partially counterbalanced by local meso- and micro-centres on the Hungarian side (Szombathely, Szentgotthárd, Sopron, Kőszeg), as well as by Lendava in Slovenia. By contrast, the Hungarian–Croatian border section appears as a relative “no-man’s-land,” where Vienna’s influence remains dominant in the west and Budapest’s in the east, while the role of local centres (e.g. Barcs, Donji Miholjac) is limited.

In summary, the two analytical perspectives employed in this study demonstrate that Hungary’s Schengen border sections exhibit considerable differences in their integration potential. Where higher border-area population concentration is coupled with significant urban gravity, denser and more hierarchical spatial linkages tend to emerge. This pattern characterizes several sections of the northwestern border area as well as large parts of the Hungarian–Romanian border.

Conversely, along border sections where linear population concentration is lower and the spatial organizing role of local urban centres is weaker, the spatial conditions for integration are more limited. Overall, the observed patterns indicate that the effects of Schengen border opening are not uniform across the entire border region, but rather manifest in zones of connectivity with varying levels of intensity and organizational structure.

CONCLUSIONS

The development of European integration and the expansion of Schengen border sections have created a new spatial context for Hungarian border regions. The diminishing role of physical borders sheds new light on the significance of cross-border linkages and border crossing points, as well as on the spatial organizing role of urban centers across different border sections. The Hungarian–Romanian border provides a clear example, having emerged as a zone of connectivity within the EU as a result of spatial structural transformation processes in the Schengen Area.

Our findings highlight territorial concentration as a persistent characteristic of border regions. Gravitational relations are not evenly distributed across space in the examined region but instead exhibit distinct hierarchies. At the macro level, Budapest and Vienna effectively divide most of the examined Hungarian border areas between them in terms of gravitational influence, particularly along sections lacking a dominant local (meso- or micro-level) urban center. In such areas, the influence of more distant macro-centers becomes more pronounced.

In the Hungarian–Croatian border region, for instance, the role of local centers is weak, the border area exhibits a low level of spatial organization, and major local centers appear only sporadically in the urban gravity structure. In contrast, the western part of this border section is dominated by Vienna, while the eastern part is influenced primarily by Budapest. Conversely, the Hungarian–Romanian border section demonstrates that the presence of regional and local centers with sufficient demographic and functional weight supports the emergence of more hierarchical spatial structures, with the border region being covered by local spheres of influence at both meso- and micro-levels.

These findings suggest that the possibilities for cross-border integration are not evenly distributed within the Schengen Area. From a spatial structural perspective, those border sections exhibit higher integration potential where nearby urban centers with significant population concentrations are accessible. By contrast, along more sparsely populated peripheral sections characterized by weak urban networks and underdeveloped transport linkages, the spatial conditions for integration are more limited.

Accordingly, our results do not support the notion of uniform convergence among border regions; rather, they point to the persistence of existing centre–periphery relations even within the more favorable context of Schengen integration.

The patterns identified through the analysis of urban gravity can be interpreted from social, economic, and transport perspectives; however, such interpretations should be approached with cau-

tion. It can be assumed that in regions with large urban centers, daily interactions are more intense, accessibility conditions are more favorable, and denser opportunities for spatial linkages may emerge. Peripheral areas lacking strong local centers, by contrast, may not benefit equally from open borders. For example, regions characterized by significant natural barriers and weak spatial connectivity are less likely to overcome their peripheral position.

Overall, the findings suggest that, in peripheral border areas, Schengen membership alone is insufficient to generate more favorable integration trajectories. This underscores the need for targeted development of cross-border infrastructure, the strengthening of institutionalized cooperation, and the promotion of integration in regions with weaker urban networks. Based on the results of this research, an important direction for future inquiry is to identify the territorial and institutional instruments that may strengthen linkages in less favorably positioned border regions, as well as the methods that may help reduce persistent development disparities rooted in centre–periphery relations.

