

Hernández de Rojas, Félix; Pita, Pilar Rodríguez; Pérez Martínez, Jorge Emiliano

Conference Paper

The phenomena of contagion of digitalization inside European Regions

24th Biennial Conference of the International Telecommunications Society (ITS): "New bottles for new wine: digital transformation demands new policies and strategies", Seoul, Korea, 23-26 June, 2024

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Hernández de Rojas, Félix; Pita, Pilar Rodríguez; Pérez Martínez, Jorge Emiliano (2024) : The phenomena of contagion of digitalization inside European Regions, 24th Biennial Conference of the International Telecommunications Society (ITS): "New bottles for new wine: digital transformation demands new policies and strategies", Seoul, Korea, 23-26 June, 2024, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/302495>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

The phenomena of contagion of digitalization inside European Regions

Author information

Félix Hernández de Rojas

Escuela Técnica Superior de Ingenieros de Telecomunicación

Universidad Politécnica de Madrid. Spain.

felix.hderojas@alumnos.upm.es

fhderojas@gmail.com

felix.hernandezderojas@telefonica.com

Corresponding author

0000-0001-8305-9734

Pilar Rodríguez Pita

Escuela Técnica Superior de Ingenieros de Telecomunicación

Universidad Politécnica de Madrid. Spain.

pilar.rodriguez.pita@alumnos.upm.es

Jorge Emiliano Pérez Martínez

Escuela Técnica Superior de Ingenieros de Telecomunicación

Universidad Politécnica de Madrid. Spain.

jorge.perez.martinez@upm.es

0000-0002-7036-3515

Highlights

The components of diffusion of digitalization in households and individuals for the use of banking services, relationship with the administration and online commerce exhibit strong signs of contagion at the regional or national level, being driven fundamentally by components of sophistication in the digital skills of the population.

The digitalization variables associated with the deployment of broadband and internet access have seen their diffusion reduced as a result of a strong convergence between regions.

Regional or national institutional quality has a strong relationship with the digitalization variables of online banking, e-administration and e-commerce, all variables showing a high level of contagion.

Abstract

Lately, we have seen a growing concern for competitiveness, strategic autonomy, and the rising of digital divide in the European Digital Single Market. To tackle these issues, in 2023 the EU¹ set forth the Digital Decade program that “empowers businesses and people in a human-centred, sustainable and more prosperous digital future”², with the aim of attracting investment and creating an innovative and digital ecosystem “made in Europe”. However, Europe faces a set of barriers that arise from the cultural, linguistic, and societal differences that exist between the Member States and that do not exist in other largely populated countries in Asia or America.

Throughout our research, we have clustered the 240 NUTS2 regions of the EU by their digitalisation, based on the Digital Economy and Society Index, and their competitiveness, based on the EU Regional Competitiveness Index, and their respective variables. we have made use of the Moran’s I and Geary’s C that allows us to determine the degree of clustering of EU regions and giving us a hint on which regions are more susceptible to “digital contagion”, and which regions are most likely of be left behind because of lack of this phenomena.

Our research identifies the above aspects and analyzes them within the heterogeneity of digitalization situations in the regions, identifying those where this "digital contagion" or “spatial spillover” works satisfactorily and where it does not, as well as considering whether national or EU policies are relevant to this end.

Keywords

Digital Contagion; Spatial Autocorrelation; NUTS2; European Union; Competitivity

¹ Throughout the article we use EU, Europe, and European Union as synonymous concepts.

² [Europe’s Digital Decade: digital targets for 2030](#)

1. Introduction

Lately, we have seen a growing concern on the competitiveness, the strategic autonomy, and the widening digital divide in the European Digital Single Market. To address these issues, in 2023 the EU established the Digital Decade programme that "empowers businesses and people in a more prosperous, sustainable and people-centred digital future", aiming to attract investment and create an innovative and digital ecosystem "made in Europe". However, Europe faces several barriers arising from the cultural, linguistic, and social differences between Member States that do not appear in other densely populated countries, such as those in Asia or the Americas.

The diffusion of innovation and digitalization are generally seen as key factors for productivity and economic improvement. However, despite the rise of digital technologies, improving productivity remains an issue in the EU, giving way to a "productivity paradox": limiting adoption in a wider range of companies, sectors, or regions that fail to disseminate such mechanisms and face difficulties in deploying their local innovation and thus sustaining a skilled workforce.

A digital transition governed by the values of "no one left behind" is likely to strengthen regional divisions across the EU, as those best prepared to deal with digitalization are also those with the highest level of economic progress. High-growth regions that also exhibit high levels of digital readiness (mainly highly urbanized areas and regions with strong industrial and technology-intensive sectors) are likely to be greatly better benefited by the digital transition, creating what is called the "Matthew Effect" that has been suggested by Kovács et al. (2022).

This is also where the concept of "Convergence Clubs" appears, which has been studied for a long time. Cutrini & Mendez (2023) examine the strong spatial dependence of these clubs where it is explained that there is no single path: "Countries might not converge to a unique long-run steady state but rather form multiple convergence clubs even if the countries have access to similar technologies". They attribute this to the strong dynamism of the more urban areas, which would act as poles of attraction for the industrialized, rural, and more peripheral areas.

In the EU, there is a great deal of interest in the study of cohesive versus divided regions and a search for a confluence between all of them, although each region would try to develop its own economic and industrial specialization (European Committee of the Regions, Bisogni, F., Renwick, R., Fontana, 2023). According to Barbero et al., 2024, by studying diversification for economic improvement, all regions of the U.S. could benefit from diversification with the incorporation of new technologies and innovation, although according to the study, the less developed would be the most benefited.

In Europe, on the other hand, Caravella et al., 2023 find the importance of "digital skills" as a source of non-convergence in the period 2011-2018: "The diffusion of Digital Skills across EU regions turns out to be characterized by persistence effects leading to divergence and polarization mechanisms.". Lucendo-Monedero et al. (2019) studies the concept of "digital divides" at the regional level in terms of broadband access and finds a certain spatial correlation in northwest and southeast spatial terms. Additionally, de Clercq et al., 2023 reinforce broadband access as a critical factor of the "digital divide" between urban and rural regions, while others show how "digital literacy and infrastructure (internet speed)" are necessary for most of the most backward regions of Europe to catch up with the most advanced ones (Rehman & Nunziante, 2023).

While most of the current effort is focused on measuring the digitalization or innovation of companies, countries, or regions, it is also important to consider the so-called "spatial spillovers" between them, i.e., analyzing how a change in one location will potentially affect outcomes in other nearby locations.

There is a lot of literature that argues the role played by geographical spaces. Studies conducted in Japan (Nishida et al., 2014) or the United States (Grubestic, 2010; Pick et al., 2015; Sarkar et al., 2023) and in general in large regions have already demonstrated the importance of geographical space, since the so-called Tobler's first law in geography would apply, which says "everything is related to everything else, but near things are more related than distant things", perhaps challenging other approaches that do not rely on the importance of distance (Cairncross, 2001).

Also, interesting samples of these geographic impacts could be found in large countries such as China. Li et al. (2023) delve into "the direct impact and spatial spillover effect of the digital economy on the efficiency of industrial green innovation"; Wang et al., (2022), study the contribution of digitalization to emissions reductions is measured by studying these "space spillovers" in 248 prefectures; and Tao et al. (2024), explore the effects of digitalization for "income rural residents in both the home province and neighboring provinces".

Considering the above, we present our research questions that will be divided into two blocks:

1. To what extent are digitalization processes homogeneous across adjacent regions of the EU? Are there positive or negative spillovers between these regions? How might this affect cohesion between regions?

To answer this question, we will use as base existing research on this topic, such as that of Piribauer et al. (2023) who, having carried out their study on European regions, explain: "Our results show that economic and sectoral characteristics (e.g. sectoral production structure, education, etc.) significantly influence the degree of regional interdependence." and further on states that "accentuated links between regions in Germany, Austria and Poland. However, regional interdependencies seem to be particularly strong between regions in Southern and Eastern Europe."

Another interesting study is that of He (2023) in which he investigates in an interprovincial panel of Chinese provinces the effect of investments in foreign technology companies to incorporate their technology at the local level ("bringing in" and "going out" effect) and how not only is the region's own innovation capacity improved ("recreation" strategy) but also the capabilities of surrounding regions are enhanced. And he attributes this to factors of talent and commerce.

According to Shahnazi (2021), who studies the EU28 from 2007 to 2017, ICT spillovers play an important role in improving productivity and concludes that 1% increase in ICT would increase the productivity of all other countries by 0.421%. In addition, according to the different dimensions of the Digital Economy and Society Index (DESI) 2022, n.d.) considered in its study and used in the EU to measure the progress of digitalization, "digital skill and internet use have the highest direct and indirect on labor productivity, respectively. Overall, the highest spillover effects were related to internet use index, connectivity index, digital skill index, e-commerce index, and e-government index, respectively."

2. What roles do certain technologies (such as connectivity) or other aspects linked to the economy and society and, in general, to the competitiveness of countries and regions play in these contagion processes?

Song et al. (2024) study the digital economy and how it stimulates green innovation in broadband pilot cities in China and find there a positive effect on surrounding cities. It thus proposes to dismantle regional administrative barriers and accelerate a green innovation market system.

Finally, in terms of Innovation and R+D, a somewhat deprecated study from 2007 on Spanish regions, (Cabrer-Borrás & Serrano-Domingo, 2007) already considered proximity factors in regions with components of similarity "socio-political conditions and commercial interdependencies and lower barriers for technological knowledge to flow, have interregional knowledge spillovers promoted

regional innovation" and that public R&D policies would be responsible for achieving this "critical mass of knowledge"

The novelty of our research consists in identifying and analyzing the different aspects highlighted above and incorporating them into the heterogeneity of digitalization situations in European regions, identifying those where this "digital contagion" could work more satisfactorily and where it could not; It also considers whether the quality of national, regional or EU institutions and policies are relevant to this end.

