EVOLVING REGIONS IN EUROPE: APPLICATION OF SPATIAL MODELS TO THE VARIOUS FORMS OF THE EUROPEAN SPATIAL CONCENTRATIONS

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Abstract

The "Blue Banana", spanning from the United Kingdom to Italy, has been symbolizing economic vitality in Europe. This paper reassesses its contemporary relevance by analyzing economic indicators and regional dynamics, particularly in Eastern and Mediterranean Europe, within the NUTS 2 framework. Leveraging Stewart's concept of demographic energy and Moran's spatial statistics, it introduces a robust methodology interweaving territorial and economic dynamics. By examining data layers, this study provides novel insights into the Blue Banana's significance and its economic impact on Europe during the late 2010s and early 2020s. Furthermore, it illuminates the core area's interconnections with adjacent economic zones and the emergence of prospective alternative spatial paradigms. The findings indicate that the majority of the Blue Banana regions have remained part of the prominent core area of Europe in terms of the most conventional regional economic indicators. However, emerging alternative spatial concentrations and a partial eastward shift are also visible.

Keywords: Blue Banana, Mediterranean Europe, Eastern Europe, spatial development, productivity

JEL classification: C1, N1, N9, R1, Y1

pp. 63-78

1. Introduction

This study adopts an interdisciplinary approach to re-evaluate the Blue Banana paradigm, aiming to shed new light on evolving economic spatial concentrations in Europe through the combined application of spatial statistics and principles derived from demographic physics. The paper is structured into three parts. The first section provides the foundational context. It aims to highlight the key steps that led to the formation of the Blue Banana concept, while offering an overview of the economic and political situation of two specific European macro-regions: Eastern Europe (formerly the "Eastern Bloc") and the regions bordering the Mediterranean Sea. The paper will illustrate a map detailing regional economic growth potential, serving as a tool for assessing economic disparities at the European NUTS 2 level, with a particular focus on the Blue Banana regions.

Correspondingly, the article will also address the main hindrances to the economic performance of these regions, specifically Eastern Europe, which has struggled to realize its potential, and the Mediterranean region, which has experienced a relative decline. The second section outlines the key statistical foundations of spatial analysis, focusing on the application of physics-based models in economics. Consequently, the Gravity Model will be employed to study the patterns of population movement and distribution within the aforementioned regions. Special attention is given to the movements within highly urbanized areas such as the Blue Banana, referencing previous studies that helped define its geographic shape (see Figure 1). This descriptive spatial analysis highlights the methodological innovation of using a rich, comprehensive, and updated dataset, as well as a comparative approach incorporating complementary spatial analysis techniques, such as Moran's I spatial statistics and the Gravity Model. The study examines how spatial concentration and heterogeneity influence economic and demographic dynamics, focusing on agglomeration economies, spatial autocorrelation, and clustering effects. The third and final section discusses the results derived from applying the Gravity Model to the Gross Domestic Product (GDP) and population data across European regions. The goal is to identify Europe’s economic backbones, regions characterized by exceptional productivity, urbanization and industrialization.

2. Evolving Regions in Europe: a theoretical background

2.1 The Blue Banana: Origins, Evolution and Role in European Spatial Economy

The Blue Banana, a highly industrialized and densely populated region in Europe, has consistently outperformed other regions of Western Europe. Throughout the late 20th century, it has exhibited substantially higher per capita income, lower unemployment rates, more robust industrial clusters and superior infrastructure in telecommunications and transportation (Van Dinteren & Meuwissen, 1994). Moreover, the Blue Banana is recognized as a vibrant hub for cultural and educational activities, including conferences, universities and cultural events, which further highlights its attractiveness. Thanks to its large population and capacity to host innovative projects, the Blue Banana possesses a diverse and flexible economic and institutional framework. Many researchers have investigated the factors contributing to the region’s emergence as an economic powerhouse, highlighting the role of dynamic externalities, innovation, and the tertiarization of traditional manufacturing industries. As a result, the Blue Banana is expected to maintain its growth leadership, particularly in specialized services such as transportation, communications, repair and leisure.

To understand the Blue Banana's historical development, it is essential to highlight several key elements. Roger Brunet is recognized as the founder of GIP RECLUS, a network of research groups that has produced important analyses of spatial dynamics, particularly investigations related to the Blue Banana. Following a 1987 study conducted by the Interministerial Delegation of Land Planning and Regional Attractiveness (DATAR), Brunet and his team of geographers were commissioned in 1989 to identify the “European Backbone”. This term referred to a high concentration of cities and populations with considerable historical significance across the European continent. The GIP RECLUS also examined the issue of Paris's strong historical centralization and the potential eastwards shift of Europe’s economic and political center (Taylor, 2015). Indeed, Brunet originally excluded Paris from the Blue Banana concept, albeit reintroducing it in later versions. The centralization critique echoed Jean-F. Gravier's 1947 publication, Paris and the French Desert, which scrutinized France’s overreliance on its capital and the resulting resource imbalance. Brunet advocated for substantial infrastructure investment, combining economic, political, and geographical factors, to link the Paris-Lyon-Marseille axis with the Blue Banana region. This spatial configuration is visually represented in Figure 1.

Figure 1: The Blue Banana in transition: Challenges in the Maritime-Land Interface

Source: Notteboom & Rodrigue (2006)

In the 1990s, the term ‘Blue Banana’ evolved in both usage and interpretation. While the core idea of a densely urbanised and economically significant corridor still persisted, the geographical boundaries became more flexible, as it encompassed a larger part of Western and Central Europe. As a result, the concept began to denote a more general concentration of economic activity and population density across these regions. This broader scope acknowledged that the economic strength and interconnectivity of the Blue Banana extended beyond the specific cities and regions originally identified by Brunet. An alternative vision, the "European Bunch of Grapes", was proposed by Klaus Kunzmann and Michael Wegener in a background study for the European Commission's "Europe 2000" communication. However, their juxtaposition with Brunet’s work is problematic for two reasons. First, Brunet used France as his frame of reference and argued that his Dorsale rarely intersected French territory, despite Kunzmann and Wegener’s portrayal. Therefore, rather than making a statement about the future development of Europe, it was an attack on Paris's hegemonic status. Second, Brunet crucially depicted the Dorsale as a polycentric urban network, characteristics that Kunzmann and Wegener attributed to their own model. Thus, both ideas have the same implications for the development of Europe. Similarly to the Bunch of Grapes, the Dorsale honours the Rhineland's specific network for serving as the foundation for its prosperity, reflecting the importance of urban networks in general. It could be argued that Brunet would have advocated polycentric development, much like Kunzmann and Wegener, had he sought to issue continent-wide policy recommendations (Faludi, 2015).