REFERENCES

- Arrighi, G. (2014). A fejlődés illúziója: A félperiféria koncepciójának megújítása [The developmentalist illusion. A reconceptualization of the semi-periphery]. *Eszmélet*, 26(103), 159–192.
- Balázs, D., & Somogyi, K. (2024). Suburbanization in multi-ethnic area: Conflicts and local strategies. *Modern Geográfia*, 19(3), 117–138.
- Dusek, T. (2016). A gravitációs modell kalibrálásának alapkérdései [The basic questions of the calibration of gravity model]. *Területi Statisztika*, 56(4), 374–389. <https://doi.org/10.15196/TS560402>
- EduCultCentre projekt. (n.d.). *Román-magyar határon átnyúló képzési központ és értéktár a kulturális és történelmi örökség számára* [A Cross-Border Romanian-Hungarian Training Center and Repository for Cultural and Historical Heritage]. <https://www.educultcentre.hu/>
- European Commission. (2011). *Second report on the implementation and functioning of the local border traffic regime set up by Regulation No 1931/2006*. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0047>
- European Commission. (2024a). *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: State of Schengen report 2024* (COM/2024/173 final). <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52024DC0173>
- European Commission. (2024b). *Ninth report on economic, social and territorial cohesion*. https://ec.europa.eu/regional_policy/information-sources/cohesion-report_en
- European Parliament. (2022). *2022/0806(NLE): Full application of the provisions of the Schengen acquis in the Republic of Croatia*. [https://oeil.secure.europarl.europa.eu/oeil/en/procedure-file?reference=2022/0806\(NLE\)](https://oeil.secure.europarl.europa.eu/oeil/en/procedure-file?reference=2022/0806(NLE))

- Gazzetta Ufficiale della Repubblica Italiana. (2023, June 30). *Gazzetta Ufficiale*, 83. https://www.gazzettaufficiale.it/atto/stampa/serie_generale/originario
- Gwiaździńska-Goraj, M. (2026). European integration as an important factor in shaping the demographic potential of border regions in Germany and Poland. *Environmental & Socio-Economic Studies*, 14(1), 1–17. <https://doi.org/10.2478/environ-2026-0001>
- Hardi, T. (2009). *Határok és városok a Kárpát-medencében* [Borders and Cities in the Carpathian Basin]. MTA RKK.
- Horeczki, R., Nagy, D., & Lados, G. (2025). Vonzó központoktól az elnéptelenedő végekig: A népességdinamika területi különbségei Közép-Európa határtérségeiben, 2014–2020. [From attractive centres to deserted hinterlands. Spatial differences in population dynamics in the border regions of Central Europe, 2014–2020]. *Területi Statisztika*, 65(1), 97–132. <https://doi.org/10.15196/TS650104>
- Horeczki, R., & Szilágyi, F. (2025). *Regionális integráció a schengeni-bővítés tükrében: A magyar–román és a magyar–horvát határszakaszok összehasonlító vizsgálata*. [Regional integration in the light of Schengen enlargement: a comparative study of the Hungarian-Romanian and Hungarian-Croatian border zones] *Tér és Társadalom*, 39(4), 161–182
- Konrad, V., Richardson, P., Prokkola, E.-K., Ridanpää, J., Rahman, M. Z., Horsti, K., Moyo, I., Laine, J. P., Lois, M., Andersen, D. J., Timothy, D. J., Więckowski, M., & Boyle, E. (2026). Geopolitics and memorialisation of borders. *Geopolitics*, 31(2), 846–899. <https://doi.org/10.1080/14650045.2025.2514754>
- Hungarian Central Statistical Office [HCSO]. (2015). *Ingázás a határ mentén* [Commuting along the border]. <https://www.ksh.hu/docs/hun/xftp/idoszaki/regiok/gyoringazas.pdf>
- Hungarian Central Statistical Office [HCSO]. (2025). *Népszámlálási adatbázis* [Census database]. <https://nepszamlalas2022.ksh.hu/adatbazis/>
- Kühn, M. (2015). Peripheralization: Theoretical concepts explaining socio-spatial inequalities. *European Planning Studies*, 23(2), 367–378. <https://doi.org/10.1080/09654313.2013.862518>
- Lados, M. (2005). A határmentiségtől az integrált határrégióig. [From Cross-border Co-operation to the Integrated Border Region] *Tér és Társadalom*, 19(2), 1–5.
- Liu, J., Lo, K., Mah, D., & Guo, M. (2021). Cross-border governance and sustainable energy transition: The case of the Guangdong-Hong Kong-Macao Greater Bay Area. *Current Sustainable/Renewable Energy Reports*, 8(2), 101–106. <https://doi.org/10.1007/s40518-021-00178-4>
- Molnár, E. (2021). *A félperiféria ipara és a globális termelési hálózatok* [Industry in the semi-periphery and global production networks: The transformation of the leather processing industry in Hungary]. Didakt Kiadó.
- Nagy, E., Lux, G., & Timár, J. (2022). Changing peripheralities and centralities in Central and Eastern Europe: Editorial. *Tér és Társadalom*, 36(3), 3–9.