2. Data and Methods

2.1. Data

We have made use of the NUTS2 territorial division defined by Eurostat³ which establishes 240 regions for the 27 European Member States. For each of the regions we have obtained the digitalization indicators that we can find in the Eurostat regional database, and whose description we show below:

Table 1: Digitalization Variable's description

Code	Name	Units	Years
isoc_r_iacc_h	Households with access to the internet at home	% of households	2008-2023
isoc_r_broad_h	Households with broadband access	% of households	2008-2021
isoc_r_iuse_IUSE	Frequency of internet access: once a week (including every day)	% of individuals	2008-2023
isoc_r_iuse_IDAY	Frequency of internet access: daily	% of individuals	2011-2023
isoc_r_iuse_IUSNET	Internet use: participating in social networks (creating user profile, posting messages or other contributions to Facebook, Twitter, etc.)	% of individuals	2013-2023
isoc_r_iuse_IUBK	Internet use: Internet banking	% of individuals	2011-2023
isoc_r_iuse_IUSELL	Internet use: selling goods or services	% of individuals	2011-2023
isoc_r_iuse_IU3	Last internet use: in last 3 months	% of individuals	2011-2023
isoc_r_iuse_ILT12	Last internet use: in the last 12 months	% of individuals	2011-2023
isoc_r_iuse_IUX	Internet use: never	% of individuals	2008-2023
isoc_r_gov_i_IUGOV12	Internet use: interaction with public authorities (last 12 months)	% of individuals	2011-2021
isoc_r_gov_i_IGOV12RT	Internet use: submitting completed forms (last 12 months)	% of individuals	2011-2021
isoc_r_blt12_i_BUY3	Last online purchase: in the last 3 months	% of individuals	2011-2023
isoc_r_blt12_i_B3_12	Last online purchase: between 3 and 12 months ago	% of individuals	2011-2023
isoc_r_blt12_i_BLT1	Last online purchase: in the 12 months	% of individuals	2008-2023
isoc_r_blt12_i BUMT12	Last online purchase: more than a year ago	% of individuals	2011-2023
isoc_r_blt12_i BUMT12X	Last online purchase: more than a year ago or never	% of individuals	2011-2023
isoc_r_blt12_i_BPG_EU	Online purchases (3 months): from sellers from other EU countries	% of individuals	2020-2023

And of which the statistical description can be found in "Annex 1: Statistical Description of data".

It is important to note that for the case of Germany, Poland, and Greece we only have data available at the NUTS1 level, so for these three countries, this territorial division has been used in the study.

³ <https://ec.europa.eu/eurostat/web/nuts/background>

On the other hand, we have used the "Regional Competitiveness Index 2022", developed by the European Commission, to measure the competitiveness of the 240 European regions. It is divided into 11 pillars made up of 68 indicators. A statistical description of the data can also be found in "Annex 1: Statistical Description of data".

To match the regions between digitalization and competitiveness, the regions of Germany, Poland and Greece have been aggregated at NUTS1 level.

2.2. Methods

The goal of the global spatial autocorrelation is to get a single measurement of the randomness of a spatial distribution of values in a map. However, to apply the statistics associated to the autocorrelation, we must define how the different regions relate to their spatial neighbors. To this end, we have made use of a statistical concept known as the Spatial Lag. In essence, *the spatial lag captures the behavior of a variable in the immediate surroundings of each location; in that respect, it is akin to a local smoother of a variable* (Rey et al., n.d.). This concept is expressed in matrix form as: $Y_{sl} = \mathbf{W} \cdot Y$, where \mathbf{W} represents the matrix of spatial weights (the neighbors of a region), and Y represents the value of the variable.

To measure the degree of spatial grouping of the variables, we used the statistical tool "Moran's I" which is expressed as (Moran, 1948)

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i z_i^2}$$

Where n is the number of regions under study; w_{ij} represents the value of row i and column j of the spatial weight matrix \mathbf{W} defined above; and z_i is the standardized value of row i of the variable.

The result of this operation is a real number that indicates the degree of clustering of the regions, if it is positive, it means that there is a tendency of similar values to cluster.

A graphical visualization of this value can be made, representing the "Moran Graph" as the relationship between the value of the variable and the Spatial lag. Moran's index (Moran's I) will be the slope of the regression line of the Moran graph.

Finally, we can calculate the statistical significance (p), for which we perform 999 permutations of the original map, randomly assigning the variable to the regions and observing the number of times we obtain a Moran Index higher than that obtained with the original distribution. We consider Moran's I's to be statistically significant when the p -value is less than 0.001.

Finally, we have calculated other spatial autocorrelation measurement indices to compare the results obtained with Moran's I. In particular, we have used Geary's Index (Geary's C), which is expressed as (Geary, 1954):

$$C = \frac{(n-1)}{2 \sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} (y_i - y_j)^2}{\sum_i (y_i - \bar{y})^2}$$

Where n is the number of regions being studied, w_{ij} ⁴ is the value of row i and column j of the binary matrix of spatial weights \mathbf{W} , and y_i is the i -th value of the variable.

In the case of the Geary Index, the grouping of values will be marked the smaller the value of the Index, keeping the limit of statistical significance at $p < 0.001$.

⁴ $W_{ij} = 1$ if the regions i and j are neighbors otherwise $W_{ij} = 0$

On the other hand, to be able to analyze better the specific success paths of the regions, it is necessary to carry out a local analysis that will indicate for each region, its comparison with respect to its neighbors, moving from the global summary perspective to an extended local perspective. Each region can be grouped into one of the following groups:

- Hot spots: Those regions with high variable values and surrounded by regions with high variable values - (HH)
- Cold spots: Those regions with low variable values and surrounded by regions with low variable values – (LL)
- Diamonds in the rough: Those regions with high variable values and surrounded by regions with low variable values – (HL)
- Doughnuts: Those regions with low variable values and surrounded by regions with high variable values – (LH)

To classify the regions into these four groups, we have made use of Moran Local's I statistical tool, which is expressed as:

$$I_i = \frac{z_i}{m_2} \sum_j w_{ij} z_j; m_2 = \frac{\sum_i z_i^2}{n}$$

Where n is the number of regions, w_{ij} the spatial weight between regions i and j, z_i is the difference between the value of the variable y_i and the mean $z_i = y_i - \bar{y}$, and m_2 is the variance of the data distribution.

2.3. Methodological steps

First, a global analysis of the spatial grouping of the regions under study has been carried out using the two tools developed above: Moran's I and Geary's C.

Secondly, 3 variables with a higher autocorrelation and 3 variables with a lower autocorrelation have been selected and an in-depth analysis has been carried out, repeating the previous statistical analysis for the period 2011-2024 and analyzing the 10-year variation.

Next, a study of the relationship between competitiveness and digitalization variables has been carried out, using Pearson's correlation. Competitiveness variables that correlate more than 0.9 with digitalization have been eliminated from the study, as these are repeated variables between the two.

Finally, the competitiveness variables that are most closely related to the digitalization variables have been selected and the contagion of these variables has been studied and compared to the contagion calculated previously.

3. Results

As indicated in the methodology, the first step of our study is to calculate the global spatial autocorrelation indices for the digitization variables, results shown in Table 2.

Table 2: Global Moran Index and Global Geary Index for digitalization variables, latest year available

VARIABLES	Moran's I*	Geary's C*
isoc_r_iacc_h	0.537	0.448
isoc_r_broad_h	0.534	0.442
isoc_r_iuse_IUSE	0.706	0.281
isoc_r_iuse_IDAY	0.705	0.311
isoc_r_iuse_IUSNET	0.768	0.243
isoc_r_iuse_IUBK	0.888	0.142
isoc_r_iuse_IUSELL	0.723	0.217

isoc_r_iuse_IU3	0.72	0.277
isoc_r_iuse_ILT12	0.684	0.298
isoc_r_iuse_IUX	0.67	0.316
isoc_r_gov_i_IUGOV12	0.833	0.179
isoc_r_gov_i_IGOV12RT	0.791	0.233
isoc_r_blt12_i_BUY3	0.837	0.155
isoc_r_blt12_i_B3_12	0.473	0.49
isoc_r_blt12_i_BLT12	0.81	0.161
isoc_r_blt12_i BUMT12	0.632	0.407
isoc_r_blt12_i BUMT12X	0.791	0.164
isoc_r_blt12_i_BPG_EU	0.705	0.287

* $p < 0.001$

As we can see in the table above, we have four variables that present a contagion greater than 0.8 according to Morán's I, from which we selected the three with the highest contagion, which are:

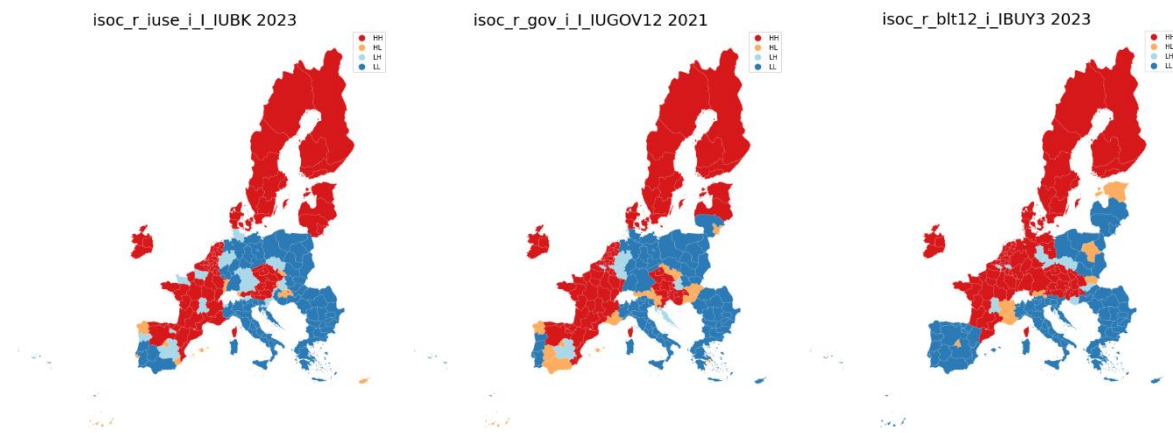
- *Internet use: Internet banking (isoc_r_iuse_IUBK)*
- *Internet use: interaction with public authorities (last 12 months) (isoc_r_gov_i_IUGOV12)*
- *Last online purchase: in the last 3 months (isoc_r_blt12_i_BUY3)*

And three variables that have a contagion of less than 0.6 according to Morán's I:

- *Households with access to the internet at home (isoc_r_iacc_h)*
- *Households with broadband access (isoc_r_broad_h)*
- *Last online purchase: between 3 and 12 months ago (isoc_r_blt12_i_B3_12)⁵*

For these variables, we performed the local Moran analysis, resulting in the following results:

Figure 1: Moran's local index values for digitalization variables with high global contagion.