The Blue Banana has become a central component of Europe’s economic core and has even generated its own ‘banana speech acts'. These acts, introduced by Michael M. Loriaux (2008) in his study of Rhineland, are said to produce geographical divides that will eventually become borders, ultimately creating new axes of prosperity. Using Loriaux’s argument, Faludi (2015) examined the theoretical underpinnings of geometrical forms used to categorise European geography. Indeed, Taylor and Hoyler (2000) developed a typology based on a main components analysis of the locations of 46 global Advanced Producer Services (APS) firms, identifying 53 European cities. This typology, structured around similarities in service firm presence, outlined a particular spatial order with three components measuring outer regions: a "Far East" (the former Soviet bloc), a "Far West" (the British Isles), and a triangular grouping of north, south-east, and south-west. Two separate components distinguish between major and minor “spine” cities. This spatial logic aligns with earlier representations of European urban distribution, though Taylor and Hoyler’s methodology added theoretical rigor through multivariate analysis. Further evidence (Amin & Thrift, 1995; Heidenreich, 1998; Puga, 2002) identifies a central European core characterised by a substantially higher GDP per capita and lower unemployment compared to peripheral areas. For example, East Flanders (Belgium) and Zeeland (The Netherlands) exemplify this dynamic. Particularly, Puga (2002) affirms that it is scarcely surprising that, at equilibrium, the centre has a bigger manufacturing sector than the periphery. The intriguing discovery is that the core's industry share is higher than the endowment shares for limited positive trade costs. As a result, the core is a net exporter of manufactured goods. We refer to this as the 'home market' or 'market access' effect. Moreover, the industry proportion of each location varies non-monotonically with trade costs. The concept is best understood by picturing a scenario where trade costs between the two locations are gradually reduced from prohibitively expensive to zero. Due to high trade expended, businesses sell mostly, but not exclusively, in their local market due to high trade expenses. If one region were to have a lot more businesses relative to its market size than the other, the increased competitiveness or crowdedness of that market would lead to the closure of some local businesses, thereby lessening disparities in industry sizes. Because of this, the proportion of industry to endowments in each region is nearly equal. While economic integration mitigates the impact of more local competitors on each firm's market share by increasing each company's sales share in the other region. However, rising returns suggest that companies manufacturing in the core generate higher profits due to increased sales. The scale of the industry in the core surpasses its proportion of global endowments if further businesses enter in reaction to those profits. Consequently, the asymmetry and disparities among various territories, particularly in access to significant waterways within political unions, necessitate increased resilience in resource and security management. The direction of economic activity is influenced by the growth of powerful economies, leading to disparities in trade routes and patterns. Such factors deepen existing inequalities and pose stability challenges. Historically, some regions acted as buffers against geopolitical shocks from neighbouring areas.

However, the evolving conceptualization of the Blue Banana attracted criticism. It was viewed by some as promoting competition among EU Member States rather than genuine European collaboration, rendering it inappropriate for the European integration process (Kunzmann & Wegener, 1991). Furthermore, broader economic transformations, including the rise of capitalism and other variables like the social and cultural assimilation to Western globalization, or the adaptation of re-distributive measures to tackle poverty and unemployment, can ultimately result in escalating inequalities in post-communist nations.

2.2 Eastern Bloc and Mediterranean Macro-Regions: Challenges and Transformations

As noted by Netrdová and Nosek (2016), the historical border of the Eastern Bloc has exerted a lasting impact, delaying changes in spatial economic patterns. As a result, since 1989, Central and Eastern Europe have experienced persistent disparities in income and wages. Even if gender gaps have narrowed, inequalities related to age, education, geography and health persist. Umiński and Nazarczuk (2021) observed that globalization has further exacerbated pre-existing disparities, exposing significant gaps in competitiveness within EU regions. Indeed, the most competitive regions host the most vibrant and productive businesses, gaining the most from operating in an open economy. EU membership has brought tangible advantages to several Eastern European countries, including financial support, access to the Single Market, infrastructure development, and trade expansion. It has also encouraged economic reforms that have raised national standards. Cities like Tallinn and Bucharest have emerged as hubs of technological innovation and entrepreneurship, particularly due to the numerous start-ups and companies headquartered there.

Capasso and Ferragina (2019) noted that the Mediterranean has historically served as a buffer zone, absorbing geopolitical shocks for the wider European system. However, instability in neighbouring regions in Africa and the Middle East increasingly challenges this buffering role, threatening both affluent Northern and less prosperous Southern shores, underlining the region's complexity.

Environmental constraints, socioeconomic disparities, and institutional inadequacies exacerbate these pressures, fuelling political weakness and migration pressures. In response to this, the 1995 Barcelona Declaration launched the Euro-Mediterranean Partnership (Euro-Med), promoting dialogue, cooperation and shared prosperity. The Barcelona Process's agenda was built around several shared values, including the promotion of democracy, good governance, human rights and the achievement of mutually beneficial trading conditions for the partners in the region. In contrast, Sarkozy's proposal for a Mediterranean Union sought to deepen regional integration, but encountered resistance from the European Commission, leading to adjustments. Sarkozy had argued that the Mediterranean Union should be modeled after the European Union, featuring a shared judicial space and a common institutional framework. As a compromise, the Union for the Mediterranean was envisioned as a new phase of the Euro-Mediterranean partnership, ultimately accepting and maintaining the acquis communautaire of the Barcelona Process. The proposal was met with resistance from the European Commission, which believed that regional cooperation should adhere to existing EU structures. Concerns were also raised regarding the use of EU funds for a project involving only some member states, potentially undermining unity. Consequently, adjustments were made to include all EU members and integrate the initiative into the Barcelona Process. This shift led to the abandonment of plans for shared institutions and a Mediterranean Investment Authority resembling the European Investment Bank. Moreover, the Mediterranean region is particularly susceptible to climate change, which threatens both gradual environmental degradation and sudden catastrophes. Accordingly, environmentally driven migration is expected to rise, placing additional pressure on Europe's socio-economy.