- OpenStreetMap. (2025). *OpenStreetMap*. <https://www.openstreetmap.org/>
- Overpass Turbo. (2025). *Overpass Turbo*. <https://overpass-turbo.eu/>
- Péntes, J. (2013a). The dimensions of peripheral areas and their restructuring in Central Europe. *Hungarian Geographical Bulletin*, 62(4), 373–386.
- Péntes, J. (2013b). Vonzásviszonyok vizsgálata a román–magyar határtérségben [An analysis of attraction patterns in the Romanian–Hungarian Border Region]. In F. Szilágyi & Z. Zakota (Eds.), *Partium: Társadalom, térszerkezet* [Partium: Society, spatial structure]. (pp. 103–133). Dokumentum Kiadó.
- Péntes, J., Czímre, K., & Papp, I. (2024). Distinctive development trajectories of the Hungarian border areas after the millennium. *Eurolimes*, 33–34.
- Perkmann, M. (2003). Cross-border regions in Europe: Significance and drivers of regional cross-border co-operation. *European Urban and Regional Studies*, 10(2), 153–171. <https://doi.org/10.1177/0969776403010002004>
- Pike, A., Rodríguez-Pose, A., & Tomaney, J. (Eds.). (2011). *Handbook of local and regional development*. Routledge.
- Pirisi, G., & Reményi, P. (2009). Kapufunkciójú kisvárosok a horvát–magyar határ mentén. [Small towns serving as gateways along the Croatian–Hungarian border]. In J. Tóth, Zs. M. Császár, & A. Hasanović-Kolutác (Eds.), *Társadalomföldrajzi kutatások makro-, mezo- és mikrotérségekben* [Social-geographical research in macro-, meso-, and micro-regions]. (pp. 153–162). PTE TTK Földtudományok Doktori Iskola.
- Population, households and families by statistical region, year and measures. (2025). *PxWeb* [Data set]. <https://pxweb.stat.si:443/SiStatDataSiStatData/pxweb/en/Data/-/05F2005S.px/>
- Rechnitzer, J. (2005). Az osztrák–magyar határ menti együttműködés múltja, jelene. [The history and the present of cooperation along the Austrian–Hungarian border] *Tér és Társadalom*, 19(2), 7–29.
- Rezultate definitive RPL 2021 – Recensământul Populației și Locuințelor. (2025) [Data set]. <https://www.recensamantromania.ro/rezultate-rpl-2021/rezultate-definitive/>
- Rónai, A. (1933). Középkelet-Európa politikai határaitra gyakorolt népnymás mértéke [The extent of demographic pressure on the political borders of Central and Eastern Europe]. *Földrajzi Közlemények*, 61(7–8), 252–260.
- SODB2021—Population—Basic results. (2025). <https://www.scitanie.sk/en/population/basic-results/number-of-population/SR/SK0/KR>
- Slovakia—Population and housing census 2021. (2023). *Statistical Office of the Slovak Republic*. <https://slovak.statistics.sk/>
- STATcube. (2025). *Statistics Austria*. <https://statcube.at/statistik.at/ext/statcube/jsf/login.xhtml>

