Measuring Exposure to EU-Funded Projects and Spatial Spillovers: A Town-Level Panel for Bulgaria, 2014 - 2026

Anna Kyosova,
Postdoctoral Researcher, University of Neuchâtel,
anna.kyosova@unine.ch

Abstract

This study examines the administration and distribution of European Union (EU) funding for projects implemented in Bulgaria from 2014 to the incomplete 2026 programming year. Administrative records were used to locate the office/legally registered address of each EU-funded project participant and then combine them into 2,302 "settlements". A balanced settlement-year panel was created and analyzed utilizing exploratory spatial data analysis techniques, including row standardized k-nearest-neighbour spatial weights, lagged neighbouring exposure variables, as well as measures to differentiate between public and private funding recipients, patterns of activity by broad categories of the projects, global Moran's I statistic, and local indicators of spatial association.

The findings reveal that EU-project participation has been highly concentrated in Sofia and other large regional centers due to both the administrative centrality and organizational capacities associated with such locations. However, the extent of neighbouring exposure to registered EU-project activity expanded significantly after 2016 and increased dramatically during pandemic and post-pandemic recovery years. Projects registered by the public sector appear to have generated greater territorial coverage than private sector beneficiaries. Overall, there is very little evidence of spatial autocorrelation across the country; however, there is some evidence of clustering in select years: particularly 2020, 2021, and 2025. Local indicators of spatial association (LISA) identified small numbers of high-high clusters (indicating localized concentrations of EU-project activity) and low-high outliers (indicating settlements in close proximity to high levels of EU-project activity but experiencing less activity themselves). In addition, this study represents a contribution to research on the subject matter by providing a map of the office-location geography of EU-project participation in Bulgaria and by distinguishing administrative exposure from actual territorial impact.

JEL classification: R12; R58;C21; H54

Keywords: EU-funded project participation; spatial spillovers; legal-address data; neighbouring exposure; spatial autocorrelation; Moran's I; Local Indicators of Spatial Association; administrative data; regional development; Bulgaria

Introduction

European Union Cohesion Policy represents one of the largest place-based development initiatives in the world, aiming to reduce regional disparities and promote economic, social, and territorial cohesion across Member States. The European Commission supports a broad array of operational programs in various regions using funds from the European Union. These programs are used to fund infrastructure development, innovations, environmental sustainability, institutional capacity building, education and social inclusion. Since Bulgaria joined the European Union in 2007, the country has received significant amounts of money through the European Union Cohesion Policy for supporting its socio-economic development.

Historically, the territorial effects of EU-funded investments were analyzed using regional indicators such as GDP, employment, productivity, innovation, and convergence. Most studies assess program outputs either nationally, regionally or at NUTS level (Nomenclature of Territorial Units for Statistics). Studies focus on the immediate effects within those regions where funding was provided. Regional development processes are rare when they occur independently. For example, economic activity, institutional capacity, administrative experiences and knowledge produced from projects registered by the public sector can affect neighbouring regions, producing opportunities for spatial spillover and diffusion of activities.

Recent Bulgarian studies highlighted the importance of administrative data at the beneficiary level in assessing EU-funded intervention and program effectiveness (Nigohosyan et al., 2021; Nigohosyan et al., 2025). Research has focused primarily on program outcomes, beneficiary performance, and policy effectiveness rather than the geographical distribution of participants and the potential for broader project participation networks connecting neighbourhoods.

This study addresses this void by developing a settlement-level spatial database of all EU-funded projects implemented in Bulgaria between 2014 and the incomplete current 2026. Using administrative data for 73,783 projects and 2,302 settlements, the analysis creates indicators for neighbouring exposure to funded projects based on beneficiary locations and spatial weighting. The study uses exploratory spatial data analysis methods including spatial lag indicators, global Moran's I statistic and geographic visualization to analyze temporal changes in project activity and potential diffusion patterns between settlements.

This study contributes in three ways. First, it is one of the first settlement-level spatial databases of EU-funded project participation ever created for Bulgaria. Second, it establishes a model for calculating exposure to neighbouring project activities utilizing spatial lag indicators developed from beneficiary level administrative data. Finally, it provides new evidence regarding the organizational pattern of participation and the emergence of spatial dependency during project activity over time. Instead of looking at the immediate impact of each project, the study looks at overall territorial patterns of participation and exposure within the EU funding system. By doing so, it adds to the growing body of literature on the spatial characteristics of public investment, regional development and territorial diffusion processes related to Cohesion Policy implementation.

Literature Review

It is becoming clearer that regional development does not take place in isolation but is a result of the interdependence of municipalities and other settlements via economic, institutional, social and knowledge-based networks. This interdependence provides the means for the exchange of labour, capital, information and innovations amongst different settlements. Therefore, the success of development can depend upon factors not just within an area itself, but also those in surrounding areas. Economic Geography, Innovation Studies and Regional Science all contain theoretical frameworks for understanding the relationships between areas. For example, Boschma (2005), showed that if an area is geographically close enough to another then it may improve its ability to interact with and learn from one another as long as there exists sufficient "cognitive", "organizational", "institutional" and "social" closeness. In addition, Schmidt and Mitze (2026) provided evidence for knowledge spillovers, labor market pooling and input/output linkage leading to increased productivity in neighbouring areas. Overall, the body of literature suggests that regional development occurs through the connections between different territorial systems as opposed to being strictly localized.

Spillovers first emerged in the field of Innovation Economics and Endogenous Growth Theory as a way to understand how knowledge generated through Research and Development (R&D) was diffused throughout the economy. Goto and Suzuki (1989) demonstrated that R&D expenditures would increase productivity not just in the sector(s) conducting the R&D but in other sectors as well. Griliches (1998) identified the role of knowledge externalities in economic growth. More recently, the idea of spillovers has been applied to territorial systems. Wang et al. (2023) demonstrated that R&D expenditures in one region generates two types of effects: Direct and Indirect. The direct effect occurred through innovation networks and economic linkages, whereas, the indirect effects occurred due to spillovers occurring in neighbouring regions. Wu et al. (2025) also demonstrated that spillovers occur across Chinese provinces. In general, this body of literature demonstrates that many times investments in innovation will produce spillover effects occurring outside of the original location of investment.

There is empirical evidence demonstrating spillovers occurring across multiple fields of study regarding regional development. Hernández de Rojas et al. (2025) demonstrated that spillovers exist in terms of digitalization and competitiveness across European Regions. They further argue that geographically mediated diffusion processes are essential for explaining such spatial clustering. Similar patterns have been observed in Environmental and Sustainability research. Nikou (2025) demonstrated positive spatial dependence on ecological footprint indicators across Europe. Vagnini et al. (2025) demonstrated significant spatial interactions in industrial decarbonization occurring in 238 European NUTS-2 regions. Outside of Innovation and Environmental/Sustainability research, Hertrich and Brenner (2026) demonstrated that shortages of skilled workers are capable of generating spillovers into neighbouring regions. These findings provide strong evidence that economic, social and environmental development are often interconnected across space.

Existence of spatial spillovers creates opportunities to better evaluate European Cohesion Policy, whose purpose is to reduce territorial disparities and stimulate balanced development by investing in infrastructure, innovation, human capital, environmental sustainability and institutional capacity. Previous assessments of Cohesion Policy have focused on convergence, productivity, employment and overall economic growth. Several studies suggest however that

policy impacts do not necessarily stop at the border of the territory supported by funds. Dall'Erba and Le Gallo (2008) argued that when assessing the impact of Structural Funds on neighbouring regions they should not be viewed independently of each other. Such findings imply that assessments based solely on administrative boundaries may significantly understate wider territorial impacts.

As spatial dependence has come to be recognized as a major factor influencing regional development, spatial analytical techniques have become widely adopted in regional science. Spatial lag models, spatial error models, etc. offer methodologies for analyzing interactions between territories and differentiating between direct vs. indirect effects (Anselin, 1988). Similarly, global/local indicators of spatial association remain important tools for identifying spatial dependencies/clustering (Anselin, 1995; Bivand & Wong, 2018). Additionally, there is a growing concern about misinterpreting observed spatial dependence as definitive proof of causal spillovers. Debarsy and Le Gallo (2025) point out that observed clustering may actually reflect shared institutional environments/structures/administrative structures/economic conditions rather than actual diffusion processes.

More recent studies conducted in Bulgaria have illustrated the potential of using administrative data associated with beneficiaries to assess effectiveness of EU-funded programs/interventions (Nigohosyan et al., 2021; Nigohosyan et al., 2025). Most assessments, however, continue to use national or regional/NUTS-2 levels of analysis with primary focus on expenditures, convergence, productivity or program results. As a result, limited attention has been given to the territorial distribution of project participants or whether concentration of fund recipients produces identifiable exposure patterns for neighbouring communities. Recognizing such patterns is relevant, because clusters of fund recipients can enhance administrative learning, institutional interaction and knowledge diffusion beyond directly funded communities.

While there is substantial evidence indicating spillovers exist in areas of innovation, competitiveness, labor markets, sustainability and development, very few studies have explored the geographic aspects of participation in EU-funding programs at a local scale. This study addresses the gap by developing a settlement-level panel dataset for EU-funded projects implemented in Bulgaria during the years 2014 - 2026 (approximately 73,783 total projects). By utilizing beneficiary legal addresses as proxy measures for administrative exposure to EU funding sources, this study investigates how project activity is dispersed across different settlements and whether neighbouring towns develop connectivity through larger exposure patterns.

Methodology

This research evaluates how the spatial distribution and diffusion of EU-funded project activity occurred in Bulgarian settlements between 2014 and 2026. The dataset was created in February 2026, which means that the 2026 data are based on a non-complete program year. Since at the time of data extraction, there were still unentered records (projects, recipients, contracts, etc.) within the EU Fund Information System for 2026, therefore, 2026 can be considered only as an indicator of future trends and patterns or as continuation of current ones, it should not be used as a full annual comparison. Consequently, any downward trend or structural changes observed in 2026 should be viewed with caution as they indicate the state per the time when the data was collected instead of being indicative of a true reduction in EU-funded project activity for the entire year.

Analysis was completed using a database of 73,783 EU-funded projects collected from the EU Funds Information System created and managed by the Bulgarian Council of Ministers (EU Funds Bulgaria, n.d.). This dataset includes project identifiers, program names, beneficiary organizations, whether the project has been completed, length of the project, amount of funding provided for the project, address and postal code of the beneficiary. Other similar administrative data has also been used to assess EU-funded projects for the regional development of select sectors in Bulgaria (Nigohosyan et al., 2021; Nigohosyan et al., 2025).