First, we can observe a concentration of heat spots in northern European areas, particularly in those countries that show very good results in the Digital Economy and Society Index (DESI) (*Digital Economy and Society Index (DESI) 2022*, n.d.): Sweden, Finland, and Denmark; while Eastern European countries such as Poland or Romania have as a general rule been left behind, and present cold spots.

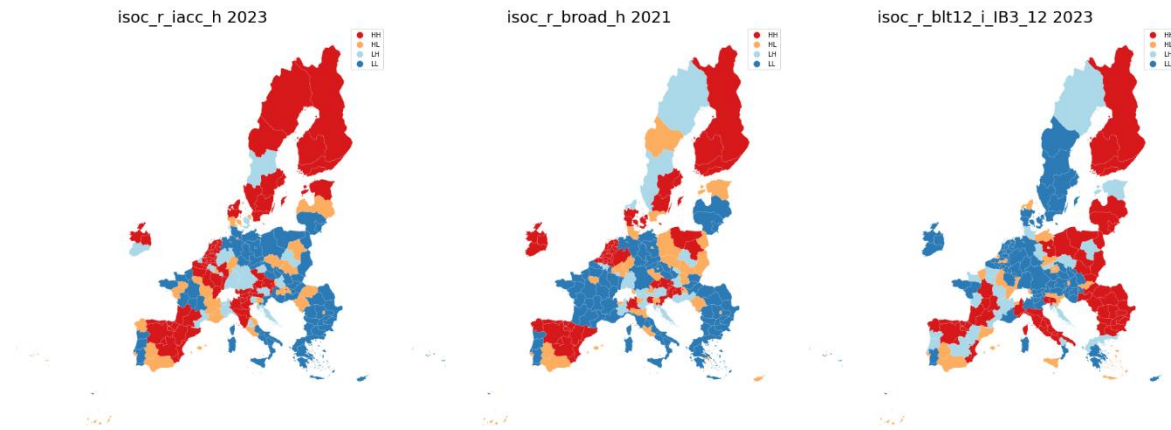
On the other hand, the Mediterranean countries Greece and Italy tend to be cold spots, while Spain presents disparate behaviors, being a cold spot in online purchases and a heat center in e-government

⁵ This indicator is complementary to isoc_r_blt12_i_BUY3. While isoc_r_blt12_i_BUY3 represents the regions with a thriving e-commerce, isoc_r_blt12_i_B3_12 represents regions in which the population does not buy online frequently.

and online banking in its northern regions and with various diamonds due to the influence of its neighbor Portugal.

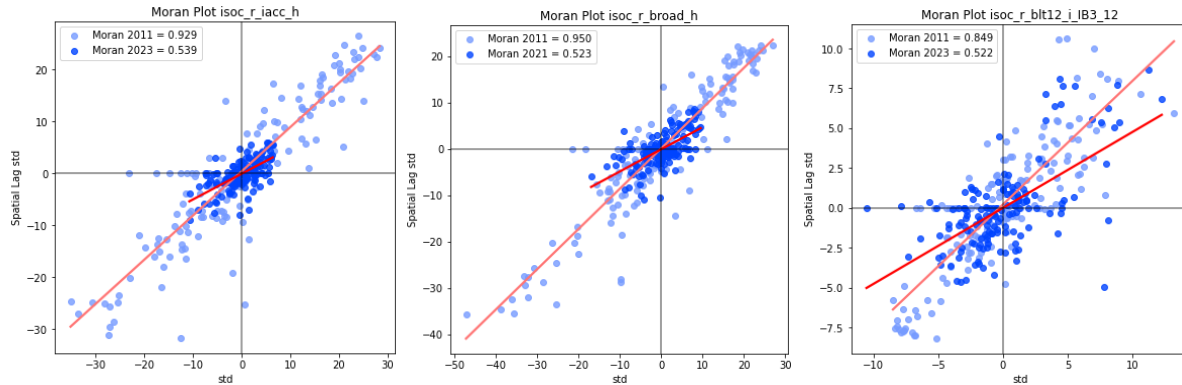
Lastly, in Central Europe we see how France tends to be a heat spot, while Germany is a cold spot in the online banking and e-government variables, and a heat spot in the online shopping variable.

Figure 2: Moran's local index values for digitalization variables with low global contagion.



On the other hand, in the variables characterized by low global contagion, we see how the regions within the countries are very different, with many diamonds and doughnuts appearing. It is necessary to evaluate these variables in more detail, introducing the temporal variable and analyzing its behavior over the period 2011-2023, which we can observe in Figure 3.

Figure 3: Moran's graph 2011-2023 digitalization variables with low contagion



We can see in Morán's first two graphs, those related to digital infrastructures, how we have moved from a highly dispersed graph, with a standard deviation in both the variable and the Spatial Lag between ± 30 to a standard, to a clustered map with a deviation between ± 10 . In addition, we can see a significant drop in the slope of the line, that is, the Morán Index, which in 2011 stood at a value of 0.9 and in 2023 has dropped to 0.5. On the other hand, in the third graph, related to online purchases, we can see how there a grouping process has also been, but much less notable than in the previous cases, since we started from a distribution with a standard deviation of both the variable and the Spatial Lag between ± 10 .

In these cases, we can see the process of saturation of the variables, which in 2011 marked important differences between the regions, but as the European plans for the deployment of infrastructures, digital skills, and generalization of the use of the internet for e-commerce or e-governance have been implemented, there has been a process of convergence between the more advanced regions and those that were lagging behind.

We then proceeded to investigate the relationships between digitalization and the competitiveness of European regions. To do this, we have first computed the Pearson correlation between the digitalization variables and the variables that comprise the competitiveness index (hereinafter RCI). In Table 3 we can see the main results of the correlations⁶, and in "Annex 3: Correlation tables between digitalization variables and RCI variables" we can find the details of the correlations with all the variables.

Table 3: Pearson correlation between digitalization and competitiveness variables

	Corruption	Quality and accountability	Impartiality	Lifelong learning	Employment rate (excluding agriculture)	Enterprises with fixed broadband access.	Individuals with above-basic overall digital skills	Knowledge workers
isoc_r_iacc_h	0.418	0.474	0.479	0.532	0.428	0.458	0.509	0.474
isoc_r_broad_h	0.278	0.411	0.379	0.536	0.323	0.476	0.525	0.290
isoc_r_iuse_i_IUBK	0.673	0.750	0.724	0.713	0.597	0.815	0.783	0.620
isoc_r_gov_i_IUGOV12	0.567	0.612	0.704	0.716	0.451	0.629	0.685	0.474
isoc_r_blt12_i_IBUY3	0.751	0.736	0.774	0.653	0.728	0.620	0.807	0.719
isoc_r_blt12_i_IB3_12	-0.392	-0.438	-0.399	-0.333	-0.314	-0.478	-0.468	-0.288

As we can see in the table above, 8 variables have been extracted from the initial 64 variables that make up the competitiveness index, all of which have a very high correlation with digitalization variables, particularly with variables that have a high contagion. Table 4 shows Morán's and Geary's indices of the competitiveness variables that we extracted earlier.

Table 4: Moran's I and Geary's C for RCI variables, 2022

	I Morán*	C Geary*
Corruption	0.838	0.146
Quality and accountability	0.854	0.158
Impartiality	0.825	0.162
Lifelong learning	0.900	0.134
Employment rate (excluding agriculture)	0.633	0.259
Enterprises with fixed broadband access.	0.955	0.072
Individuals with above-basic overall digital skills	0.902	0.119
Knowledge workers	0.579	0.363

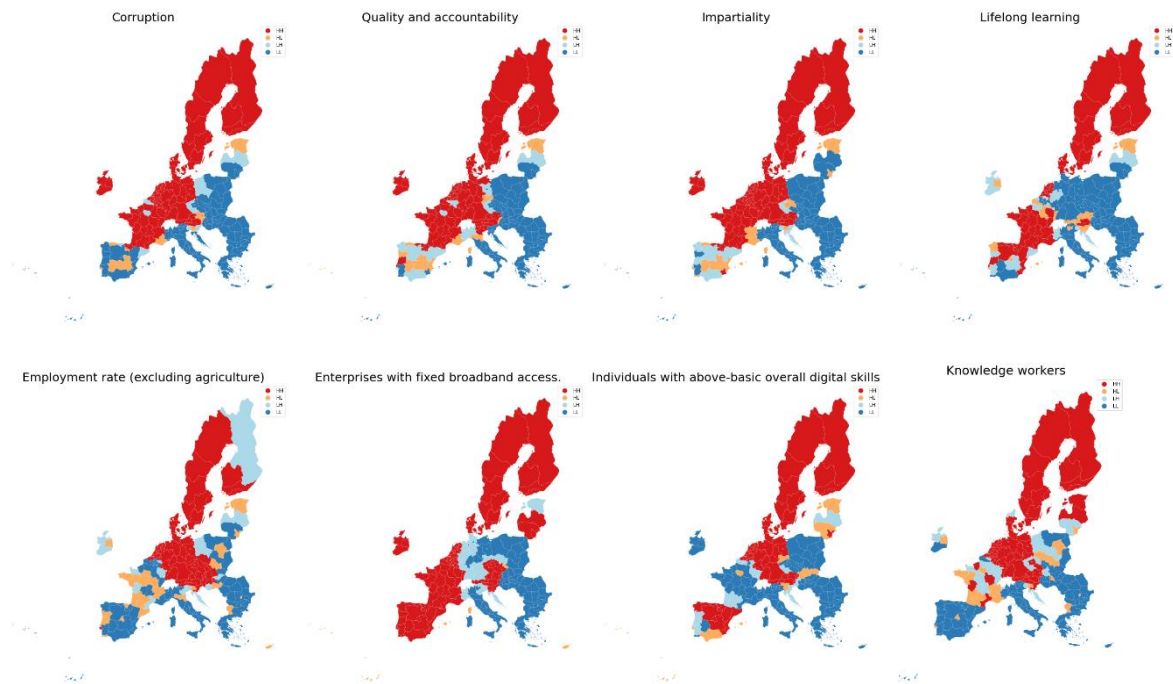
*p<0.001

Firstly, we see how the variables most related to digitalization, companies with *Enterprises with fixed broadband access*, and *Individuals with above-basic overall digital skills* have Morán indices above 0.9. Next, we can see how more transversal variables such as *Corruption*, *Quality and accountability*, *Impartiality*, or *Lifelong learning* also have very high contagions, exceeding Morán's I of 0.8. And finally, we have two variables: *Knowledge workers* and *Employment rate*, which have lower contagion than the previous ones.