The four cooperation chapters developed under the Barcelona Process - Political and Security, Economy and Trade, Socio-cultural, and Justice and Home Affairs - remain relevant. Supplementary programs have also been introduced, addressing issues like marine pollution, maritime governance and alternative energy. Currently, the progress of this project appears to be halted by various issues: conflict in North Africa, the ongoing Arab-Israeli conflict, political fragmentation among Mediterranean countries, and opposition from certain member states.

3. A Spatial Research: Understanding the Gravity Model and Moran's I

Spatial research, particularly the study of spatial concentration, examines the tendency of human activities and populations to aggregate within specific geographic areas. Such clustering, observed across both urban and rural contexts, has profound implications for various aspects of societal organization, from economic development to environmental sustainability. Before delving into Stewart's and Moran's empirical findings, it is important to mention additional relevant perspectives and methodological approaches that enrich our understanding of spatial concentration.

Rey and Smith (2013) study provides a comprehensive examination of spatial concentration, focusing on the interplay between demographic energy and spatial patterns. Through their analysis, they reveal how factors, such as population density and economic activity, contribute to the spatial distribution of resources and people. Their research underscores the role of agglomeration economies in urban development and highlights the significance of understanding spatial concentration dynamics for effective urban planning and policymaking.

In a complementary contribution, Panzera and Postiglione (2020) emphasize the importance of accounting for spatial heterogeneity and scale effects when analyzing concentration patterns and employing techniques, such as spatial autocorrelation and cluster analysis.

Consequently, it is important to contextualize the present analysis within the broader framework of demographic gravity, as originally proposed by physicist John Stewart in 1941.

Stewart's (1941) groundbreaking work applied physical laws to social sciences, demonstrating that demographic events can be effectively captured using gravitational principles. He discovered that large population centers – for instance major cities - act as attractors, drawing individuals towards them. The concept, known as "demographic gravity", is encapsulated in the formula:

$$F_{ij} = k\left(\frac{PiPj}{D_{ij}^2}\right) \qquad (1)$$

where F is the interaction force between the demographic centres i and j, k is a constant, Pj is the population of area j and D is the distance between i and j.

This formula illustrates how the force of interaction between two regions is influenced by the size of their populations and is inversely proportional to the square of the distance between them.

In order to obtain a more refined estimate of the interaction force F, Stewart suggested using different population estimates for each country, accounting for the "molecular weight" of each group's members (1948, p. 34). The rationale is that this conceptual "molecular weight" would naturally vary across different demographic groups. Such differences could meaningfully influence calculations when computing the demographic gravity, and as such, it should be incorporated into the model. The author suggested the measurements for the sake of simplicity by resorting to using the molecular mass of the average American as a unit, bearing in mind that this would carry significantly more mass than one of an Australian Aboriginal, which is in turn expected to be below one. From a methodological standpoint, this refinement involves replacing absolute population counts with weighted ones. By ascribing a differential coefficient based on the origins and development status, it is possible to better capture the attractivity exerted by different economies on neighbouring countries. Therefore, different weights are assigned to population size, multiplied by the number of inhabitants and then standardized: a value of 1 is assigned to an American citizen, a value less than 1 for less developed countries, and a value greater than 1 for more developed countries (relative to the United States). The theory evolved significantly with Stewart's (1948) concept of demographic energy and population potential. One way to interpret a location's population potential is as a measure of how proximally people are distributed around it. In his calculations, Stewart took into account that each person's contribution to potential diminishes with increasing distance from the point in question.

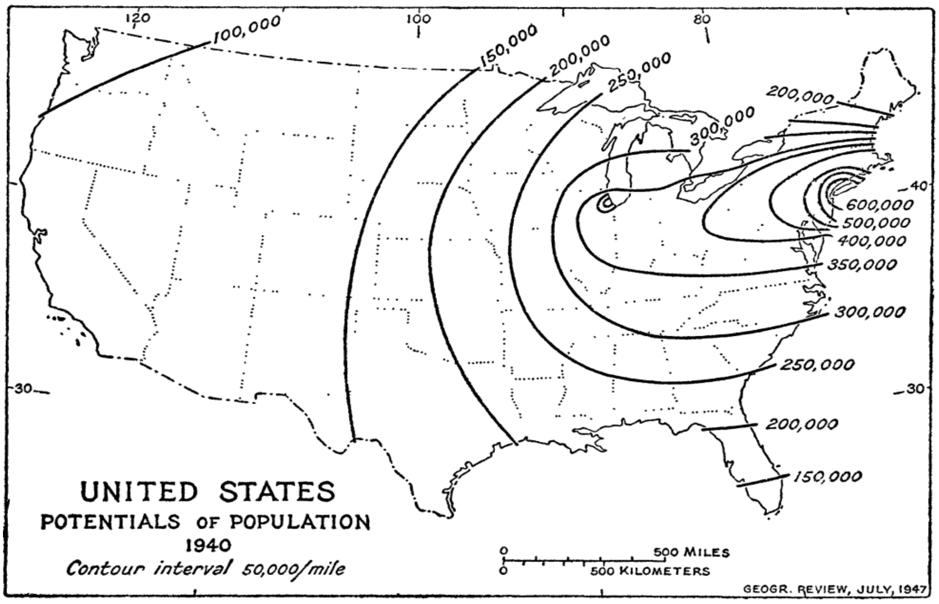
Population density tends to rise progressively, as one moves from rural areas toward a major metropolitan centre. As one approaches the city boundary, the incline gets steeper. In the case of a roughly spherical city, the potential continues to increase toward the centre. However, it is often in the neighbouring rural areas that population potential reaches significantly high values.

Stewart focused on the gravitational field's mutual energy as well as the magnetic field's intensity at a given population center. He proposed that the number of human connections per unit of time may be regarded as demographic energy. While offering broad generalisations, Stewart left room for new hypotheses and prospective developments. The astronomer showed in multiple studies how to apply the results of his calculation to map the surface, using a method called "contours of equipotential".