Data preparation, spatial analysis, statistical analysis, and all visuals were produced using R version 4.5.2. Packages included readxl, janitor, dplyr, tidyr, stringr, sf, spdep, ggplot2, rnaturalearth, scales, viridis, forcats, openxlsx, and broom. Each of these packages was used to prepare data for imports, clean data for panel construction, perform spatial analysis, create visualizations, report statistics, and produce output that could be analyzed. The R analysis procedures were conducted using fully reproducible workflows, the scripts were designed in accordance with the Bivand et al., (2021), the Comprehensive R Archive Network (2021), Paez, A. (2021). Sparks (2019).

Settlement names as well as program categories and beneficiary classification variables were standardized to maintain consistency across the study period. Projects were geocoded based on the legal entity address of the beneficiary organization where it was registered. Many ministries, public institutions, universities, municipalities and large enterprises are officially registered in larger urban centers, but the projects might be implemented across multiple municipalities and regions. Therefore, the spatial indicators will represent the geography of organizational participation in EU-funded programs rather than the physical location of project investments. Geographic coordinates were manually assigned to settlement names and postal codes from the BG Post Code (BG Post Code, n.d.), where postcodes were linked to geographic coordinates and verified. Project-level data was then aggregated to form a balanced panel data set for towns and villages into 2,302 settlements in Bulgaria over 2014 - 2026. In addition to aggregating project-level data into a settlement-year panel format, this procedure allowed the computation of settlement-year indicators for new project starts and grants allocated as well as the type of the beneficiary organization.

The spatial relationship between settlements was modelled using a row-standardized k-nearest neighbour (kNN) weight framework. Settlement coordinates were converted to spatial objects using the sf package. Neighbourhood relationships were defined by selecting the 5 nearest neighbours (k=5). The final spatial weight matrix was constructed and used to compute a spatial lag indicator that would indicate the weighted averages of activities seen in neighbouring settlements. Possible diffusion effects were captured through measuring exposure to spillover effects by constructing a log-transformed one-year lagged spatial lag of project activity. The resultant indicator captures the degree of exposure a settlement is experiencing as a result of project activity in its neighbouring settlements last year. Due to significant positive skewness of spillover exposure, this variable was logged before analyzing it. Furthermore, separate spillover indicators were developed for public sector and private sector beneficiaries to allow for comparison of institution and market driven diffusion processes.

The presence of spatial dependence was assessed through the calculation of global Moran's I statistics as implemented in the spdep package (Anselin, 1988; Bivand & Wong, 2018; The Comprehensive R Archive Network, 2021). Annual Moran's I Statistics, z scores and p-values were computed to assess changes in the pattern of spatial autocorrelation in project activity among

Bulgarian Settlements over the course of the current study. Additionally, local indicators of spatial association (LISA) were computed as an exploratory tool to help identify clusters of high concentration of activities and possible spatial outliers (Anselin, 1995).

Patterns both in space and time were identified by creating cumulative settlement-level maps of project activity, annual public-private spillover exposure maps, macro category time series visualizations, boxplot of lagged spillover exposure and spatial autocorrelation diagnostics. The resultant spillover indicators are meant to reflect only administrative and organizational exposure to EU-funded project activity and not direct evidence of causal spillover effects. Similar to Debarsy and Le Gallo (2025), this analysis will investigate Territorial Patterns of Participation and Potential Diffusion Mechanisms associated with EU-funded programs.

Results

This segment examines the spatial organization of the EU-funded project participation in Bulgaria from 2014 until the current 2026 by utilizing a town level dataset for all 73,783 projects. The focus will be on the spatial distribution of recipients of funds, the development of spatial spillover exposure, and how much project activity was spatially clustered through time. Projects are allocated to the legal address of recipient, therefore, the outcomes should be interpreted as measures of organizational and administrative participation in EU-funded programs and not at the location of the actual implementation of project activities.

The outcomes will be shown in multiple complementary steps. First, the cumulative spatial distribution of EU-funded projects will be studied to determine the main centers of project activity, and larger scale territorial concentrations. Secondly, spillover maps for public and private sectors will be utilized to study the progression of neighbouring project exposure during the programming period and if there were different diffusion patterns for institutional versus market based recipients. Third, a time series analysis for macro categories will examine the shifts in priority within programs through time. Fourth, a boxplot for lagged spillover exposure will be utilized to analyze variations in both the distribution and dispersion of exposure in each settlement. Lastly, global Moran's I statistics and Local Indicators of Spatial Associations (LISA) will be applied to measure whether project activity has exhibited significant spatial autocorrelation and to identify clusters that exist locally.

Overall, the results provided a complete description of how EU-funded programs' participations have been geographically dispersed across Bulgarian territory, how adjacent settlements became exposed to project activity, and whether they show an increase in territorial concentration or diffusion through time.

Cumulative Spatial Distribution of EU-Funded Projects in Bulgaria (2014 - 2026)

Figure 1 illustrates the cumulative spatial allocation of EU-funded project activities at Bulgarian settlement level from 2014 - 2026 using data for the legal addresses of the beneficiaries of these projects. The size of the circle indicates the cumulative number of projects undertaken by each settlement.

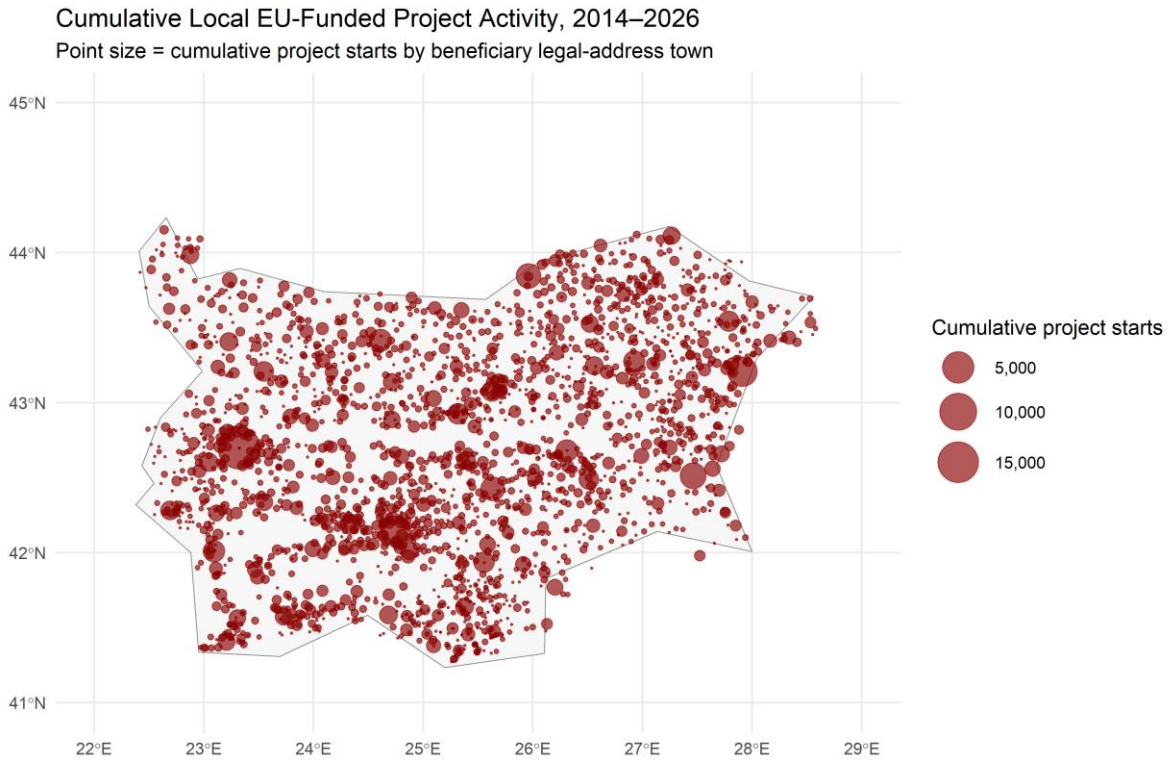


Figure 1 Cumulative Local EU-funded Project Activity 2014 - 2026

It is visually clear that there has been a very uneven geographical allocation of project activities. The most prominent participant in EU-funded activities is clearly Sofia, having far exceeded the total number of projects at all other settlements. It is this high degree of concentration that is mainly due to the fact that ministries, central government departments, national institutions, universities and large enterprises have benefited from EU-funded programs and therefore represent the main points through which many of the project applications are submitted or registered.

There also exist significant secondary concentrations of activity around the larger urban centers such as Varna, Burgas, Plovdiv, Ruse and Stara Zagora. These settlements provide an essential base for administration and commerce and show significantly higher levels of project activity than their surrounding municipal areas. The elevated concentrations along the Black Sea coast would appear to result from a combination of tourism related investments, transportation infrastructure projects and fisheries program funding provided through European Structural and Investment funds.

On the other hand, it is apparent that the majority of Bulgaria's settlements have shown relatively low cumulative numbers of EU-funded project activity. This pattern supports the idea that participation in EU-funded program continues to be heavily geographically concentrated rather than being dispersed equally throughout the country. The findings support the concept of cumulative administrative advantage, i.e., settlements with greater institutional capacity,

administrative experience, and organizational development will participate more often in EU-funded initiatives.

As projects were allocated to the legal address of the beneficiary and not where they physically occurred, the map should be viewed more as a representation of administrative/organizational participation in EU-funded programs rather than actual geographic locations. Therefore, the clusters found in Figure 1 represent a mixture of real geographic clustering and the administrative centralization of the beneficiary organizations.

The spatial clustering depicted in Figure 1 also implies possible neighbouring effect exposures. Settlements proximate to larger administrative centers may enjoy indirect benefits from labour market connections, organizational networks, partnership agreements, sub-contracting relationships, and knowledge diffusion. While the map itself establishes no causal spillover relationship among settlements, it does offer justification for the use of a spatial analysis to examine how neighbouring project exposures contribute to spatial dependencies.

Public vs Private EU Project Spillover Exposure

The public and private spillover maps provide insight into how the territorial organization of EU-funded project activity evolved across Bulgaria between 2014 and 2026. The cumulative map of projects shows the general geographic distribution of participation among the beneficiaries; on the other hand, the spillover maps show how neighbourhoods' project activity influenced each other through time, in addition, they also illustrate how interaction between public and private beneficiaries have progressively created an increasingly complex territorial web. Together, the two types of maps reflect the evolution of the institutional concentration at a high level of centralization towards a well-developed national network with large-scale spatial exposure as well as growing overlap between the public and private actors.