To better observe the process, we can see in Figure 4 the figures of the Moran maps that we obtain with the 8 competitiveness variables.

⁶ The previously analyzed digitization variables with a higher Moran's I have been shown in green, and the digitization variables with a lower Moran's I have been shown in red.

Figure 4: Moran's maps for selected competitiveness variables



We can see in the graphs above how in the cases of structural variables (*Corruption*, *Quality and accountability*, and *Impartiality*) there are two separate behaviors, on the one hand the Nordic countries together with Central Europe that are heat spots, and the countries of Eastern and Southern Europe that are cold spots, with the exception of Spain that contains diamond regions – Castilla la Mancha and Extremadura – and doughnut regions – Galicia, Catalonia and Castilla y León and Andalusia, due to their contact with the French and Portuguese regions.

On the other hand, in *Lifelong learning* we can see how Germany, Ireland and Belgium have become cold spots, while the northern area of Spain appears as a heat spot along with the region of Murcia.

In the case of the *Employment rate*, we can see how the trend is reversed, and Germany begins to appear a heat spot while France presents very diverse regions, with Paris and surroundings being HH and the rest of the regions with lower values. Spain is shown as a cold spot except for the Community of Madrid, which is a diamond.

For *Enterprises with fixed broadband access*, we can see how Spain's fiber deployments and prices have made the entire Spanish territory into a heat spot, along with France and the Nordic countries, while Germany becomes a cold spot as it has based its fixed connectivity on cable deployments, that have a lower performance.

For *Individuals with above-basic overall digital skills*, we see how Germany and Spain become heat spots, except for the regions of Andalusia (doughnut) and Extremadura (Cold Spot), while France is lagging in this regard, appearing as a cold spot.

Finally, in *Knowledge workers* we see Germany, the Nordic countries, and the urban areas of France as heat spots while Eastern and Southern Europe are cold spots with the exceptions of the capitals.

In general, for the competitiveness variables we can see a marked national behavior, which show the still existing barriers within the single market.

4. Discussion

The digital contagion observed throughout this study shows marked national and regional characteristics, where we see how the most advantaged countries and regions slowly blur with those less advantaged that are geographically close.

The variables associated with digitalization and with greater contagion include access to online banking (transactions in the EU are commonly national), and relationships with the public administration (national or regional). In the case of online shopping, although most happens through the global e-commerce platforms, it is usually performed at a national level, i.e. a buyer in Spain will most likely purchase from Amazon Spain and not in other countries. We have seen that these three contagion phenomena are closely related to the number of individuals *with above-basic overall digital skills* and, to a lesser extent, to *Lifelong learning* in a region, and that they share an important component of similarity in their regional contagion, which could suggest that these two variables could act as accelerators in the use of access to online banking, e-administration and e-commerce.

Our study would therefore be aligned with the evidence found in the literature, regarding the importance of talent and the culture of tolerance together with technology itself, so that, thanks to entrepreneurship and reciprocal knowledge exchanges, the consequent "spillovers" are generated (Belitski et al., 2023). Also in the case of online banking, we align with evidence of the spillover effects in this sector, described by Lan (2024): "Fintech evinces a pronounced spatial spillover in adjacent regions. Remarkably, Fintech evinces a pronounced spatial spillover, sequentially tempering and then amplifying capital misallocation in adjacent regions". Additionally, another cross-cutting area that shows a relationship with the three variables of digitalization previously mentioned, and that also shows a high contagion corresponds to the quality of the regional institutions (*Corruption, quality and accountability, and impartiality*).

Moreover, we found specific relationships of access to online banking with companies that have fixed broadband, knowledge workers or high employment rates, which are also variables with high contagion and that would indirectly measure the sophistication of companies and their consumers in the regions and a subsequent impact on competitiveness. This phenomenon would be better expressed negatively through the indicator that measures a lower intensity of online shopping and that is moderately negatively related to the associated competitiveness factors: less competitive regions have lower online shopping behaviors.

On the other hand, the variables related to households' access to broadband and the internet show a progressive slowdown of contagion between 2011 and 2023, due to the generalization of its use and saturation of the variable in most regions of the EU. In addition, from our study, we did not find any type of relationship (and impact) of these variables with the competitiveness indicators of the RCI (except for those indicators that are self-referential). We could therefore conclude, that thanks to European policies focused on deployments of physical infrastructure, fixed broadband networks tend to behave as an enabling infrastructure and not an accelerator of competitiveness.

In this case, it is very likely that network deployments will be influenced by the existing technological legacy. For instance, certain regions such as Romania, previously lagging in terms of connectivity, have been able to make significant and rapid fiber deployments in recent years by taking advantage of the lack of obsolete networks to migrate, lax regulatory models, and mature and cheap fiber technologies. Thus, they have evolved their networks without impacting the competitiveness of their economy.

At the same time, other relationships between the competitiveness variables and the selected digitalization variables have not been observed either; This would suggest that competitiveness

variables are more related to the digital transformation of companies and the use of advanced technologies such as Cloud or AI than to the digitalization of households and individuals or the infrastructures enabling of broadband or internet access. As seen throughout our study, most of the literature found that analyzes contagion does so consider companies. For example, on policy implications and the need to maintain broad policies for public and manufacturing environments, in Huang et al. (2022) they focus on evaluating, in the Tangtze River Delta of China from 2007 to 2017, whether the digital economy improves the productivity of firms and whether it contributes to the improvement of the local economy, concluding that "The digital economy requires the establishment of a digital infrastructure in a large geographic area to implement its 'network effect'. Improving regional digital infrastructure and growing the regional digital economy are important in stimulating new dynamics in the local economy."

Surely, therefore, the strengthening of the Single European Market will promote possible contagion effects between regions located in different countries. Thus, eliminating the high digital barriers detected and currently under public discussion⁷ (for example, in the deployment and harmonization of 5G networks, restrictions against the flow and interoperability of data and Cloud services), and will have an impact on the greater diffusion of the digitalization of companies between EU countries, surely improve their competitiveness.

5. Conclusions

The components of diffusion of digitalization in households and individuals for the use of banking services, relationship with the administration, and online commerce show strong regional or national components and are fundamentally driven by components of digital sophistication of users. The digitalization variables associated with the deployment of broadband and internet access have seen their diffusion reduced due to the generalization of these high-capacity networks, since the capacity deployed would already be sufficient for the most common uses of the population. That is why there is currently no impact on the competitiveness of countries in Europe for access to the Internet for individuals and households.

Finally, regional or national institutional quality (*Corruption, Quality and Accounting, and Impartiality*) has a strong relationship with the digitalization variables of online banking use, e-administration and e-commerce, all variables showing a high level of contagion.

It would be very beneficial for country regulators to have specific regional indicators of penetration of digital technologies by companies to understand their diffusion and impact on competitiveness and thus be able to deploy the appropriate public policies to achieve the objectives proposed by the European Commission in the Digital Decade.

6. Limitations

It is important to note that throughout this study, the adverse effects of the lack of statistical significance, which can be observed in Annex 2: Moran Digitization Maps, have not been evaluated. In the appendix we can see how the maps at the bottom left represent the areas with a pseudo-p

⁷ European Commission recently launched a broad consultation of Member States, civil society, industry, and academics which outlines scenarios and seeks input to inform future proposals by the Commission in the domain of digital infrastructure: <https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs>

greater than the 5% significance value. A close examination of the map shows that there are a large number of regions whose local statistics are small enough to be the result of chance. We can observe that less than half of the regions have a sufficiently high degree of spatial association to be able to reject the hypothesis of chance. In general, those regions with statistical significance are focused on the heat cores of northern Europe (Scandinavian countries) and the cold cores of the east (Romania and Bulgaria), complemented with some local exceptions such as certain Spanish regions.

Acknowledgements

The authors thank Alberto Urueña for his help in developing the methodology and revision efforts.

Funding sources

Cátedra Telefónica Economía Sociedad y Transformación Digital ETSIT UPM for financing this research

Escuela Técnica Superior de Ingenieros de Telecomunicación for financing assistance and presentation at the ITS conference.