This framework resembles a 'synoptic weather chart', as shown in Stewart's Figure 2 below. Due to the resulting visual representation, it is safe to claim that the equipotential outline resembles a gravitational or magnetic field.

This theoretical structure is visually summarized in Stewart's original map, which illustrates the equipotential curves across the United States population landscape.

Figure 2: "Demographic energy and potential of population"



Source: Stewart, 1948, p.38

Delving into the intricate dynamics of spatial concentration, Moran's spatial statistics and the Gravity Model emerge as indispensable tools for this study. These are distinct spatial analysis techniques, each with specific applications for identifying spatial and regional clusters of high concentration. Moran's I is useful to identify related regions that share high values of a given variable. However, its reliance on spatial contiguity makes it sensitive to the shape and configuration of the regions considered. On the other hand, the Gravity Model mitigates this limitation by incorporating potential values, which are not constrained by regional geometry. This approach allows a more flexible analysis of spatial flows and regional interactions. Nonetheless, it should be emphasized that the Gravity Model performs best when using absolute values of potential, while it is less effective at handling relative or proportional values, limiting its applicability in specific contexts. Together, these methods offer complementary perspectives, making them indispensable tools for spatial analysis when chosen based on the specific research objectives.

By employing these different spatial analysis techniques, we can construct both a comprehensive descriptive analysis for the year analyzed and a sophisticated, innovative lens for examining the complex interplay of factors shaping spatial concentration phenomena. In the pursuit of economic understanding and regional development, their integration unveils critical insights into the drivers of spatial agglomeration and its implications for broader economic dynamics. At its core, the Gravity Model posits that the interaction between two entities is directly proportional to their economic sizes (measured by GDP, population, or other relevant factors) and inversely proportional to the distance separating them.

It is important to mention, in this context, LeSage and Pace (2008), who proposed a new method based on "spatial weight structures that model dependence among the N Origin-Destination pairs in a fashion consistent with standard spatial autoregressive models" (LeSage, J.P., & Pace, R.K., 2008). Therefore, a "spatial econometric interaction model" is presented in order to directly capture spatial dependence in Origin-Destination flows (Dargel& Thomas-Agnan, 2023).

Stewart's model served as the direct inspiration for the economic model, which replicates its logic and dynamics but replaces a flow of people with a flow of commerce. The application to international trade was popularized by Tinbergen's (1962) standard bilateral form, which was directly related to Newton's Law of Universal Gravitation. Tinbergen was a professor of regional sciences at MIT University in the United States and his works were then revisited by numerous economists. Having borrowed the gravitational field equation from physics, Tinbergen constructed a theory to examine global trade, posting that commerce is favoured by geographic proximity in the form of reduced transaction costs: lower travel expenses, regional and cultural closeness, institutional resemblance and so on. Commerce between states is positively correlated with each state's economic size, as it is determined by its Gross Domestic Product (GDP) or Gross National Product (GNP). To calculate the equation in international economics, we report Isard's (1954, p.308) formula below:

$$iV = \sum_{j=1}^{n} \left(k \frac{Y_j}{d_{ij}^a} \right) \quad (2)$$

In the formula, iV is the income potential produced by all countries upon state i, iVj is the income potential produced by state j upon state i, Yj is the income of state or region j, $\boldsymbol{d_i}$ is the average effective distance between states i and j, $\boldsymbol{k}$ is a constant comparable to the gravitational constant, and $\boldsymbol{a}$ is an exponent determined by observation, which is lower than the squared exponent by Stewart. Despite the potential simplicity of this operation, taking into account single areas of multiple different countries is beneficial. Any researcher approaching international economics should be aware that, in a world as globalized and interconnected as ours, excluding other countries could represent an oversimplification of the scheme, regardless of the actual distance. It is also useful to acknowledge that based on an economist's interests, which can range from general to specific, a market can also be subdivided into various markets. While the global market is generally considered as a unified space, from a purely methodological standpoint, it is still possible to isolate and analyze certain geoeconomic areas, an approach particularly valuable in assessing econophysics models.

For the sake of this analysis, which is focused on the Blue Banana area, it is therefore appropriate to restrict the field of inquiry to the European regional markets. According to Capoani *et al.* (2023), the gravitational force between states is assessed by summing the "point mass" inputs that make up the bodies. Similarly, when different masses are held apart, the vector integration of the component fields yields the gravity field. Analogously, to how a change in mass, even at the peripheral, influences the gravitational field of the entire universe in physics, a variation in the market's commercial forces can influence the forces driving international trade. As economies grow increasingly interrelated, the dynamics of global trade will change consequently. The work of Isard (1954:308) and Carey (1858:42), who considered individuals as molecules within society, highlights the link between physics and social sciences. The advantage of considering gravitational forces in economics offers a precise answer to these issues. Thanks to the idea of superposition, composition, and decomposition of vector forces, it is possible to apply the same principles of trade attraction to both broad international markets and smaller regional economies. Even though the Eurozone is geographically compact, a single currency further reduces economic distance by simplifying transactions. Indeed, an insightful notion in econophysics is derived from the concept of “gravity barycenter”. In physics, it is the centre of mass where multiple objects gravitate around. Striking an analogy with physics, from an economic standpoint, it can be also individuated as a gravity barycentre, which is usually located closer to the more massive economy. Under this perspective, any market can be said to be functioning around a given centre of gravity: the barycentre where its primary trade routes intersect that emerges due to the convergence of multiple forces of attraction. Unlikely in physics, it is more useful in economics to understand the gravity barycentre as a more or less extensive economic area qualified by the interplay of strong economic forces that shape the market and influence all other regions, rather than as a mere single point in space.

Additional theoretical support for the idea of a commercial barycentre comes from the works of Pownall (1764), Pirenne (1936), Braudel (1949) and Persson (2010). Throughout history, numerous examples of economic gravity centers can be found in urbanized and industrialized regions. A few examples in this regard are the Mediterranean region (notably Italy during the Roman era); the urban quadrilateral of Venice, Milan, Genoa, and Florence during the 16th century; the region of Europe known as ‘the Blue-Banana’; or the most recent Northeast Megalopolis (also BosWos) in the USA. Grether and Mathys (2009) focused on big metropolitan regions to estimate an approximate global economic center of gravity.