Phase 1: Initial Spillover Development (2014 - 2015)

The beginning of the programming period exhibits almost no spillover exposure and a lot of project activity that focused on large metropolitan areas (see Figure 2). During 2014, most of the obvious activity related to the program's projects were visible in Sofia as well as one other major city in Bulgaria - Burgas. All observed activity was among the public sector beneficiaries. This represented an early phase of the program where governmental departments (ministries), managing bodies, municipalities, and other government agencies were responsible for organizing and launching many of the individual projects.

Spatial dependency is measured by examining the use of a lagged variable. However, due to 2014 being the first year, what is displayed on the map shows the original geographic locations and is the only map without the use of the year spatial lag. Therefore, it cannot provide evidence of the spatial relationships created due to nearby project activities. Thus, at this point in time, it can be said that the level of spatial dependence is very low and that project participant involvement is largely confined to a relatively small number of central administration centers.

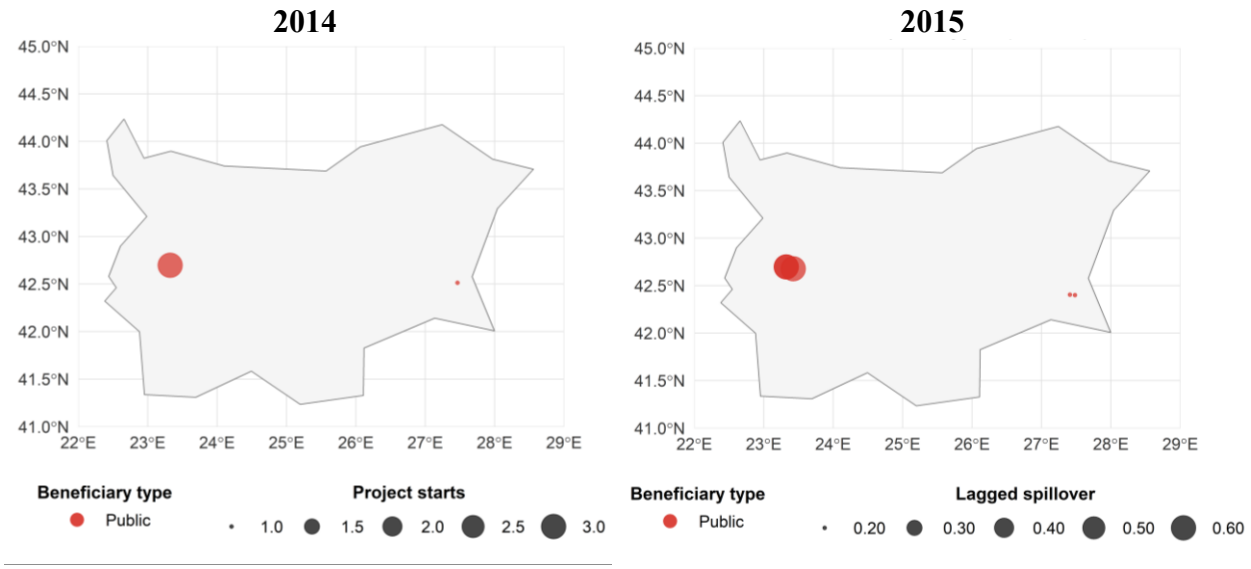


Figure 2 Public vs Private EU Project Spillover Exposure 2014 - 2015

During 2015, some local exposure can be observed; however, these spillovers are also generally geographically localized and have been concentrated around Sofia and the secondary administrative center of Burgas. The private sector continues to be nonexistent in the programs' spatial landscape. Therefore, the resulting spatial structure of the programs' project activity has thus far developed into a hierarchical structure rather than a networked structure, with project activity located primarily around central administration centers and much less diffused throughout the remainder of the country.

Phase 2: Expansion and Network Formation (2016 - 2020)

From 2016 on, spillover exposure grows quickly across Bulgaria (see Figure 3), expanding from the capital region to other western, central, northern-eastern, and southern-eastern parts of the country. For the first time, significant portions of spillover exposure are due to private sector participants; these exposures occur primarily around key urban centers and economic activity zones.

A large growth in the geographic extent of spillover exposure implies that the program has reached a more mature stage of development. Beneficiaries gained experience, the administrative process became more familiar, and participation grew among both public and private actors. Additionally, spillover clustering begins to develop in areas other than Sofia which shows that neighbouring exposure was no longer occurring only through the capital city, but increasingly by secondary regional centers.

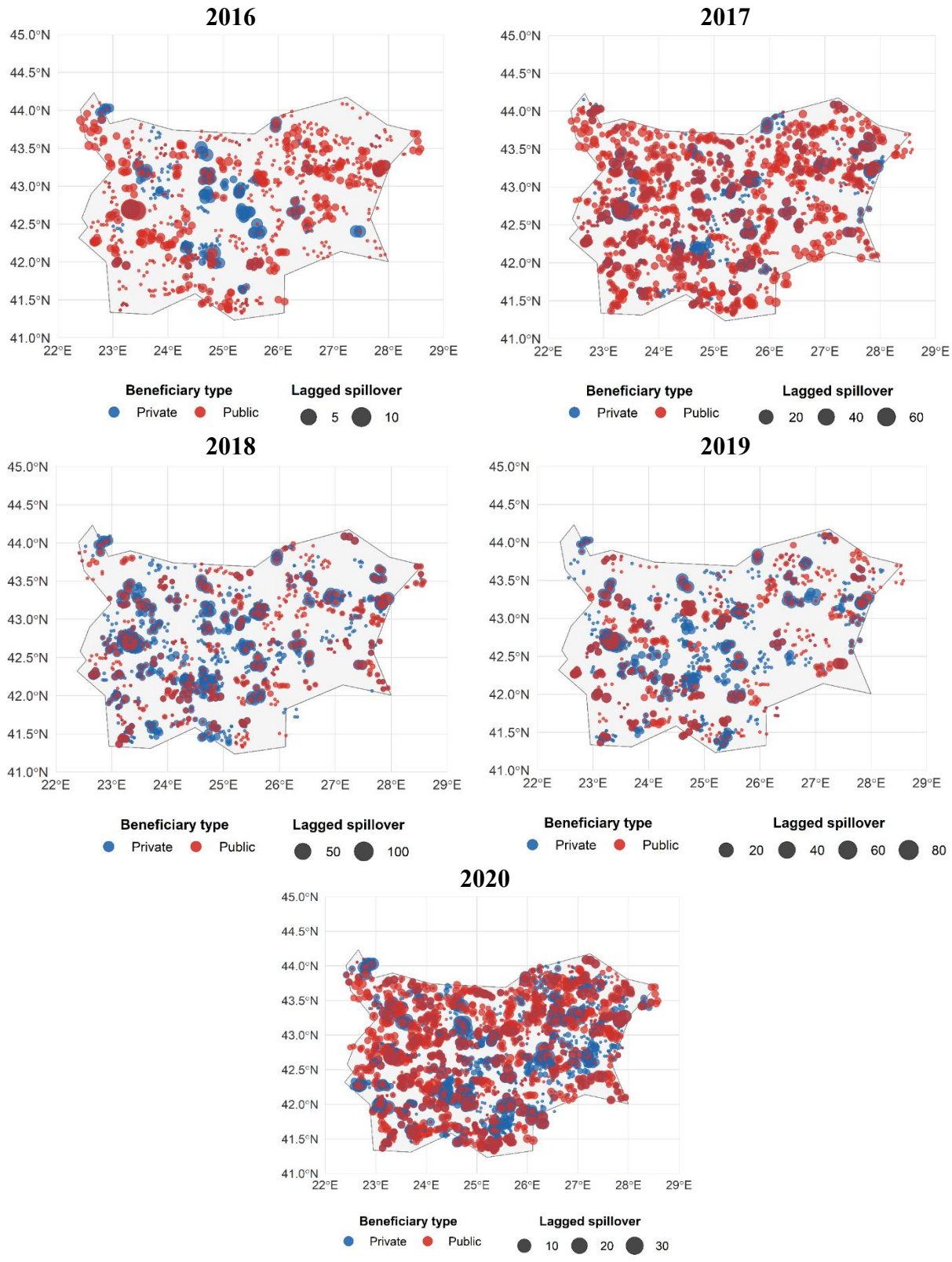


Figure 3 Public vs Private EU Project Spillover Exposure 2016 - 2020

The maps for 2017 and 2018 show a continued increase in network density. While the presence of public sector beneficiaries remains very high throughout all of Bulgaria, there is a notable expansion of private sector participation. Private spillover exposure is especially common in the area immediately surrounding Sofia and in central Bulgaria, suggesting that private firms are playing an increasingly larger role in the EU-funded project environment. Also, as private and public spillover patterns become more intertwined, it seems that institutional (public) and market (private) actors are being embedded in the same territorial networks, rather than in their own separate structures.

In 2019, spillover exposure appears to have been relatively equally distributed between public and private sectors. There is significant neighbouring exposure present in many different regions of Bulgaria. The spatial distribution has moved away from a few dominant focal points. It appears that participation in EU-funded programs has become an integral part of the overall regional economy and administration.

In 2020, the map illustrates the end of the expansion phase of spillover exposure. Exposure to neighbouring settlements is widespread throughout much of Bulgaria and the degree of overlap between public and private activities is extremely high. By now, EU-funded programs do not represent isolated pockets of activity but instead are components of a nationwide spatial system. Maps indicate that neighbouring effects (the effect one settlement's project activity generates at nearby settlements) are becoming a critical aspect of participation in EU-funded programs.

Phase 3: Maturity and Spatial Integration (2021 - 2026)

There is an unprecedented spillover exposure in the amount present in 2021 for both public and private recipients. This results from both sectors having extended spatial coverages (both sectoral and geographic) and spillover intensities are at their peak. By 2022 there is a very high degree of exposure present in almost every region of Bulgaria, as well as a significant contribution by each sector towards the national spillover structure.

The timing of this increased spread corresponds with the implementation of post-pandemic recovery programs, the implementation of Recovery and Resilience Fund financing mechanisms, as well as the initiation of new financial tools. Even though the maps alone cannot determine cause-and-effect relationships, the magnitude of this change indicates that it was a time when there were many projects being undertaken simultaneously and/or geographically diffused on a large scale.