References

- Barbero, J., Diukanova, O., Gianelle, C., Salotti, S., & Santoalha, A. (2024). Technologically related diversification: One size does not fit all European regions. *Research Policy*, *53*(3), 104973. <https://doi.org/10.1016/J.RESPOL.2024.104973>
- Belitski, M., Korosteleva, J., & Piscitello, L. (2023). Digital affordances and entrepreneurial dynamics: New evidence from European regions. *Technovation*, *119*, 102442. <https://doi.org/10.1016/J.TECHNOVATION.2021.102442>
- Cabrer-Borrás, B., & Serrano-Domingo, G. (2007). Innovation and R&D spillover effects in Spanish regions: A spatial approach. *Research Policy*, *36*(9), 1357–1371. <https://doi.org/10.1016/J.RESPOL.2007.04.012>
- Cairncross, F. (2001). *The Death of Distance: How the Communications Revolution is Changing Our Lives*. Harvard Business School Press. https://books.google.es/books?id=6W_-8GvYgD0C
- Caravella, S., Cirillo, V., Crespi, F., Guarascio, D., & Menghini, M. (2023). The diffusion of digital skills across EU regions: structural drivers and polarisation dynamics. *Regional Studies, Regional Science*, *10*(1), 820–844. <https://doi.org/10.1080/21681376.2023.2265498>
- Cutrini, E., & Mendez, C. (2023). Convergence clubs and spatial structural change in the European Union. *Structural Change and Economic Dynamics*, *67*, 167–181. <https://doi.org/10.1016/J.STRUECO.2023.07.009>
- de Clercq, M., D’Haese, M., & Buysse, J. (2023). Economic growth and broadband access: The European urban-rural digital divide. *Telecommunications Policy*, *47*(6), 102579. <https://doi.org/10.1016/J.TELPOL.2023.102579>
- Digital Economy and Society Index (DESI) 2022*. (n.d.). Retrieved June 2, 2023, from <https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022>
- European Committee of the Regions, Bisogni, F., Renwick, R., Fontana, S. (2023). *The future of regional smart specialisation strategies : sustainable, inclusive and resilient*. <https://doi.org/https://data.europa.eu/doi/10.2863/89427>
- Geary, R. C. (1954). The Contiguity Ratio and Statistical Mapping. *The Incorporated Statistician*, *5*(3), 115. <https://doi.org/10.2307/2986645>

- Grubestic, T. H. (2010). Efficiency in broadband service provision: A spatial analysis. *Telecommunications Policy*, 34(3), 117–131. <https://doi.org/10.1016/J.TELPOL.2009.11.017>
- He, W. (2023). The Impact of OFDI Reverse Technology Spillover on Regional Innovation Capabilities—A Spatial Analysis Based on Provincial Panel Data. *Finance Research Letters*, 58, 104652. <https://doi.org/10.1016/J.FRL.2023.104652>
- Huang, J., Shen, Y., Chen, J., & Zhou, Y. (2022). Regional Digital Economy Development and Enterprise Productivity: A Study of the Chinese Yangtze River Delta. *Regional Science Policy & Practice*, 14(S2), 118–138. <https://doi.org/10.1111/RSP3.12559>
- Kovács, T. Z., Bittner, B., Huzsvai, L., & Nábrádi, A. (2022). Convergence and the Matthew Effect in the European Union Based on the DESI Index. *Mathematics*, 10(4), 613. <https://doi.org/10.3390/math10040613>
- Lan, Y. J. (2024). Does Fintech development affect capital misallocation: A non-linear and spatial spillover perspective. *Finance Research Letters*, 60, 104847. <https://doi.org/10.1016/J.FRL.2023.104847>
- Li, G., Li, X., & Huo, L. (2023). Digital economy, spatial spillover and industrial green innovation efficiency: Empirical evidence from China. *Heliyon*, 9(1), e12875. <https://doi.org/10.1016/J.HELIYON.2023.E12875>
- Lucendo-Monedero, A. L., Ruiz-Rodríguez, F., & González-Relaño, R. (2019). Measuring the digital divide at regional level. A spatial analysis of the inequalities in digital development of households and individuals in Europe. *Telematics and Informatics*, 41, 197–217. <https://doi.org/10.1016/j.tele.2019.05.002>
- Moran, P. A. P. (1948). The Interpretation of Statistical Maps. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 10(2), 243–251. <https://doi.org/10.1111/j.2517-6161.1948.tb00012.x>
- Nishida, T., Pick, J. B., & Sarkar, A. (2014). Japan's prefectural digital divide: A multivariate and spatial analysis. *Telecommunications Policy*, 38(11), 992–1010. <https://doi.org/10.1016/J.TELPOL.2014.05.004>
- Pick, J. B., Sarkar, A., & Johnson, J. (2015). United States digital divide: State level analysis of spatial clustering and multivariate determinants of ICT utilization. *Socio-Economic Planning Sciences*, 49, 16–32. <https://doi.org/10.1016/J.SEPS.2014.09.001>
- Piribauer, P., Glocker, C., & Krisztin, T. (2023). Beyond distance: The spatial relationships of European regional economic growth. *Journal of Economic Dynamics and Control*, 155, 104735. <https://doi.org/10.1016/J.JEDC.2023.104735>
- Rehman, N. U., & Nunziante, G. (2023). The effect of the digital economy on total factor productivity in European regions. *Telecommunications Policy*, 47(10), 102650. <https://doi.org/10.1016/J.TELPOL.2023.102650>
- Rey, S., Arribas-Bel, D., & Wolf, L. J. (n.d.). *Global Spatial Autocorrelation — Geographic Data Science with Python*. Retrieved May 1, 2024, from https://geographicdata.science/book/notebooks/06_spatial_autocorrelation.html
- Sarkar, A., Pick, J. B., & Rosales, J. (2023). Multivariate and geospatial analysis of technology utilization in US counties. *Telecommunications Policy*, 47(7), 102572. <https://doi.org/10.1016/J.TELPOL.2023.102572>
- Shahnazi, R. (2021). Do information and communications technology spillovers affect labor productivity? *Structural Change and Economic Dynamics*, 59, 342–359. <https://doi.org/10.1016/J.STRUECO.2021.09.003>

- Song, S., Wen, J., Li, Y., & Li, L. (2024). How does digital economy affect green technological innovation in China? New evidence from the “Broadband China” policy. *Economic Analysis and Policy*, *81*, 1093–1112. <https://doi.org/10.1016/J.EAP.2024.01.008>
- Tao, J., Wang, Z., Xu, Y., Zhao, B., & Liu, J. (2024). Can the digital economy boost rural residents’ income? Evidence from China based on the spatial Durbin model. *Economic Analysis and Policy*, *81*, 856–872. <https://doi.org/10.1016/J.EAP.2024.01.004>
- Wang, J., Luo, X., & Zhu, J. (2022). Does the digital economy contribute to carbon emissions reduction? A city-level spatial analysis in China. *Chinese Journal of Population, Resources and Environment*, *20*(2), 105–114. <https://doi.org/10.1016/J.CJPRE.2022.06.001>

Annex 1: Statistical Description of data

In this annex we can find the statistical description for the variables used throughout this study.

Table 5: Statistical description digitalization variables

VARIABLE	LAST YEAR AVAILABLE	AVERAGE	STANDARD DEVIATION	MINIMUM	MAXIMUM
isoc_r_iacc_h	2023	93.01	3.67	82.40	99.53
isoc_r_broad_h	2021	89.90	5.18	73.50	100.00
isoc_r_iuse_IUSE	2023	90.41	5.41	74.55	100.00
isoc_r_iuse_IDAY	2023	86.14	6.35	70.51	98.96
isoc_r_iuse_IUSNET	2023	63.07	12.61	35.07	92.78
isoc_r_iuse_IUBK	2023	66.67	19.13	13.67	97.10
isoc_r_iuse_IUSELL	2023	21.85	9.98	2.51	44.52
isoc_r_iuse_IU3	2023	91.60	5.31	74.83	100.00
isoc_r_iuse_ILT12	2023	92.49	4.82	76.89	100.00
isoc_r_iuse_IUX	2023	5.88	4.01	0.00	17.29
isoc_r_gov_i_IUGOV12	2021	62.45	21.48	10.46	94.35
isoc_r_gov_i_IGOV12RT	2021	47.81	21.03	5.53	84.28
isoc_r_blt12_i_BUY3	2023	58.31	15.85	19.76	87.83
isoc_r_blt12_i_B3_12	2023	11.40	3.43	0.87	23.63
isoc_r_blt12_i_BLT1	2023	69.71	13.95	33.77	95.40
isoc_r_blt12_i BUMT12	2023	6.11	2.83	1.05	17.21
isoc_r_blt12_i BUMT12X	2023	22.64	10.83	4.22	46.11
isoc_r_blt12_i_BPG_EU	2023	21.95	10.84	3.20	49.58

Table 6: Statistical description competitiveness variables

VARIABLE	AVERAGE	STANDARD DEVIATION	MINIMUM	MAXIMUM
Corruption	-0.03	0.97	-2.32	1.58
Quality and accountability	0.01	0.98	-2.51	1.69
Impartiality	0.03	0.97	-2.33	1.50
Individuals who used the internet for interaction with public authorities	67.95	20.98	12.00	96.00
Presence of corruption in the national public institutions in the country	0.72	0.15	0.34	0.91
Presence of corruption in the local or regional public institutions in the country	0.71	0.15	0.32	0.93
Ease of doing business	76.49	3.29	66.14	85.29
Property rights	5.04	0.70	3.75	6.60
Intellectual property protection	5.12	0.70	3.70	6.53
Efficiency of legal framework in settling disputes	4.01	1.03	1.87	5.96
Efficiency of legal framework in challenging regulations	3.66	0.96	2.01	5.68
Organized crime	5.09	0.76	3.70	6.78
Reliability of police services	5.27	0.74	3.39	6.72