Both Brinkhoff (2009) and Quah (2011) have provided information on global metropolitan areas. Quah observed a shift in the gravitational centre of the global economy, which typically corresponds to the concentration of global GDP. According to Balsa Barreiro et al. (2019), the center of gravity has shifted over the centuries up to today. However, in their study, they extended the analysis beyond GDP, also considering three additional variables - urban agglomerations, the general population, and CO_2 emissions - to capture broader factors influencing the global landscape.

The Swedish economist Torsten Persson (1954) employed the Gravity Model to conduct a historical and economic analysis of Europe. Through his inquiry, he predicted a shift in the balance of power on the global stage from Europe to the Atlantic Area. The rationale for this geopolitical transition was explained through a strong connection between property ownership and economic power, a relationship that can be illustrated through the gravity model. Persson’s results not only demonstrate the flexibility of the econophysics conceptual framework, but also the surprising accuracy of a model grounded in intuitions as fundamental as those of Newtonian Physics. Using gravitational forces of attraction as an analogy, Persson explains how larger economies tend to generate greater international trade flows - the “pulling force” - with geographically closer economies. As distance from the gravitational center increases, the intensity of the pulling force diminishes. It is important to remark, however, that in the long run, international trade itself tends to close the gap between neighbouring economies by lowering the perceived distance: through the spread of common languages, commercial laws, culture, preferences, and technology promoted by stable trade relations, the transaction costs are lowered even when physical distances remain unchanged. An earlier inquiry into similar phenomena was conducted in the context of the British Empire in the 18th century by Pownall (see Cazzola, 2018, pp. 178-201).

Moreover, Persson explicitly addressed the impact of economic distances and the centrality of trade in the European Union’s integration process. He claimed that nations or unions, like the EU, can deliberately trigger border effects through *ad-hoc* economic policies or via the adoption of common currencies, thereby reshaping trade flows. Persson is referring to the phenomenon of ‘economic regionalism’: the creation of economic or political agreements among geographically proximate nations. Such interactions, common in international economics, enhance efficiency and productivity through economies of scale, cooperation and mutual interdependence. The most relevant types of economic regionalism are Preferential Trade Agreements (PTAs), where countries reduce tariffs among themselves but not for the rest of the world. Under World Trade Organization (WTO) rules, such discriminatory practices are generally not allowed due to the Most Favored Nation (MFN) principle, which mandates equal treatment among trading partners. However, exceptions exist, notably in the case of Custom Unions (like the EU) and Free Trade Areas (FTAs), where internal tariffs are abolished. It is important to acknowledge that, when inquiring about the overall impact on national welfare, PTAs are "two-faced" (Bhagwati & Panagariya, 1996), since they increase welfare by creating trade (e.g. when high-cost domestic production is replaced by low-cost imports from other members) but might decrease welfare when trade is diverted (e.g. when low-cost imports from non-members are diverted to high-cost imports from member nations).

In 1991, Krugman began investigating the effects of economies of scale, firm clustering, technical development and the digitization of inventions, thereby opening a new field of international economics called New Economic Geography (NEG). Crucially, this new theoretical framework emphasized the spatial dimension as a critical factor in analysing economic activities. It was not merely the interactions between economic agents that were of interest, but more so how geographical proximity influenced the mechanisms and outcomes of those interactions. The goal of this theory was to explain how the economic and geographic distances existing in international trade, impact the concentration/dispersion of economic activity in different countries. The resulting economic model, therefore, heavily relies on econophysics, more specifically on the same notion of economic barycenter discussed above. As reported by Liang and Plakias (2022), Krugman's original work presented a model of endogenous industry location, explaining how, under realistic assumptions, the spatial distribution of economic activity would naturally evolve into a core and a periphery structure. The process described in the model would subsequently be labeled as 'agglomeration', i.e., clusters of economic agents reaping benefits of working in proximity. Krugman, thus provides a wide conception of trade equilibrium that takes into account issues such as location, spatial dimension and factor mobility. Since distance and trade costs in international economics have mostly been investigated using the gravity equation, it is unsurprising that empirical research connected to Krugman's theory of "New Economic Geography" has extensively employed data-driven approaches and gravitational models. Given their shared foundations in econophysics, it is unsurprising that Persson's Gravity Model and Krugman's New Economic Geography have influenced one another. The gravitational model has attempted for a long time to place space at the centre of the economy. Krugman, referencing Isard's early use of gravity models to measure regional "magnetic fields," emphasized two competing forces: centrifugal forces, which push firms toward broader markets, and centripetal forces, which encourage agglomeration due to economies of scale and specialization. As firms and workers gravitate toward more prosperous regions, production becomes increasingly concentrated. According to research on distances and transportation costs suggests that the "home market effect"-the tendency for firms to locate production near the largest market for their goods- is the tendency for firms to locate production near the largest market of their goods.

A few years after the initial applications of the Universal Gravitation Law in social sciences, Tobler (1970), a Geography professor at the University of Michigan, proposed a fundamental principle for spatial science, which bore a striking resemblance to Newton's law and was termed as 'the first law of geography'. Tobler drew inspiration from gravity models in an attempt to develop a comprehensive spatial law that would encompass both spatial interaction phenomena, such as those described by gravitational models, but also more static spatial phenomena.

There is a profound connection between the Gravity Model and Moran's I statistics, exemplified by Tobler's First Law of Geography: "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970, p. 236). This specific law is particularly relevant in econophysics, as it narrows the research scope by implying the presence of a distance decay function, which exists on top of the interdependence influencing the trajectories of all elements in a given economic system. Tobler's law thus implies that, even if in a global economy all elements are mutually influenced, the intensity of how market agents become exposed to this influence gradually diminishes as spatial distance increases. Therefore, there exists a "threshold distance" beyond which the influence between market agents diminishes to a non-detectable, and thus negligible, level.