Spillover exposure is lessened after the 2021 high point, however, it is still considerably above that of the pre-2020 time frame. Maps from 2022 through 2024 show evidence of stabilization (i.e., no contraction) of public and private entities operating within highly interconnected territorial networks, and spillover exposure appears to be spatially widespread. As in previous years, Sofia is once again functioning as the central hub of activity; however, additional cluster hubs are becoming apparent throughout central, northeastern and southeastern parts of Bulgaria.

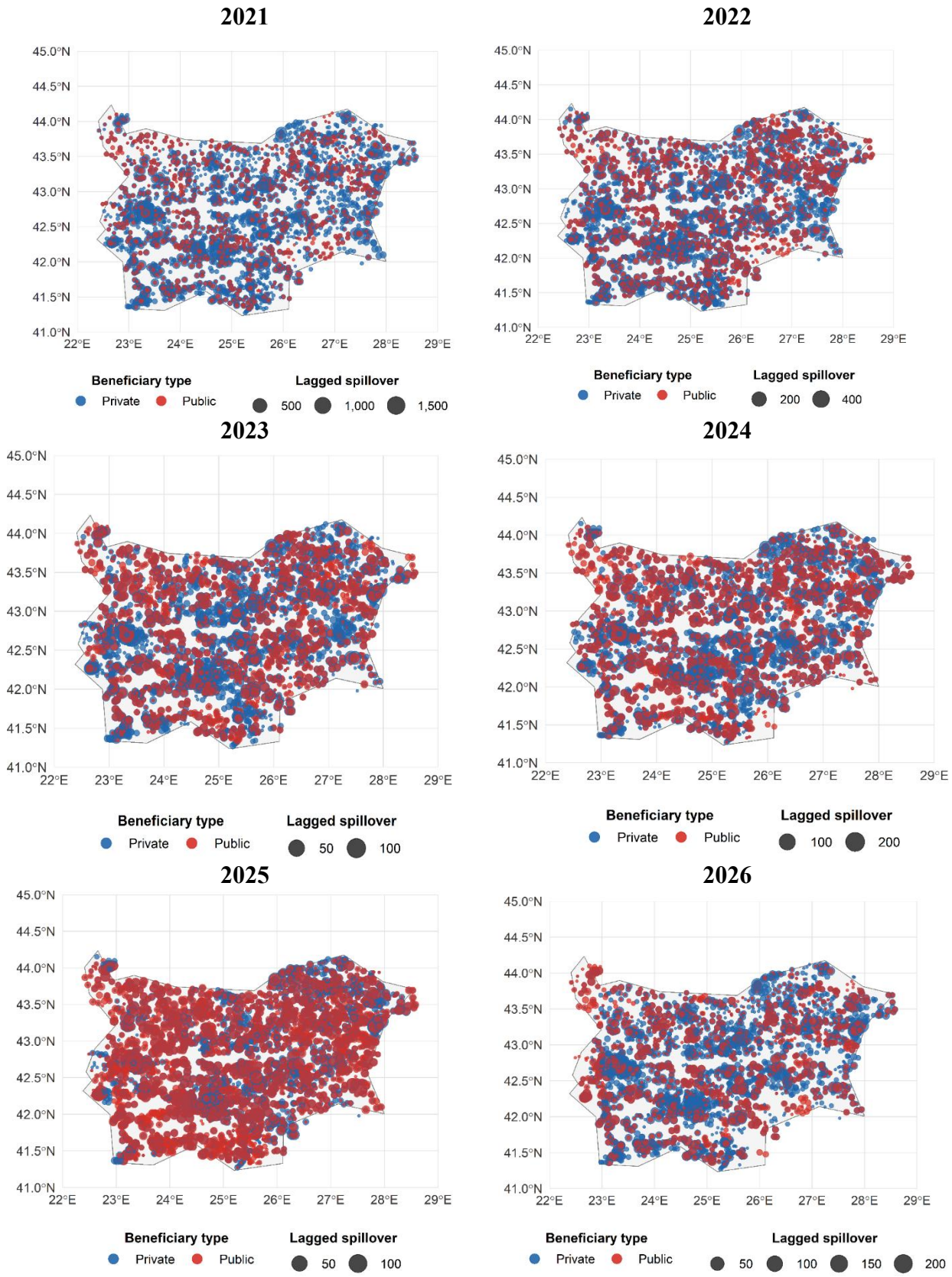


Figure 4 Public vs Private EU Project Spillover Exposure 2021 - 2026

Figure 4 also suggests a trend toward the decentralizing of neighbouring exposure. There is evidence suggesting a shift away from using only Sofia as the main center of spillover generation and instead, several regional centers have emerged to generate large amounts of neighbourhood spillover. These patterns are supportive of an increase in institutional capacity at the local level and increased participation in EU-funded programs.

A substantial increase in public sector spillover exposure becomes evident by 2025. Simultaneously large concentrations of public activity appear across multiple areas (regions), indicating an accelerated institutionalization process associated with the programming framework for 2021 - 2027. Conversely, the current 2026 map shows a tendency to shift back to a relatively well-balanced distribution of public and private recipients, which has the potential to change upon the completion of the year.

The findings show some distinct trends related to the public/private spillovers. Firstly, neighbouring spillovers increased significantly during the study period; this expanded from a few administrative centers into a country-wide spatial network. Secondly, Sofia remained the most significant contributor to spillovers for each year, though the contribution decreased in relation to the rest of the country, due to emerging secondary regional centers. Finally, there was a trend towards increasing cooperation between institutional and market actors regarding public and private beneficiaries. Furthermore, secondary spillover corridors developed around Sofia, implying that participation in multiple rounds of EU-funded programs contributed to developing local institutional capacity and strengthening regional connections. At the end of the study period, spillover effects were no longer limited to a small number of administrative centers, but had been integrated into larger national systems, connecting various settlements. Therefore, the maps are indicative of growing territorial cohesion and substantiate that participation in EU-fund programs produce types of neighbourly exposure that go beyond specific recipient locations.

Macro-Category Time-Series Analysis

The macro category time series in Figure 5 enables understanding of the development of the strategic priorities for implementing EU-funded projects in Bulgaria from 2014 to 2026. Project activity did not follow an unchanging or linear trend but instead followed the shifts in priority among the different policies (that were supported through the funding) over time as the national development goals changed, the EU programs changed, as well as the global economic and political situation. The analysis indicates that there are three major periods with respect to the institutional support for and implementation of programs; the first period being early years focused on institutional support and program implementation, the second was the pandemic-related large-scale economic interventions and the third is recent focus on both crisis resilience and territorial cohesion.

The trend for each of the seven main categories[1] differs significantly over the course of this period. The most notable was the tremendous (and unprecedented) explosion of projects funded under the Economic Category beginning in 2020 and peaking at approximately 24,000 projects in 2021. During the early years of the programming period (i.e., prior to 2020), the number of new economic programs initiated remained remarkably constant; typically, less than 1000. In addition

[1] For more information about which programs are included in each macro category, see Appendix, Table A1.

to being by far the greatest amount of new program initiations observed in the data set, this explosion in new economic programs was also directly associated with the onset of the COVID-19 pandemic; government implemented emergency business support measures, rapid absorption of funds provided through these programs; and the implementation of various forms of economic recovery programs. As a result, during this period, economic programs accounted for the majority of all project activities undertaken by Bulgaria using European Union funding.

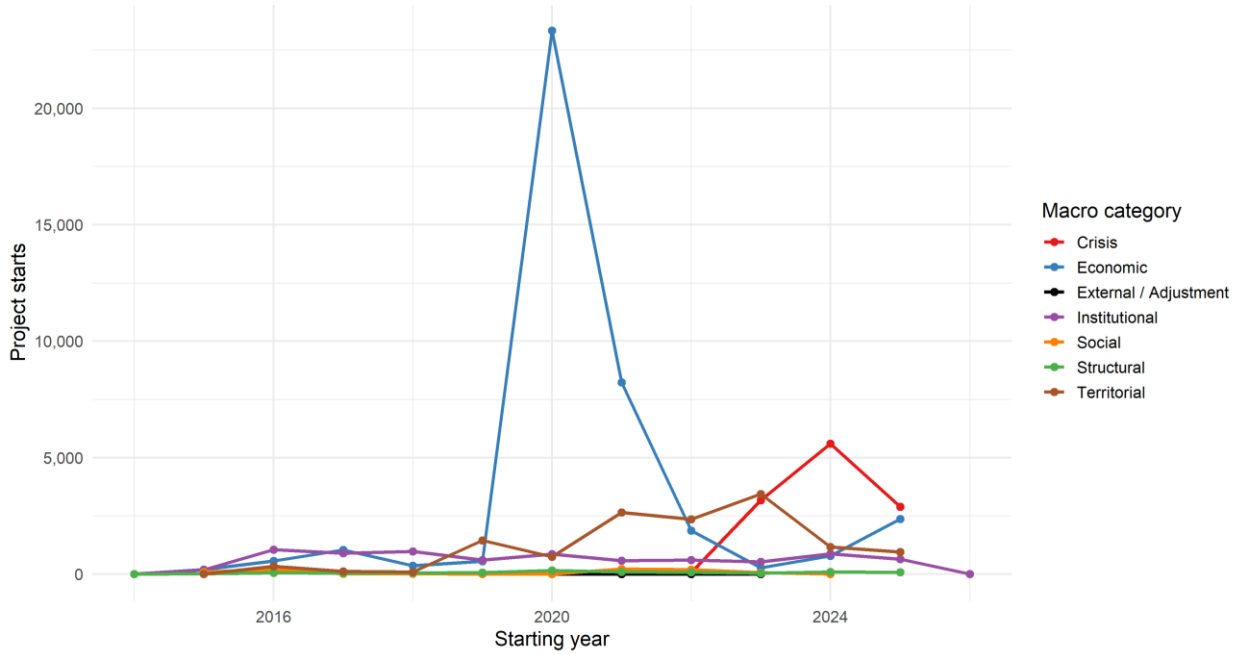


Figure 5 Macro-Category Time-Series, 2014 - 2026

While economic program activities are still well above what they were in the first few years of the programming period, it would be inaccurate to assume that the substantial decline seen immediately post-pandemic represents an indication that the economic programs implemented were unsuccessful. Instead, the decline seems to represent the natural consequence of responding to an extremely unusual circumstance. Additionally, since program activity declined but did not fall back to pre-pandemic levels, it can be inferred that the pandemic may have enhanced the ability of institutions and administrations involved in delivering economic support measures.