Judicial independence	4.62	1.03	2.38	6.64
General government deficit/surplus	-4.24	2.21	-6.90	2.07
National savings	23.55	6.76	0.00	35.66
Government bond yields	0.62	1.05	-0.38	4.02
Government debt	84.53	40.04	15.23	193.43
Net international investment position	-12.41	60.87	-168.80	99.20
Road transport performance	77.76	19.56	26.58	111.22
Rail transport performance	6.62	7.49	0.00	44.66
Accessibility to passenger flights	429.92	491.35	6.80	2607.05
Road fatalities	52.60	22.13	9.25	144.20
Healthy life expectancy	75.11	3.58	66.47	80.06
Child mortality	3.35	1.26	1.17	8.40
Cancer disease death rate (x1000)	79.15	19.45	46.32	147.60
Heart disease death rate (x1000)	46.60	34.76	18.02	179.74
Suicide death rate	10.06	4.13	2.65	29.20
Low achievement in reading (15-year-olds)	23.41	7.37	11.05	47.10
Low achievement in math (15-year-olds)	45.24	8.85	31.01	71.05
Low achievement in science (15-year-olds)	22.89	7.37	8.76	46.51
Higher educational attainment	33.55	10.59	12.30	60.60
Lifelong learning	11.39	7.24	1.00	34.09
Early school leavers	10.03	4.67	1.76	25.75
University accessibility	81.28	17.77	25.59	100.00
Lower-secondary completion only	21.18	12.17	2.63	63.13
Employment rate (excluding agriculture)	65.97	8.79	36.59	81.10
Long-term unemployment	2.89	2.73	0.50	17.36
Unemployment rate	7.22	4.27	2.10	26.72
Labor productivity	96.44	29.89	36.15	228.98
Gender balance unemployment	1.61	1.86	0.03	10.40
Gender balance employment	9.46	5.44	0.80	25.90
NEET rate	10.22	5.15	2.76	29.93
Labor market slack	14.24	7.30	3.10	41.40
Temporary employment	7.01	5.55	0.07	25.08
Disposable income per capita	18657.58	5541.71	6200.00	32100.00
Potential market size expressed in GDP	137.00	154.09	3.17	922.07
Potential market size expressed in population	170.42	154.11	6.56	758.53
Households with broadband access (%)	89.88	4.92	75.00	99.00
Individuals buying over internet the last year	66.72	16.28	26.00	93.00
Enterprises having received orders online (at least 1 %)	19.45	6.97	8.33	36.67
Enterprises with fixed broadband access.	95.41	4.57	81.00	100.00

Access to high-speed broadband	40.44	32.97	0.00	100.00
Individuals with above-basic overall digital skills	103.89	47.15	4.70	192.69
Employment (K-N sectors)	14.68	5.69	2.94	28.92
Gross value added (GVA) (K-N sectors)	23.51	5.94	12.21	48.16
Innovative SMEs collaborating with others	112.93	67.01	0.00	287.97
Marketing or organizational innovators	95.32	46.77	0.00	184.07
Total patent applications	93.82	148.08	0.00	1032.83
Core creative class employment	10.80	3.76	3.27	22.44
Knowledge workers	27.70	8.61	6.68	52.82
Scientific publications	1.26	0.89	0.04	4.73
Total intramural research and development expenditure	1.60	1.03	0.06	5.21
Human Resources in Science and Technology	45.70	10.33	19.70	68.00
Employment in technology and knowledge-intensive sectors	4.32	2.42	0.81	12.56
Trademark applications	93.13	51.44	9.80	240.12
Design applications	97.55	44.31	20.18	204.98
Sales of new-to-market and new-to-firms innovation	98.85	32.13	15.66	167.32

Annex 2: Moran's Maps for digitalization variables

In the following annex we can find the maps for the Moran analysis of the digitalization variables, where we show on the right upper corner, the local statistics of the variable, on the right upper corner the Moran's map, on the left bottom corner the statistical significance map, and on the right bottom corner the Moran's cluster map.