The relationship between the Gravity Model and Moran’s I (Formula 3) can be further clarified by observing their complementarity. Indeed, the gravity model is particularly effective when dealing with absolute measures, such as GDP or population, whereas the global Moran’s I is more suitable to quantify the spatial concentration of relative measures, such as regional GDP per capita or other ratios. While the global Moran's I analyzes the degree to which similar values cluster spatially, it does not provide insights into the underlying causes of such clustering. Due to this methodological limitation, to test whether the spatial concentration is a result of spatial autocorrelation, researchers must employ additional methods - such as spatial regression analysis. Spatial regression can help uncover the relationships between variables and assess the impact of spatial factors on observed patterns. Unlike one-dimensional autocorrelation, Moran’s I captures correlation among nearby locations in a multidimensional and multidirectional spatial framework, thereby adding complexity to the analysis. The value of ***I*** (Formula 3) relies on the assumptions embedded in the spatial weights matrix, denoted as w_{ij}. This matrix is essential, as it helps to manage spatial autocorrelation and to model spatial interactions by outlining the neighboring locations to be included. Moran’s approach is closely related to the above-mentioned Tobler's first law of geography, as it implies a proximity factor. It is to be noted that Moran’s index is generally calculated excluding the islands, as contiguity is crucial in this analysis. Islands are often unique regions and are therefore excluded because they lack adjacent regions. For geoeconomic inquiries that do need to account for islands, it is best for a researcher to resort to gravity maps as well. Global Moran’s I is designed as

$$I = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i -)(x_j - \underline{\bar{x}})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (3)$$

Where N is the number of spatial units indexed by i and j is the variable of interest; $\underline{x}$ is the mean of x; w_{ij} are the elements of a matrix of spatial weights with zeroes in their diagonal (i.e.,w_{ij} = 0); and W is the sum of all w_{ij} .

The mathematical formulation of Moran's I estimate is provided above. This statistic captures both the mean and the variance of the factor under investigation. To compute it, the deviation of each feature value from the mean is first determined by deducting the average from each feature value. The deviation values of all neighboring features (e.g. those that fall within the specified distance range) are multiplied to create a cross-product. It is important to note that the numerator of the Moran's I consists of the sum of these cross-products. If the values for the adjacent elements are both greater or lower than the mean, then the cross-product will be positive. Conversely, if one number is below and the other is above the mean, the cross-product will then be negative.

In any case, the greater the deviation from the mean, the larger the resulting cross-product will be. When the dataset exhibits positive spatial autocorrelation (high values cluster near to other high values; low values cluster close to other low values), the Moran's Index will be positive. If high values are predominantly located near low values, the index will be negative. If the positive and negative cross-products balance out, the index will be close to zero, indicating a random spatial distribution.

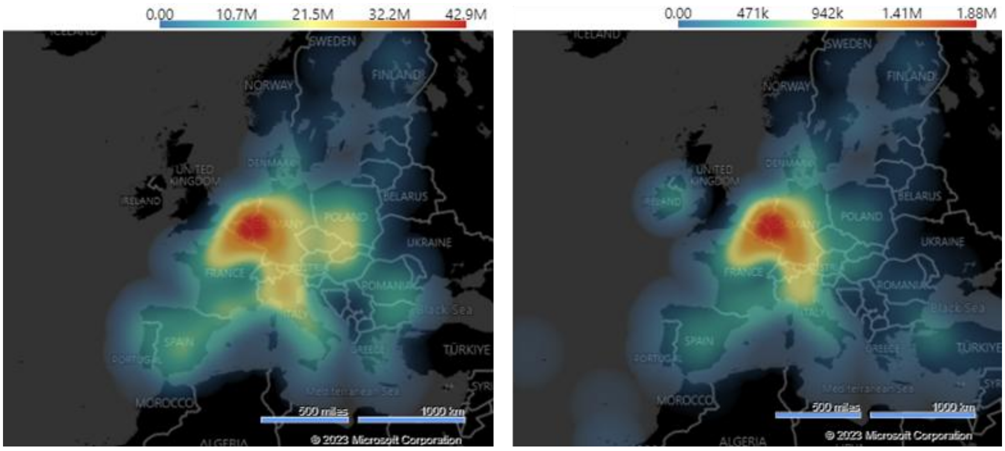
Given that the Spatial Autocorrelation tool is inferential, any findings based on Moran’s I should always be interpreted in light of the null hypothesis. The null hypothesis for the Global Moran's I statistic assumes that the spatial distribution of features in the study region is random with respect to the variable under consideration – that is, any observed pattern is the result of random chance rather than systematic spatial organization.

4. Results and discussion of the spatial analyses

In our investigation, we juxtapose contemporary data with historical studies on the Blue Banana phenomenon. This comparative approach enables us to ascertain its current relevance and persistence in European economic discourse. By examining the dynamic interplay between evolving economic landscapes and geographic concentrations of prosperity, we aim to contribute valuable insights to the discourse of regional development. We analyze key development factors, such as population and GDP, across the European regional landscape to determine whether the Blue Banana still represents the economic backbone of Europe. We apply the Gravity Model to both population distribution and regional GDP (Figure 3). The results show that while these two variables are similarly concentrated, their distribution is not entirely uniform. Specifically, both population and GDP exhibit high concentration in the Blue Banana area, which suggests its continued economic importance.

This spatial concentration is clearly illustrated in Figure 3, which displays the gravitational fields derived from both population (on the left) and GDP data (on the right).

Figure 3: empirical elaboration of the population (on the left) and 2021 GDP (on the right) gravitational field of NUTS 2 areas of the EU27