Crisis programs developed differently. Prior to 2022, crisis programs represented a very minor portion of total EU-funding used in Bulgaria. However, due to an expanding need for resilience-based governance strategies that responded to multiple interrelated crises such as inflationary pressures, energy insecurity, and geopolitical instability - along with the pandemic - crisis program activity began to grow exponentially starting in 2023. By 2024, crisis programs had become one of the largest categories supported by EU funding. It appears that this significant expansion of crisis programs is indicative of a long-term structural adjustment in how EU-funding priorities are determined.

Territorial programs consistently grew over the course of this study. While there were minimal amounts of territorial program funding available at the outset of this study, territorial program funding grew steadily after 2018 and peaked between 2021 and 2023. The continuous and steady growth in territorial programs indicates that regional cohesion, local development, infrastructure investment and decentralizing territorial governance became increasingly important components of Bulgaria's EU-funded approach to implementing interventions.

Institutional and Social programs demonstrated relative stability throughout this study. Institutional programs appeared relatively constantly over successive years, which reflected ongoing needs for governance reforms; administrative modernizations; technical assistance; and institutional capacity-building. Social programs similarly indicated some degree of growth without demonstrating the volatility seen in Economic or Crisis categories. Because their consistency was evident throughout the entirety of this study, it is reasonable to conclude that employment support, social inclusion; and social service delivery will remain central to EU-funded development policies regardless of whether or not such support is needed as a reaction to particular shock events.

Both Structural and External/Adjustment categories were relatively small and demonstrated limited volatility compared to larger categories. Despite their size and lack of volatility, both categories continue to provide indications that Bulgaria continues to invest in modernizing its infrastructure base and adapting policy frameworks to respond to external conditions.

Together, the macro-categories illustrate that Bulgaria's EU-funded project portfolios changed through a number of discrete periods (or "epochs") as opposed to evolving through a singular path. The initial epochs (prior to 2020) were characterized by relatively consistent institutional and social support measures; the second epoch (pandemic years) featured exceptionally high economic intervention; and most recently (post-pandemic), the focus has shifted toward creating greater territorial cohesion and enhancing crisis resilience, illustrating a transition toward EU-funding based governance frameworks that emphasize adaptation; regional development; and long term stability.

Additionally, the time-series analysis illustrates that these temporal changes are highly correlated with spatial relationships identified within the spillover maps. Specifically, the explosive growth in economic programs during 2020 - 2021 corresponds to a similar level of private sector spillover growth; likewise, the subsequent increases in territorial and crisis-oriented programs appear to coincide with increases in density of national wide exposure networks. Although time-series analysis cannot determine causalities; it does suggest a relationship exists between how EU-funding priorities evolve temporally and how geographically extensive spillovers occur.

Collectively, the findings demonstrate that EU-funding in Bulgaria has transitioned from being an institutionally focused mechanism for promoting program implementation towards a multi-dimensional framework, providing economic stabilization, crisis resilience, territorial cohesion, and social development. These transitions demonstrate EU-funding mechanisms' flexibility to adapt to changing economic and policy environments as well as create new territorial landscapes where project participation occurs nationally.

Distribution of Lagged Spillover Exposure by Year

The boxplot in Figure 6 for log-transformed lagged spillover exposure provides a statistical view of how neighbouring exposure changed across settlements over time. Although maps show

where exposure was located, boxplots display how widely it is distributed and whether exposure became more equal or concentrated. While both map data and boxplot results can be used to analyze the spatial distribution of neighbouring exposure, they are used differently: maps display where exposure occurred, while boxplots display how widely it was distributed.

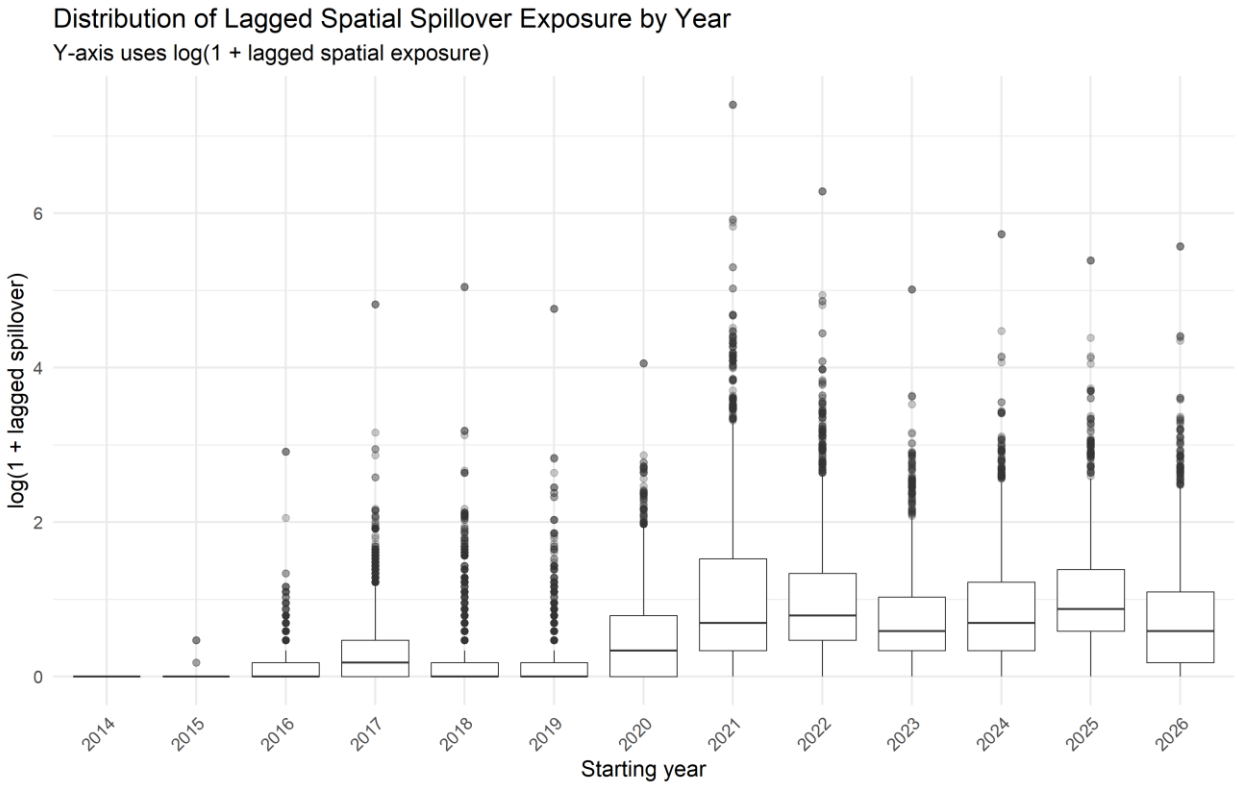


Figure 6 Boxplot of Lagged Spillover Exposure by Year

During the years 2014 and 2015, the distribution is compressed near zero. This confirms that neighbouring exposure was still weak in the beginning of the programming period. Because the indicator is lagged, 2014 contains no accumulated prior exposure. Although some early formation of project networks had already taken place by 2015, the indicator still reflects only a small portion of the overall project activity. These years, therefore, represent the initialization phase of the spatial exposure system.

Starting from 2016, the distribution expanded sharply. The interquartile range increases, upper-tail values rise, and more extreme observations appear. This shows that neighbouring exposure has become not only more widespread but also much more uneven than before. More settlements became exposed to project activity in nearby places, however, many settlements accumulated higher exposure than the average. This indicates that diffusion and concentration have been ongoing simultaneously.

Between the years 2017 and 2019, the distribution continued to expand but less abruptly. Increasing median values suggest that exposure became more common across settlements. However, the continued growth of upper-tail observations indicates that highly connected

administrative and economic centers accumulate exposure more rapidly than other settlements. As such, the result will be a hierarchical exposure structure; more places become connected to the EU-funded project system, yet leading centers retain an advantageous position.

A larger structural shift took place between the years 2020 and 2022 especially during 2021. During this period, both the central tendency and dispersion of exposure increased substantially.

The 2021 distribution contains the highest exposure values in the dataset, with several settlements reaching values far above those observed in previous periods. This confirms that the pandemic and recovery years changed not just the volume of EU-funded activity but also its spatial distribution. Exposure became more national in reach, however, the upper tail also became more pronounced; showing that the most connected settlements accumulated high levels of neighbouring activity.

Following 2022, the distribution entered into a stabilization phase. Median exposure remained well above pre-pandemic level while variability declined from peak value of 2021.

Nonetheless, persistence of high outliers indicates that the most exposed settlements maintained their relative position within the spatial system. This suggests that neighbouring exposure became structurally embedded across Bulgaria while continuing to produce territorial inequality amongst highly connected centers and less connected settlements.

Spatial Autocorrelation of EU-Funded Project Activity

Spatial autocorrelation at a significant scale would increase the confidence that there is a non-random geographical distribution of EU-funded project activity in Bulgaria. As opposed to being random, the presence of significant spatial autocorrelation indicates that areas which have been successful in attracting funding through EU-funded projects are often found in close proximity to each other. Therefore, such a finding supports the use of spatial analysis to examine whether EU-funded beneficiary activity has a non-random spatial association.

Global Moran's I

Global Moran’s I statistics (Table 1) were generated on an annual basis to determine if project activity had any form of spatial autocorrelation among the Bulgarian settlements between 2014 and 2026. Global Moran’s I can produce either a positive or negative value, based upon whether neighbouring settlements tend to have similar or differing levels of project activity. If Moran’s I produces a value closer to zero, it implies that there is no systematic spatial arrangement of project activity among neighbouring settlements.

The data illustrates that overall spatial autocorrelation has been very low for most of the study period; however, some temporal variations did occur at statistically significant intervals. For many years during the initial years of the programming cycle, there was very little evidence of spatial correlation existing as related to the location of project activity. The global Moran's I was essentially zero for the first year studied (i.e., $I = -0.0004$; $p = .998$); therefore, there was a completely random distribution of project initiations among the settlement locations during that year. Also, five subsequent years (2017, 2018, 2022, 2023 and 2024) yielded statistically non-significant global Moran's I values indicating that there was no systematic grouping of high/low

levels of project activity among nearby settlements. Due to the fact that the full data for 2026 is yet to be completed, from the available data as of February 2026, it can be seen that there hasn't been significant spatial dependence, however, this could change after all projects for the year have been registered after the completion of the year.