Figure 5: *isoc_r_iacc_h* Moran map, 2023

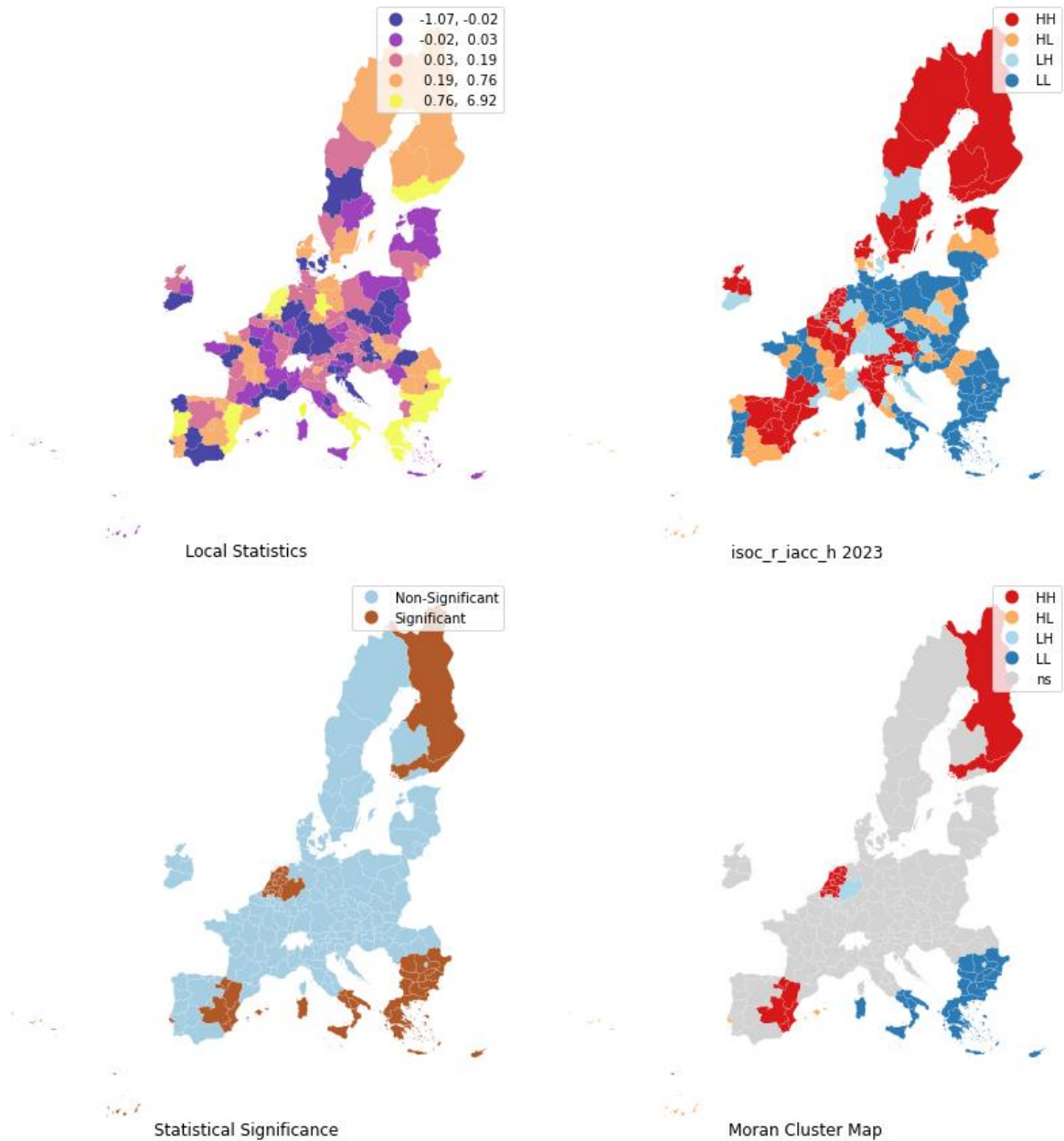


Figure 6: *isoc_r_broad_h* Moran map, 2021

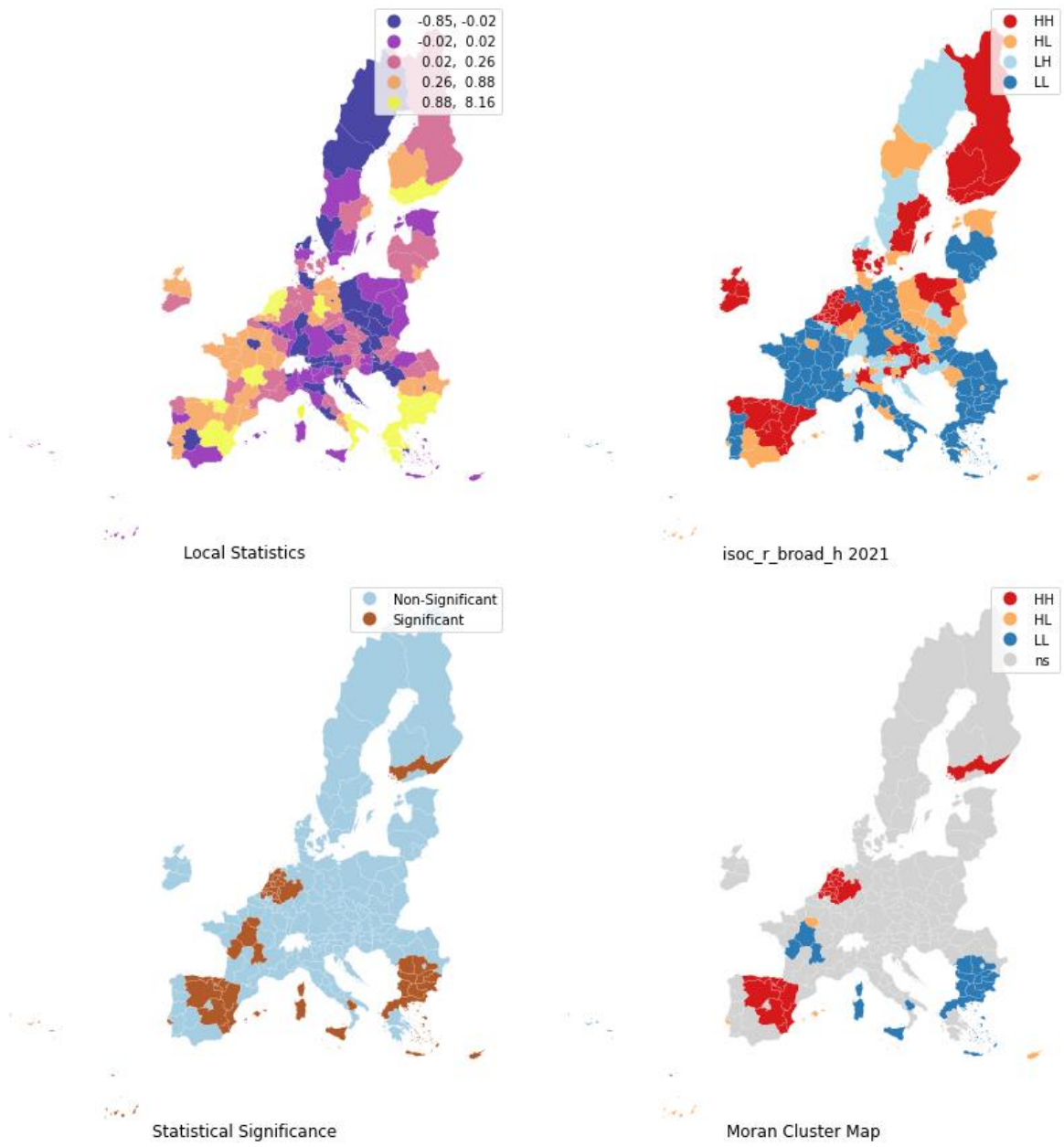


Figure 7: *isoc_r_iuse_IUSE* Moran map, 2023

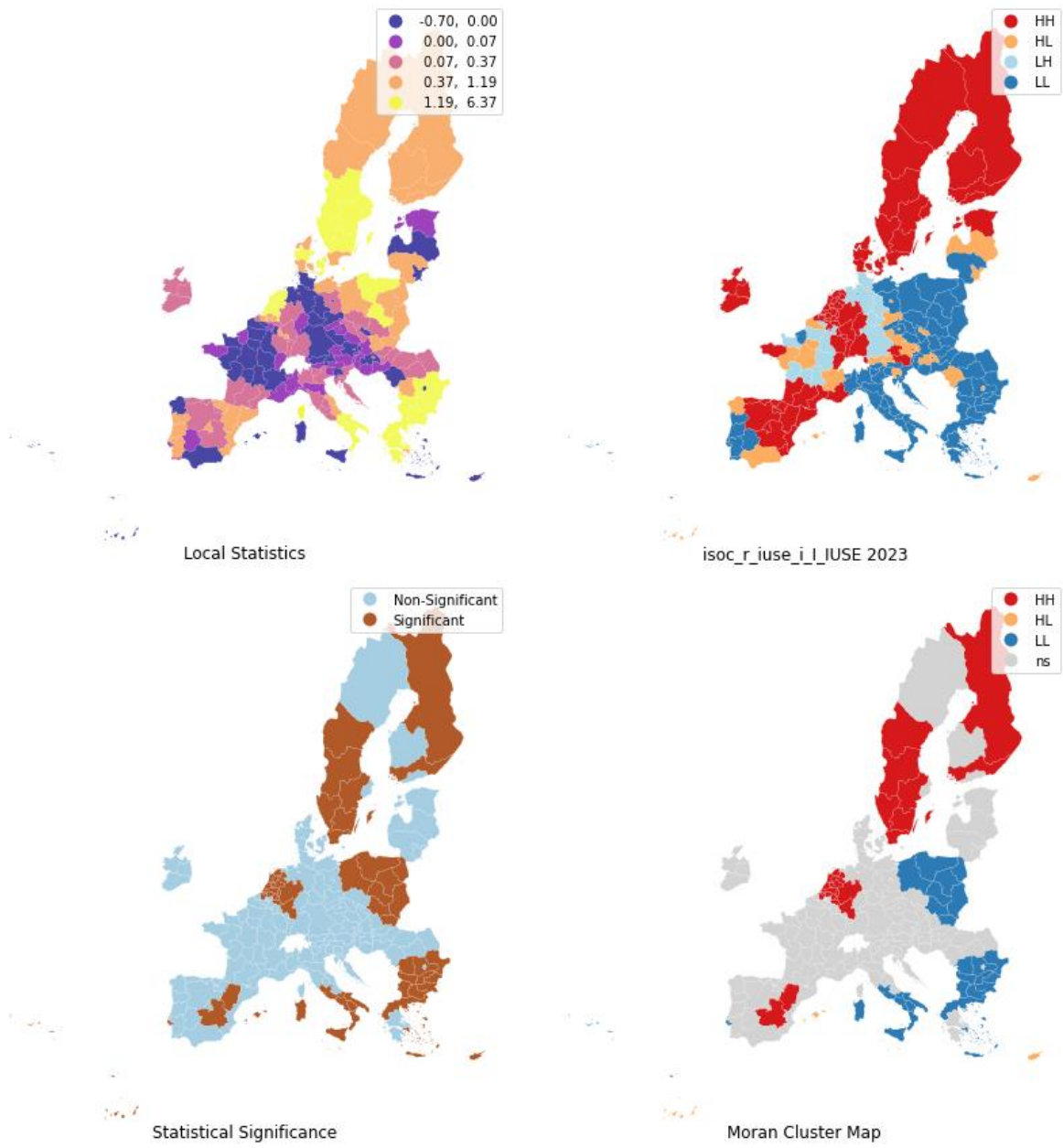


Figure 8: *isoc_r_iuse_i_DAY* Moran map, 2023

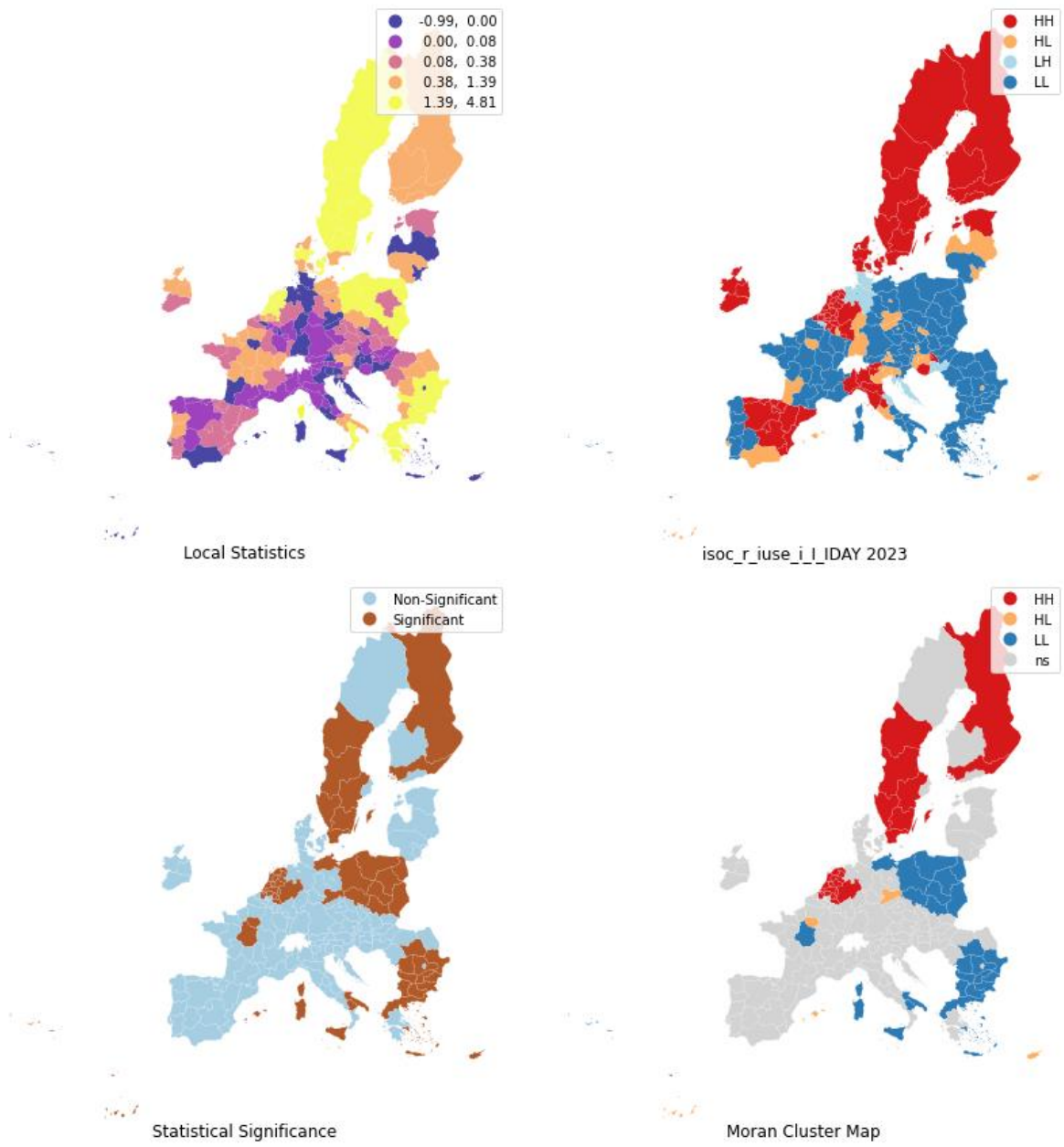