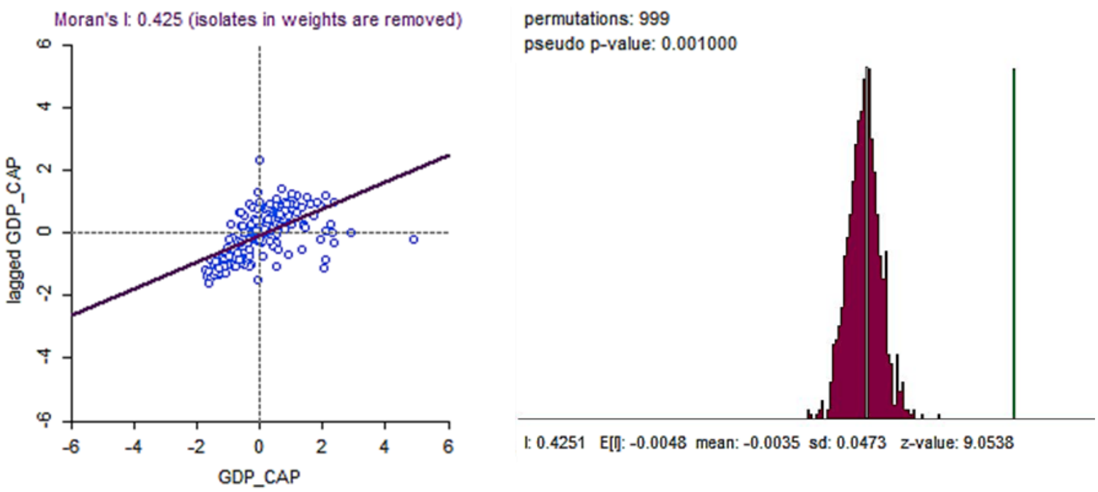
Source: own elaboration

By complementing the Gravity Model with Moran's I statistics, we provide a more sophisticated analysis. As mentioned above, Moran's I statistics is better suited than the Gravity Model for relative measures and ratios, such as GDP per capita. Concerning this variable, the global Moran's I and its permutation test (Figure 4) confirm a statistically significant (42,5%) spatial concentration among the continental EU NUTS 2 regions. Statistically speaking, we have to reject the null hypothesis and accept the alternative, that spatial distribution is uneven, confirming the existence of significant spatial concentration.

By integrating these analytical approaches, our study not only confirms the persistent dominance of the Blue Banana as a pivotal economic force in Europe but also underscores the imperative for policymakers to tailor interventions that both sustain this momentum and foster equitable growth across the wider European landscape. This holistic understanding is essential for crafting nuanced policies that address regional disparities while leveraging the Blue Banana's dynamism to propel overall economic advancement on the continent.

These spatial patterns are further supported by the results shown in Figure 4, which illustrates the global Moran's I statistic alongside its permutation test.

Figure 4: Global Moran's I statistics (on the right) and its permutation test (on the left) for NUTS2 regional GDP per capita in 2020 in the continental EU



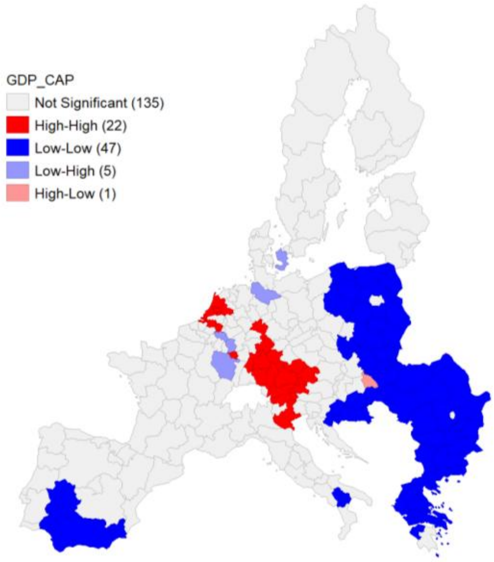
Source: own elaboration

The local Moran's I (Figure 5) shows that the concentration of NUTS 2 regions with high GDP per capita partially overlaps with the Blue Banana area. Conversely, most Eastern

European and some Mediterranean NUTS 2 regions exhibit a concentration of low GDP per capita. As anticipated in the first section, capital regions are usually understood as exceptional cases. For instance, consider an Eastern European case: in Central Hungary (that is Budapest and its surrounding county), the capital region has a significantly higher value of GDP per capita than the neighbouring regions, a value that is also higher value than the EU average.

These spatial patterns of GDP per capita are depicted in Figure 5, which shows the local Moran's I results across NUTS 2 regions in the continental EU.

Figure 5: Local Moran's I statistics for NUTS2 regional GDP per capita in 2020 in the continental EU



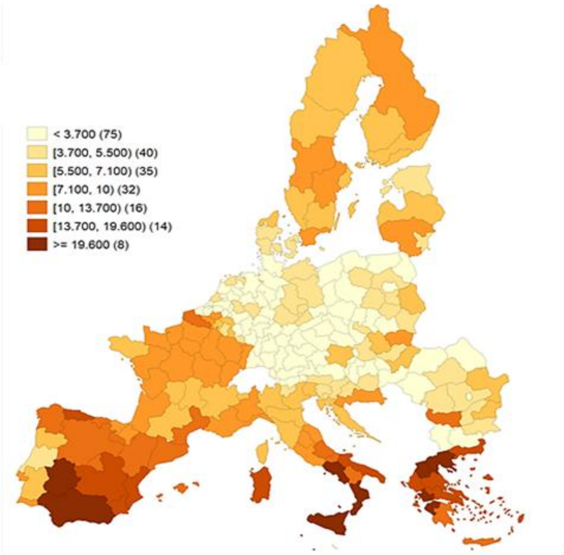
Source: own elaboration

Regional economic output, expressed in GDP per capita, depends on mobile factors (among other variables), such as labor and capital market. Regarding labor, we consider the unemployment rate to provide a broader overview of the European economy and working situation (Figure 6). The year selected is 2019, as it predates the COVID pandemic outbreak and reflects a markedly different labor market context in Europe.

In this regard, most of the Central and Eastern European regions performed better in 2019 than the Western and (especially) Southern European regional average. However, as Capoani et al. (2023) find, this is attributable to high dependence on FDI and, in some CEE regions with low unemployment rates, a prevalence of less productive industrial manufacturing sectors. Conversely, the share of employment in the most value-added high-technology and knowledge-intensive sectors shows a spatially more evenly distributed picture (Figure 7). In this regard, the capital regions generally perform the best.

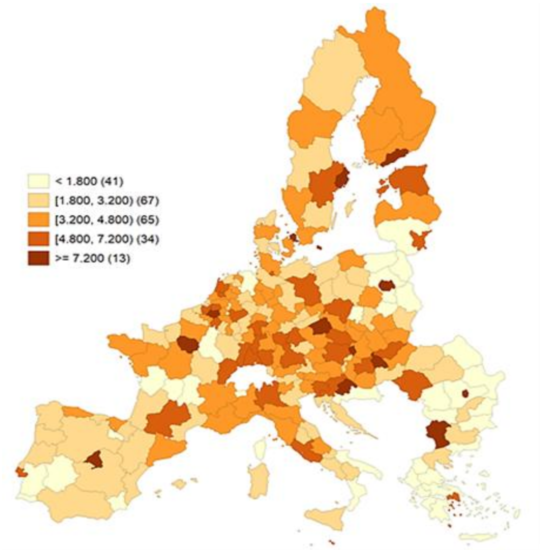
The spatial configuration of unemployment levels across Europe is presented in Figure 6. A complementary overview of employment in high-technology and knowledge-intensive sectors is shown in Figure 7.