- Statistički sustav Republike Hrvatske. (2023). *Prvi digitalni Popis stanovništva, kućanstava i stanova u Republici Hrvatskoj 2021* [First Digital Population, Household and Apartment Census in the Republic of Croatia 2021]. <https://dzs.gov.hr/u-fokusu/popis-2021/88>
- Statistik Austria. (2023). *Zensus Volkszählung 2021: Ergebnisse zur Bevölkerung aus der Register-zählung* [2021 Census: Population Results from the Administrative Census]. https://www.statistik.at/fileadmin/user_upload/Zensus-VZ-2021.pdf
- Statistics Austria. (2025). *Population census*. <https://www.statistik.at/en/about-us/surveys/register-based-census/population-census>
- Szilágyi, F., Horeczki, R., & Rácz, S. (2025). The potential effects of Schengen enlargement on the Croatian-Hungarian and Hungarian-Romanian border. *Deturope: The Central European Journal of Regional Development and Tourism*, 17(3), 130–149.
- Tagai, G., Péntzes, J., & Molnár, E. (2009). Methods of the analysis of integration effect on border areas: The case of Hungary. *Eurotimes*, 177–188.
- Territorial units for statistics (NUTS) – GISCO – Eurostat. (2021). <https://ec.europa.eu/eurostat/web/gisco/geodata/statistical-units/territorial-units-statistics>
- Van Houtum, H. (2005). The geopolitics of borders and boundaries. *Geopolitics*, 10(4), 672–679. <https://doi.org/10.1080/14650040500318522>
- Vukovich, G. (Ed.). (2022). *Magyar statisztikai évkönyv 2021* [Hungarian Statistical Yearbook 2021]. Központi Statisztikai Hivatal.
- Wallerstein, I. M. (1974). *The modern world-system*. Academic Press.
- Žnidaršič, M., & Miklič, E. (2022). *Register-based census of population, households and housing, Slovenia*. Statistical Office of the Republic of Slovenia. <https://www.stat.si/StatWeb/File/DocSys-File/8033/05-322-ME.pdf>

APPENDIX

Appendix 1. Schengen border sections and border-area population

County	Border length	Natural border	Conv.	Border-area population	Natural border %	BPCI	Scores	Average
Békés	169	4.5	164.5	154234	2.66	913	1.83	3.07
Csongrád-Csanád	64.2	21.3	42.9	200899	33.18	3129	6.26	
Hajdú-Bihar	91.7	0	91.7	85879	0.00	937	1.87	
Szabolcs-Sz. RO	96.5	0	96.5	112553	0.00	1166	2.33	
Baranya+B-K/2	134	62	72	100013	46.27	746	1.49	1.43
Somogy	142	108	34	49257	76.06	347	0.69	
Zala (SL+HR)	85.4	56.2	29.2	90837	65.81	1064	2.13	2.70
Vas (SL+A)	188.5	89	99.5	180928	47.21	960	1.92	
Győr-Moson-Sopron	238.9	114.4	124.5	416506	47.89	1743	3.49	
Komárom-Esztergom	77.5	77.5	0	230057	100.00	2968	5.94	3.21
Pest	44.2	33.6	10.6	60513	23.98	1369	2.74	
Nógrád + Hev/2	131	123.7	7.3	154884	94.43	1182	2.36	
BAZ + Hev/2+SzSzSK/2	248	162.8	85.2	224571	65.65	906	1.81	
Eszék-Baranya	114	37.9	76.1	61317	33.25	538	1.08	2.55
Kapronca-K.+BB	82.6	48.6	34	67297	58.84	815	1.63	
Medimurje+Varazdin	33.7	33.7	0	114525	100.00	3398	6.80	
Virovitica -Drav.	91.7	91.7	0	62700	100.00	684	1.37	
Prekmurje	87.5	52.8	34.7	82509	60.34	943	1.89	
Arad	121	0	121	234730	0.00	1940	3.88	3.44
Bihar	161	4.5	156.5	325662	2.80	2023	4.05	
Satu Mare	92	0	92	197926	0.00	2151	4.30	
Timiș	47	21.3	25.5	36175	45.32	770	1.54	
Bratislava	7.9	4.2	3.7	425348	53.16	53842	10.00	4.75
Nagyszombat	49	49	0	115544	100.00	2358	4.72	
Nyitra	145	130.8	14.2	174461	90.21	1203	2.41	
Banská Bystrica	183	168.3	14.7	182589	91.97	998	2.00	
Kosice	193	118.8	74.2	445590	61.55	2309	4.62	
Southern Burgenland +Ostst.	118	23.7	94.3	123848	20.08	1050	2.10	2.25
Central Burgenland+NÖS/2	76.3	34.5	41.8	61198	45.22	802	1.60	
Northern Burgenland+NÖS/2+WUS	120	35.5	84.5	183463	29.58	1529	3.06	

Source: own calculation



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