Table 1. Moran's I Statistics for EU Project Starts (2014 - 2026)

Year	Moran's I	Z- Score	P- Value	Significance	Interpretation
2014	- 0.0004	0.002	0.998	Not Sig.	No significant spatial dependence
2015	- 0.0227	- 1.80	0.071	Not Sig.	Weak dispersion
2016	- 0.0315	- 2.50	**0.012**	**Significant**	Significant spatial dispersion
2017	0.0051	0.45	0.654	Not Sig.	No significant spatial dependence
2018	- 0.0086	- 0.67	0.506	Not Sig.	No significant spatial dependence
2019	- 0.0301	- 2.39	**0.017**	**Significant**	Significant spatial dispersion
2020	**0.0636**	**5.15**	**<0.001**	**Highly Sig.**	**Moderate spatial clustering**
2021	**0.0337**	**2.74**	**0.006**	**Significant**	**Weak spatial clustering**
2022	0.0054	0.47	0.639	Not Sig.	No significant spatial dependence
2023	0.0125	1.04	0.300	Not Sig.	No significant spatial dependence
2024	0.0082	0.69	0.490	Not Sig.	No significant spatial dependence
2025	**0.0893**	**7.21**	**<0.001**	**Highly Sig.**	**Highest observed spatial clustering**
2026	- 0.0007	- 0.02	0.980	Not Sig.	No significant spatial dependence

There were two years in which there was statistically significant negative spatial autocorrelation. Years 2016 ($I = -0.0315$; $p = .012$) and 2019 ($I = -0.0301$; $p = .017$) indicated that settlements with similar levels of project activity were located farther apart than those without similar levels of activity. Although the size of both values was small, these results suggested a general trend toward a lack of uniformity in project activity concentrations around neighbouring settlements instead of concentrations around groups of contiguous settlements.

In addition, after 2020, there was an observable shift in the global Moran's I values. Year 2020 resulted in a global Moran's I of 0.0636 ($p < .001$); thus, it demonstrated a small degree of statistically significant positive spatial autocorrelation, suggesting that settlements having similar levels of project activity were becoming geographically clustered. This same type of relationship was observed in year 2021 ($I = .0337$; $p = .006$).

These results demonstrate that over time, the geographic organization of EU-funded project activities changed in nature from being fragmented and geographically unconnected to displaying multiple degrees of statistically significant positive spatial autocorrelation. However, the spatial autocorrelation appeared in selected years, especially 2020, 2021, and 2025, but did not continue throughout the whole post 2020 period. This demonstrates that there is a growing body of empirical evidence that illustrates the impact that EU-funded interventions have on creating dependencies between territories over time; therefore, increasing the importance of using explicit spatial analysis techniques versus traditional non-spatial methodologies when investigating the territorial impacts resulting from EU-funded projects.

Local Indicators of Spatial Association (LISA)

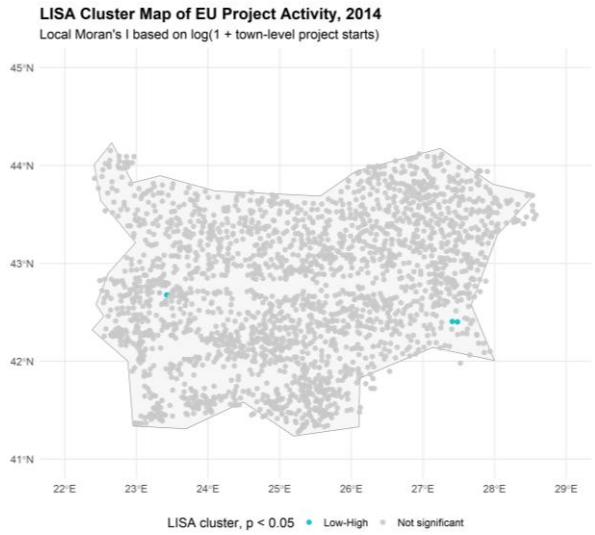
While Global Moran's I give one an idea of how much there is of spatial autocorrelation on an area-wide basis, the Local Indicators of Spatial Association (LISA) helps in finding the specific geographic locations that have statistically significant local clustering or are "spatial outliers" (Anselin, 1995). Therefore, LISA helps complement the global analysis by showing the geographic specifics behind the aggregate Moran's I statistics.

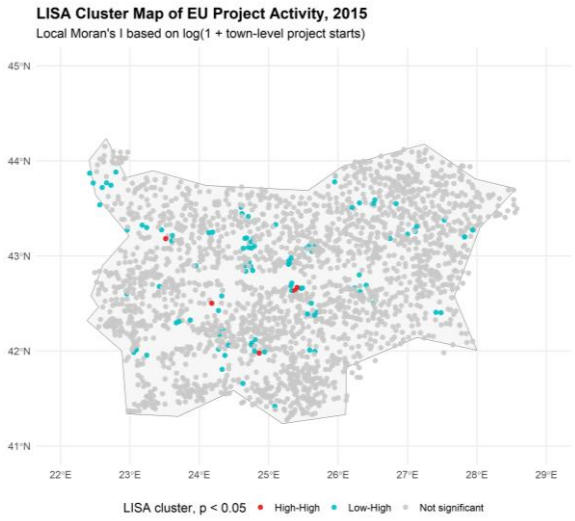
Statistically significant local spatial patterns (as defined by LISA), however, were relatively rare compared to the number of all available data. Over the duration of this study (across 2,302 settlements and 13 years), 471 observation units had been identified as High-High clusters, 758 observations as Low-High spatial outliers; and 28,697 observations were not statistically significant. Neither Low-Low nor High-Low clusters were identified under the selected spatial-weight.

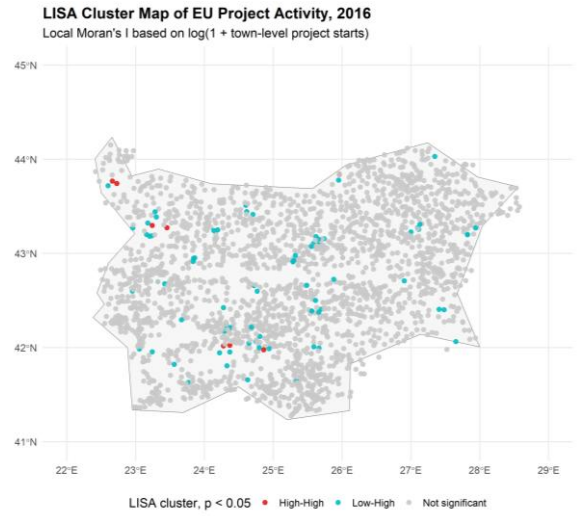
Figure 7 displays the spatial distribution of statistically significant LISA Clusters. Red-colored dots represent High-High Clusters, i.e., those areas where project activity was above average in each participating unit as well as among its neighbours. Turquoise-colored dots indicate Low-High Clusters i.e., those areas where project activity was below average in each participating unit while activity among neighbouring units was above average. Finally, grey dots signify observations which did not exhibit statistically significant local spatial autocorrelation at the 5% significance level.

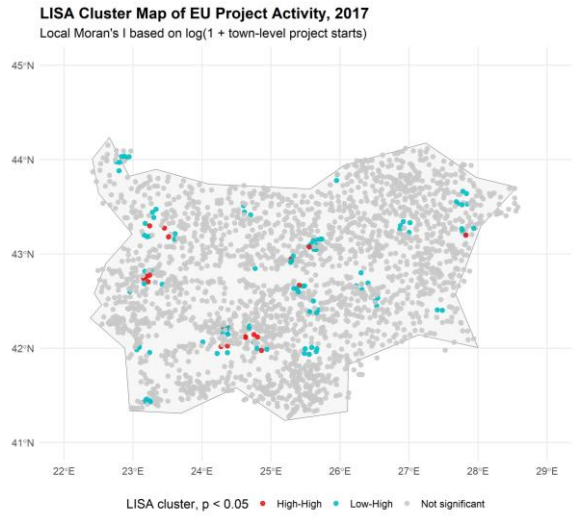
The results have two important implications. Firstly, there is no uniformly grouped or clustered national spatial system formed by EU-funded beneficiary activities. Most of the settlement-year observations are not spatially associated at a statistically significant level. Secondly, when statistically significant local associations occur, Low-High outliers occur more frequently than High-High clusters. In terms of settlement location and registered project activity: there are more instances of Low project activity settlements occurring close to High project activity settlements than High registered project activity settlements being located near one another.

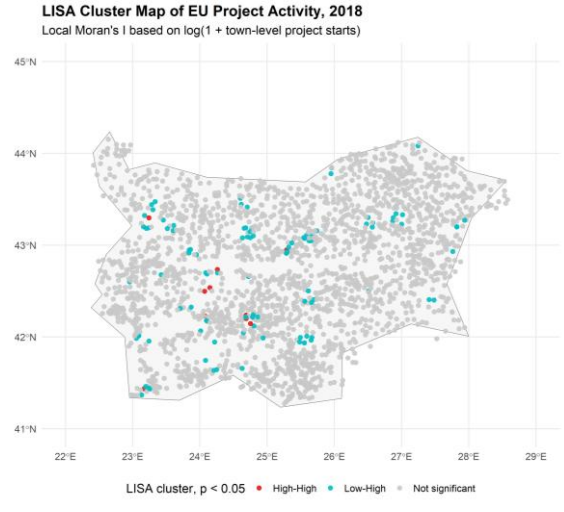
In addition to understanding how these associations vary across time and space for the entire sample population, additional information about the distribution of both types of associations over time can be gained by examining the frequency distributions of both Low-High outliers and High-High clusters on an annual basis. As shown below, High-High clusters were infrequent in the early years of the sample. For example, there were only 5 cases in 2015, 8 in 2016, and 21 in 2017. There was then a marked increase in 2020 when High-High cluster values increased to 99 settlement-year observations. These values continued to be relatively high in 2021 and 2022 before reaching their highest observed values in 2025 when there were 105 High-High settlement-year observation cases. Therefore, it appears that localized administrative hubs of EU-funded beneficiary activity became more apparent during the pandemic, recovery, and later programming years.