Figure 6: Regional unemployment rate in 2019



Source: Eurostat

Figure 7: Employment in high technology and knowledge-intensive sectors in 2019 as a percentage of total employment

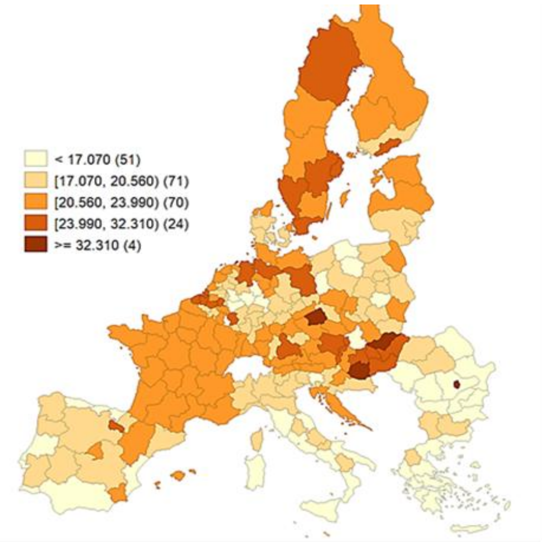


Source: Eurostat

Regarding the capital market Gross Fixed Capital Formation (GFCF) is an adequate proxy to express the capital availability through investments. Again, we refer to 2019 to avoid pandemic-related distortions.

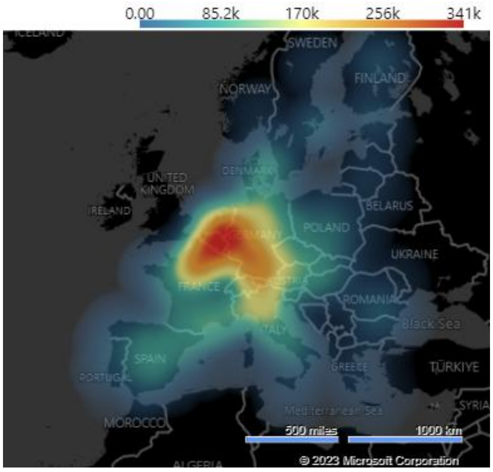
In 2019, regional GFCF as a percentage of regional GDP was the highest in four CEE regions (see Figure 8). Two of them, namely Prague and Bucharest, are the capital regions of the Czech Republic and Romania respectively, while the two others are non-capital regions of Hungary. While noteworthy, it is worth mentioning that regional GDP in these areas remains lower than in most of the Western European regions. Therefore, the higher GFCF share of GDP does not necessarily translate into higher absolute investment levels. The Gravity Model on the (total) regional GFCF supports this assumption (Figure 9), confirming the results that the highest absolute concentration GFCF concentrations remain within the Blue Banana area.

Figure 8: GFCF as a percentage of regional GDP in 2019



Source: Eurostat

Figure 9: Empirical elaboration of the 2019 GFCF gravitational field of NUTS 2 areas of the EU27



Source: Own elaboration

Overall, the results of the Gravity Model, Moran's I statistics, and supporting studies confirm that, in terms of population, GDP, and GDP per capita, most of the Blue Banana area remains a prominent economic territory in Europe. However, as noted in several studies, emerging spatial concentrations are becoming visible, suggesting a reorganization and growth trend towards Northwestern and Central-Eastern Europe (Hospers, 2002; Metaxas & Tsavdaridou, 2013). It is therefore reasonable to anticipate further territorial transformations in the decade ahead.

5. Conclusion

This paper has focused on the concept of the gravitational field (Isard, 1954; Capoani, 2023) and market potential (Harris, 1954) as descriptive tools for spatial analysis. Inspired by physicist Stewart's pioneering application of physical laws to social sciences, the theory of demographic gravity demonstrates the tendency of population centers to behave as magnets, attracting individuals to areas with larger populations. It is worth noting briefly that a larger population does not necessarily guarantee better economic performance. In some cases, as observed in Nordic regions, areas with lower population density outperform others both socially and economically. While population concentration can lead to economies of scale, in the absence of proper coordination, it could also result in coordination diseconomies. However, it is crucial to acknowledge that more developed regions often act as attractors for individuals in a European labour market characterized by high labor mobility. In relation to this phenomenon, the paper also discussed the evolution of Stewart's ideas, including the concept of demographic energy and population potential, as well as how they relate to gravitational and magnetic fields.

Furthermore, the paper investigated the application of the Gravity Model in economics, particularly in explaining interregional dynamics. This economic model, inspired by Stewart's work, used a similar gravitational framework to analyze trade patterns based on GDP and spatial distance. The study emphasized the importance of distance not only as a determinant of trade volumes but also as a contributor to transaction costs.

Moreover, by integrating Moran's I statistics with the Gravity Model, we achieved a more sophisticated understanding of the spatial distribution of economic indicators across European regions. Moran's Index helps identify whether spatial clustering or dispersion of these indicators exists, while the Gravity Model provides a theoretical framework to interpret these spatial patterns, offering insights into Europe's economic geography and assessing the continued significance of the Blue Banana regions.

An overview of the Blue Banana and the adjacent European economic areas was then provided. In particular, the dynamics occurring in the 'Widening Countries' were mentioned, along with the consequences of radical market transitions in post-communist countries. Our spatial analyses confirmed that the Blue Banana regions continue to outperform most other EU regions in terms of conventional development measures. Furthermore, empirical research could delve into the dynamics of territorial changes over recent decades and explore patterns of spatial concentrations using broader socioeconomic and well-being measures.

In summary, this paper shed light on the significance of demographic gravity in understanding population movements and its application to economic trade flows. It underscored the interplay between physics and the social sciences, illustrating how economic models have been inspired by gravitational principles. As globalization deepens and economies become increasingly interconnected, the study of demographic gravity and its implications remains highly relevant for understanding human behavior and international trade patterns.

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