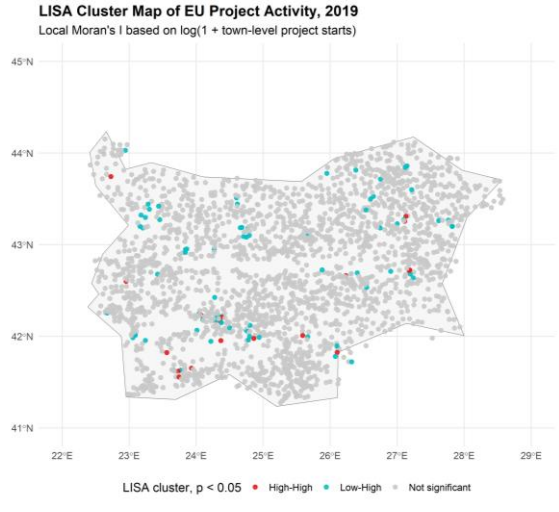

LISA Cluster Map of EU Project Activity, 2014
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
Low-High
Not significant

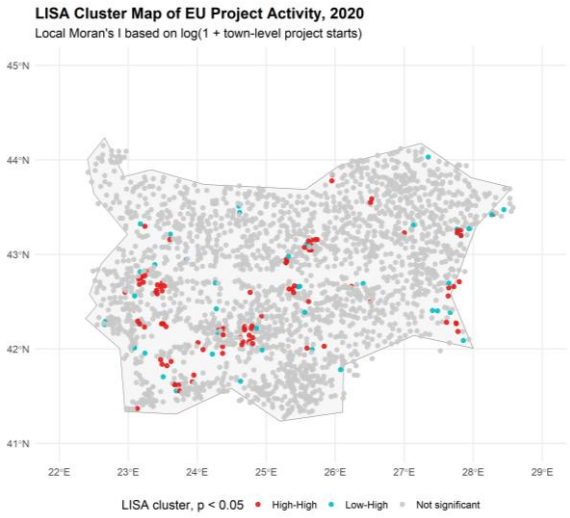

LISA Cluster Map of EU Project Activity, 2015
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

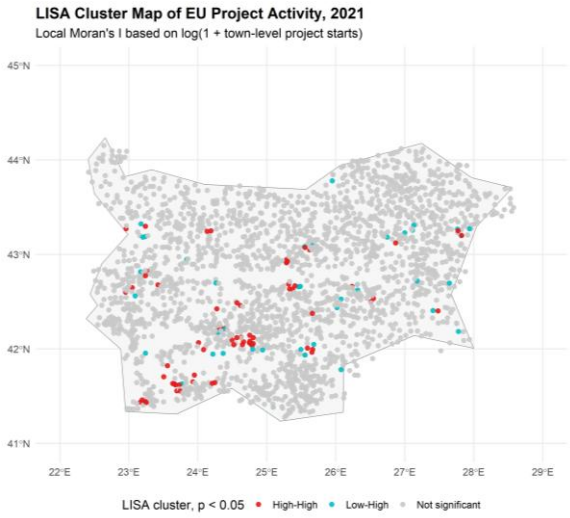

LISA Cluster Map of EU Project Activity, 2016
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

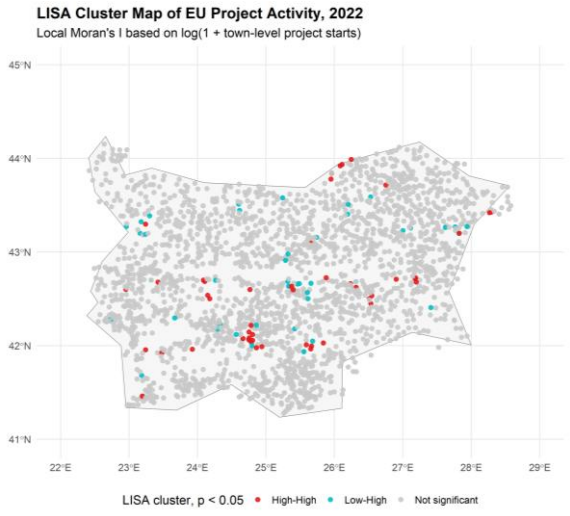

LISA Cluster Map of EU Project Activity, 2017
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

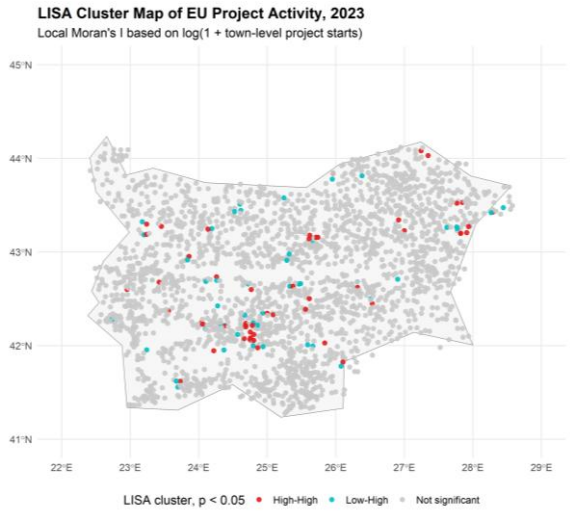

LISA Cluster Map of EU Project Activity, 2018
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

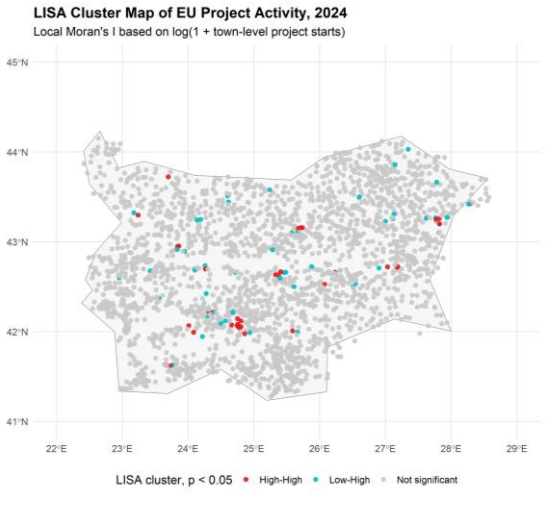

LISA Cluster Map of EU Project Activity, 2019
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

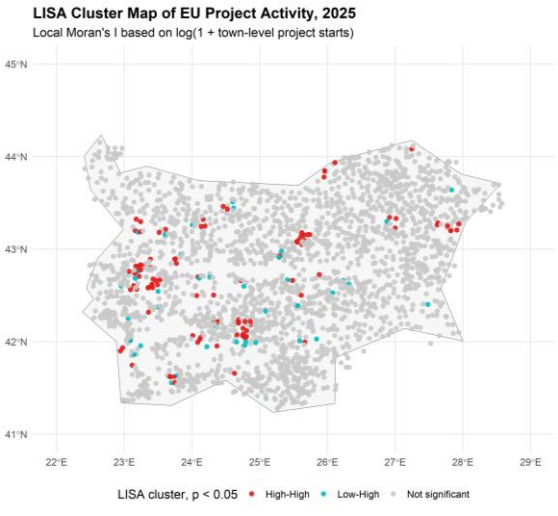

LISA Cluster Map of EU Project Activity, 2020
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant


LISA Cluster Map of EU Project Activity, 2021
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant


LISA Cluster Map of EU Project Activity, 2022
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant


LISA Cluster Map of EU Project Activity, 2023
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant


LISA Cluster Map of EU Project Activity, 2024
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant


LISA Cluster Map of EU Project Activity, 2025
Local Moran's I based on log(1 + town-level project starts)
45°N
44°N
43°N
42°N
41°N
22°E
23°E
24°E
25°E
26°E
27°E
28°E
29°E
LISA cluster, p < 0.05
High-High
Low-High
Not significant

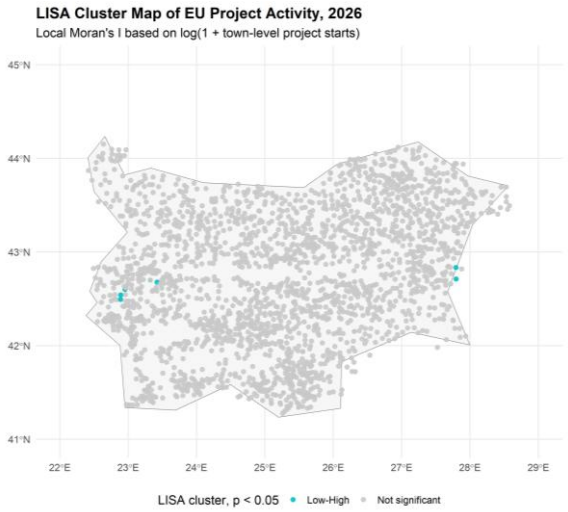


Figure 7. LISA Cluster Map of EU-funded Project Activity in Bulgaria

As illustrated in the figure above, Low-High outliers have been particularly frequent in certain years. Specifically, Low-High outlier values were most common in 2015 and 2017 when they totaled 107 cases per year. Values also remained high in 2018 when there were 102 cases. Thus, it can be seen that numerous settlements exist in the immediate vicinity of active beneficiary centers, yet these settlements demonstrate very little in terms of their own registered project participation. The fact that Low-High outliers persisted over several years provides further evidence that a proximity-based model is not sufficient enough to explain why some nearby settlements participate in EU-funded programs while others do not. Rather, it can be argued, that the ability of nearby settlements to access EU-funded projects is facilitated by factors such as administrative capacity, institutional experience, beneficiary composition, and local organizational resources.

Finally, the absence of Low-Low cluster values suggests that this analysis identifies no large geographic regions with statistically significant low levels of registered project activity. Likewise, the lack of High-Low cluster values implies that highly active EU-funded project participant communities are typically embedded within larger local systems which consist of either other active settlements or neighbouring communities with low levels of registered participation.

In conclusion, overall, the LISA results suggest the existence of a selective core-periphery structure among administrative geography related to EU-funded project participation. High-High clusters refer to areas representing localized beneficiary hubs whereas Low-High outliers denote communities who possess much weaker representation despite their proximity to active neighbours. Therefore, these results provide further support for a conservative reading of spatial exposure - i.e., EU-funded beneficiary activity exists within specific geographic locations and/or specific temporal frames, however, this structure is localized in nature rather than universally applicable and thus cannot be used as direct evidence of confirmed territorial impact.

Conclusion

The study examines the administrative geographies of EU-funded project participations in Bulgaria between 2014 and the current 2026 with 73,783 administrative project registrations that were then aggregated into a balanced panel of 2,302 settlements. The paper analyzed the distributions of registered beneficiary activity across space, how neighbouring exposures developed over time, and whether EU-funded participations exhibited statistically significant spatial associations. The location of each beneficiary at their legal office or administration address was used for the study. Thus, the results report the administrative geography of the registered participations and the administrative exposures, and not the geographical location of the projects' implementations nor the causal socioeconomic impacts of EU-funded interventions.

The findings indicate that EU-funded project participations are highly concentrated within Sofia and large regional centers, such as Plovdiv, Varna, Burgas, Ruse and Stara Zagora. These concentrations represent both the high density of government offices, university administrations, municipal governments, companies and other types of organizations capable of applying for and managing EU funds. Therefore, while the concentration of participations within Sofia is indicative of territorial concentration, it is also reflective of the administrative centralization of participant registration. Additionally, the analyses reveal that EU fund participations are not limited solely to the largest urban centers. Exposure to neighbouring registrants increased after 2016 and was particularly evident during the pandemic and post-pandemic recovery periods, suggesting that many settlements have become proximal to active registrants.

An additional layer of analysis distinguishes between public sector and private sector spillovers. Project registrations by public sector beneficiaries exhibit wider territorial coverage, consistent with the territorial distribution of municipalities, schools, universities, public agencies and/or institutional actors. In contrast, project registrations in the private sector are denser around economically strong urban/peri-urban areas where businesses, firms, business organizations' offices are denser. These distinctions suggest that public and private sectors register for EU-funded programs through distinct administrative and territorial structures.

The spatial autocorrelation results show that global Moran's I values are typically small. In addition, most years did not exhibit statistically significant spatial autocorrelation. Statistically significant positive clustering occurred only in specific years (i.e., 2020, 2021 and 2025). Therefore, EU-funded registrant activities do not comprise a continually clustered national spatial system. Rather, spatial association exhibits selectivity temporally and spatially. The LISA results support this conclusion. Specifically, most settlement-year observations are not statistically significant, whereas, significant observations occur predominantly in localized High-High clusters and Low-High outliers, with the outliers outnumbering the High-High clusters. These results suggest that proximity to active center/s does not necessarily generate similar levels of registered participation in adjacent settlements.

Therefore, the primary contributions of this study lie in both its methodology and empirical evidence. The study illustrates how individual registrant-level administrative data can be converted into a settlement level spatial panel and subsequently utilized to analyze the administrative organization of EU-funded project participation. Using a smaller territorial unit than national/NUTS level evaluations allow for a better understanding of where participant management capacity is concentrated, when neighbouring exposure is developing, and where settlements remain underrepresented due to their proximity to active center/s.

However, several limitations exist for this study. First, since beneficiary locations represent only the locations of their legal/administrative offices, the analyses cannot identify the actual implementation sites for each project. Second, the study does not evaluate any socio-economic variables, such as employment, productivity, innovation, income levels, infrastructure quality and welfare effect. Third, the exposure indicators are calculated utilizing geographic distance and do not quantify any direct connections between settlements (e.g., commuting relationships, subcontracting relationships, institutional cooperations, supplier network, service delivery); Fourth, the 2026 exposure indicators are incomplete due to the fact that the data set was downloaded in February 2026, thus conclusions drawn from the 2026 data should be considered directional rather than comparative with all prior years.

Subsequent studies could attempt to correlate individual registrant offices with project implementation sites, project recipient sites and/or socioeconomic impact variables. Subsequent studies could also assess the sensitivity of spatial exposure metrics via varying specification of spatial weights as well as incorporating alternative forms of connectivity (such as transportation access, commuting flow, institutional partnership and inter-firm networks). By extending methodologies towards assessing territorial impacts from administrative geographies of EU funding participation, future researchers will be able to expand upon this preliminary work.

Finally, this study highlights the significance of considering space when evaluating European-funded programs. By documenting changes in project activity, spatial exposure and localized clustering among Bulgarian settlements over the course of the programmatic period this study provides substantial evidence supporting a growing body of research concerning territorial aspects of public investments.

Funding

This research was supported by the Swiss National Science Foundation (SNSF) under grant IZSF-0_235781, for the project “Regional Economic Impact of EU Funds and Swiss Projects in Bulgaria.”

References

Anselin, L. (1988). Spatial econometrics: Methods and models. Kluwer Academic Publishers. https://doi.org/10.1007/978- 94- 015- 7799- 1

Anselin, L. (1995). Local indicators of spatial association—LISA. Geographical Analysis, 27(2), 93-115. https://doi.org/10.1111/j.1538- 4632.1995.tb00338.x

BG Postcode. (n.d.). BG Postcode. https://bgpostcode.com/

Bivand, R. S., & Wong, D. W. S. (2018). Comparing implementations of global and local indicators of spatial association. TEST, 27, 716-748. https://doi.org/10.1007/s11749- 018- 0599- x

Bivand, R., Millo, G., & Piras, G. (2021). A review of software for spatial econometrics in R. Mathematics, 9(11), Article 1276. https://doi.org/10.3390/math9111276

Boschma, R. A. (2005). Proximity and innovation: A critical assessment. Regional Studies, 39(1), 61-74. https://doi.org/10.1080/0034340052000320887

Council of Ministers of the Republic of Bulgaria. (n.d.). EU funds: Unified information portal for European Union funds. https://www.eufunds.bg/en/home

Dall'Erba, S., & Le Gallo, J. (2008). Regional convergence and the impact of European structural funds over 1989-1999: A spatial econometric analysis. Papers in Regional Science, 87(2), 219-244. https://doi.org/10.1111/j.1435- 5957.2008.00184.x

Debarsy, N., & Le Gallo, J. (2025). Identification of spatial spillovers: Do's and don'ts (Version 2). SSRN. https://doi.org/10.2139/ssrn.4751335

Goto, A., & Suzuki, K. (1989). R&D capital, rate of return on R&D investment and spillover of R&D in Japanese manufacturing industries. The Review of Economics and Statistics, 71(4), 555-564. https://doi.org/10.2307/1928096

Griliches, Z. (1998). Issues in assessing the contribution of research and development to productivity growth. In Z. Griliches (Ed.), R&D and productivity: The Econometric Evidence (pp. 17-45). University of Chicago Press. http://www.nber.org/chapters/c8340

Hernández de Rojas, F., Rodríguez Pita, P., & Pérez Martínez, J. E. (2025). The phenomena of spatial spillovers of digitalization and competitiveness inside European regions. Telecommunications Policy, 49, Article 102989. https://doi.org/10.1016/j.telpol.2025.102989

Hertrich, T. J., & Brenner, T. (2026). The impact of skills shortage on economic development in Germany: A mixed method approach. Global Challenges & Regional Science, 6, Article 100027. https://doi.org/10.1016/j.gcrs.2026.100027

Nigohosyan, D., Vassileva, I., & Vutsova, A. (2025). The effects of EU grants on SMEs: Evidence from Bulgaria. Economic Systems, 49, Article 101244. https://doi.org/10.1016/j.ecosys.2024.101244

Nigohosyan, D., Vutsova, A., & Vassileva, I. (2021). Effectiveness and efficiency of the EU-supported energy efficiency measures for SMEs in Bulgaria in the period 2014-2020: Programme design implications. Energy Efficiency, 14, Article 24. https://doi.org/10.1007/s12053- 021- 09933- 4

Nikou, V. (2025). Spatial interdependence and cross- border spillover effects in the ecological footprint of consumption: The role of inclusive policies and public procurement. Journal of Cleaner Production, 494, Article 144992. https://doi.org/10.1016/j.jclepro.2025.144992

Paez, A. (2021). An introduction to spatial data analysis and statistics: A course in R. McMaster University. https://doi.org/10.17605/OSF.IO/WHMUV

Schmidt, T. D., & Mitze, T. (2026). Location- specific wage effects from offshoring and backshoring. Global Challenges & Regional Science, 6, Article 100030. https://doi.org/10.1016/j.gcrs.2026.100030

Sparks, C. (2019, January 23). DEM 7263: Exploratory spatial data analysis. RPubs. https://rpubs.com/corey_sparks/460703

The Comprehensive R Archive Network (2021, September 13). Exploratory spatial data analysis. CRAN. https://cran.r- project.org/web/packages/geostan/vignettes/measuring- sa.html

Vagnini, C., Canal Vieira, L., Longo, M., & Mura, M. (2025). Regional drivers of industrial decarbonisation: A spatial econometric analysis of 238 EU regions between 2008 and 2020. Regional Studies, 59(1), Article 2380369. https://doi.org/10.1080/00343404.2024.2380369

Wang, C., Xing, S., & Xu, L. (2023). A multi- regional input-output model to measure the spatial spillover of R&D capital. Sustainability, 15(14), Article 11208. https://doi.org/10.3390/su151411208

Wu, F., Wang, C., Ibrahim, H., & Zhao, J. (2025). Research on the spatial and temporal evolution and spatial spillover effects of regional green innovation in China under the ESG context. Journal of Cleaner Production, 520, Article 146116. https://doi.org/10.1016/j.jclepro.2025.146116

Appendix

Table A1 Distribution of EU-funded projects by macro-category and program, 2014 - 2026

Macro Categories	Program	Number of projects
Crisis	Recovery and Resilience Plan	11724
		11724
Economic	Innovations and competitiveness	35332
	Programme "Competitiveness and Innovation in Enterprises" 2021-2027	2821
	Maritime and Fisheries Programme	1143
	Maritime, Fisheries and Aquaculture Programme for Bulgaria	84
	Programme "Research, Innovation and Digitalisation for Smart Transformation"	83
	Cultural Entrepreneurship, Heritage and Cooperation	55
		39518
External / Adjustment	BG BILATERAL FUND EEA AND NFM	6
	Brexit Adjustment Reserve	3
		9
Institutional	Human Resources Development	4403
	"Human resources development" programme 2021 - 2027	1781
	Good governance	706
	Science and education for smart growth	376
	Programme "Education" 2021-2027	136
	Internal Security Fund	108
	Asylum, Migration and Integration Fund	59
	Programme Bulgaria - BMVI	50
	Technical Assistance Programme 2021-2027	38
	Programme Bulgaria - AMIF	31
	Programme of the Republic of Bulgaria under Internal Security Fund	26
	Home Affairs	22
	Justice	17
		7753
Social	Food and/or basic material assistance	548
	"Food and Basic Material Support" Programme 2021-2027	250
		798
Structural	Environment	391
	Programme "Environment" 2021-2027	135
	Transport and transport infrastructure	80
	Renewable Energy, Energy Efficiency, Energy Security	64
	Environment Protection and Climate Change	34
	Transport connectivity programme 2021 - 2027	28
		732

Territorial	Rural Development Programme	12144
	Regions in growth	824
	Development of Regions Programme 2021-2027	217
	Local Development, Poverty Reduction and Enhanced Inclusion of Vulnerable Groups	64
		13249
	Grand Total	**73783**