Figure 9 isoc_r_iuse_IUSNET Moran map 2023

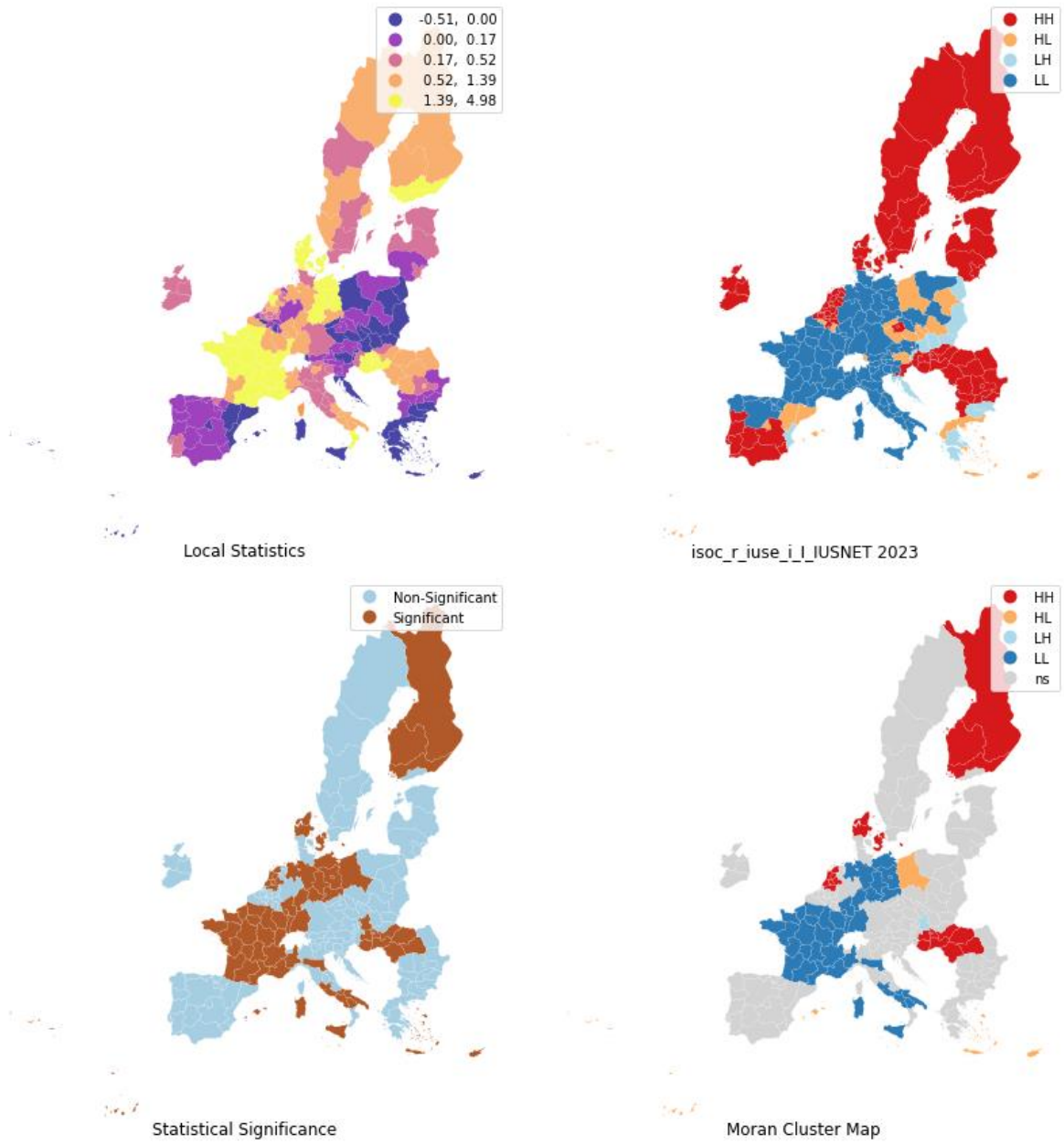


Figure 10: *isoc_r_iuse_IUBK* Moran map, 2023

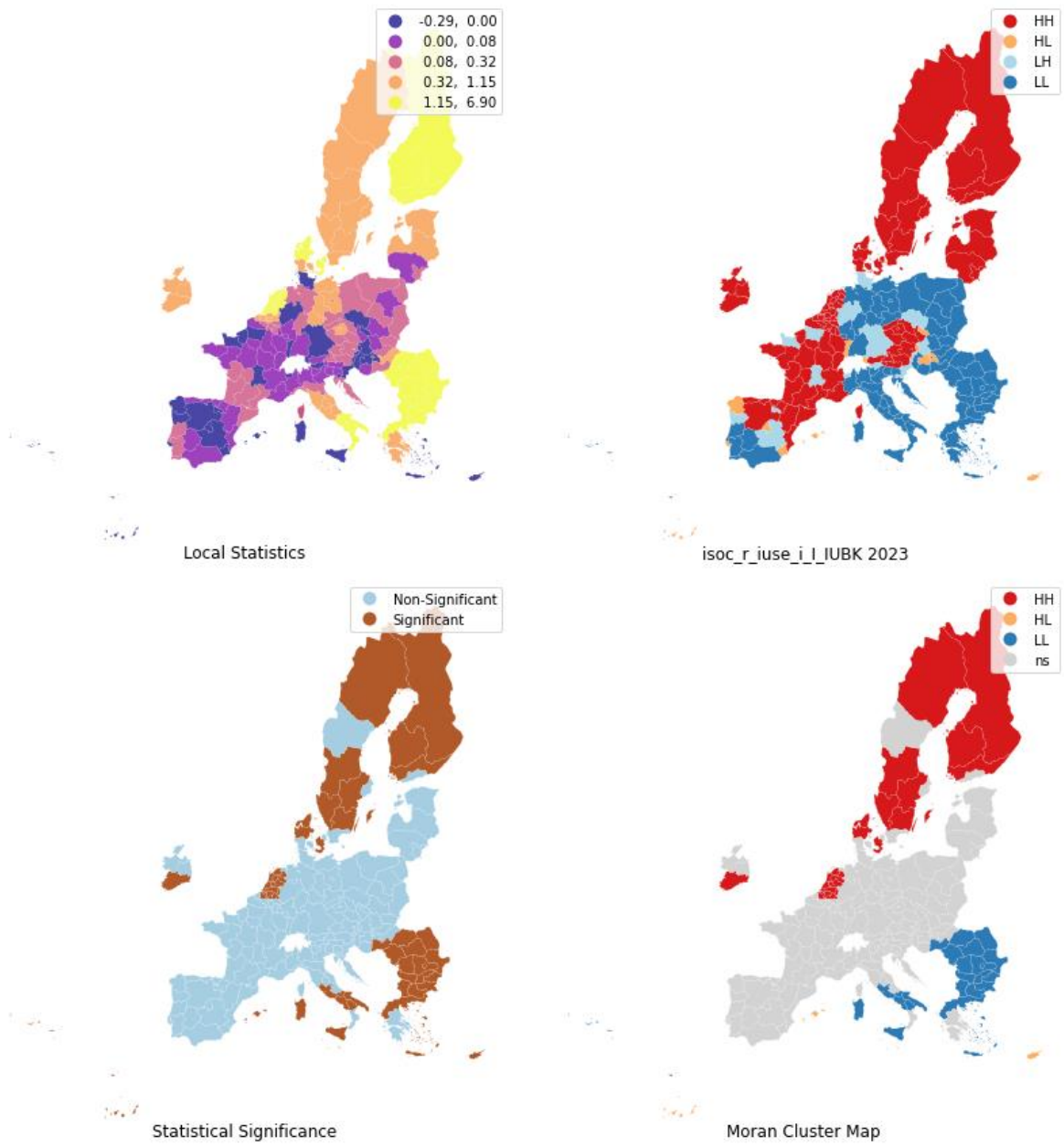


Figure 11 *isoc_r_iuse_IUSELL* Moran map, 2023

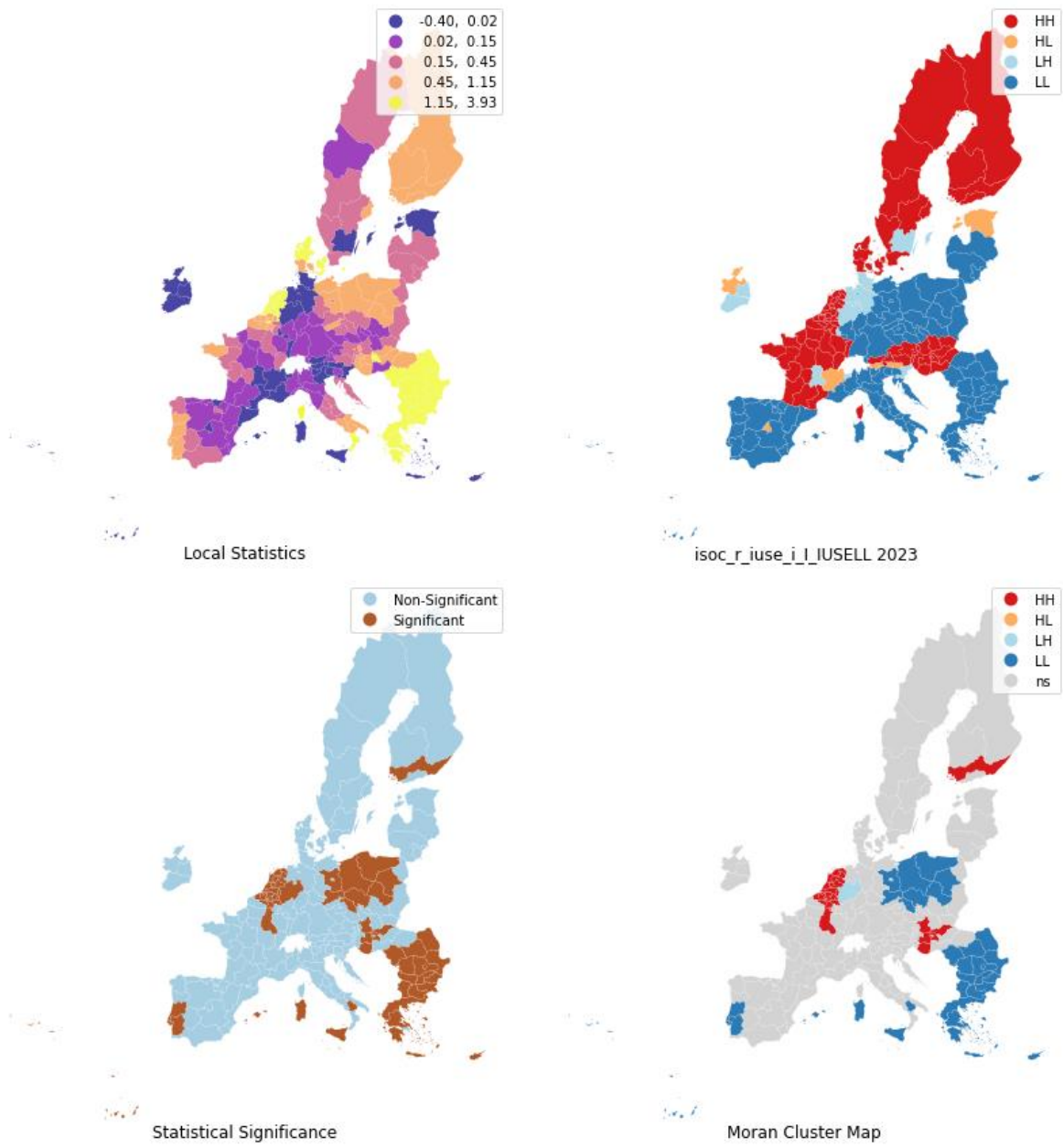


Figure 12: *isoc_r_iuse_IU3* Moran map, 2023

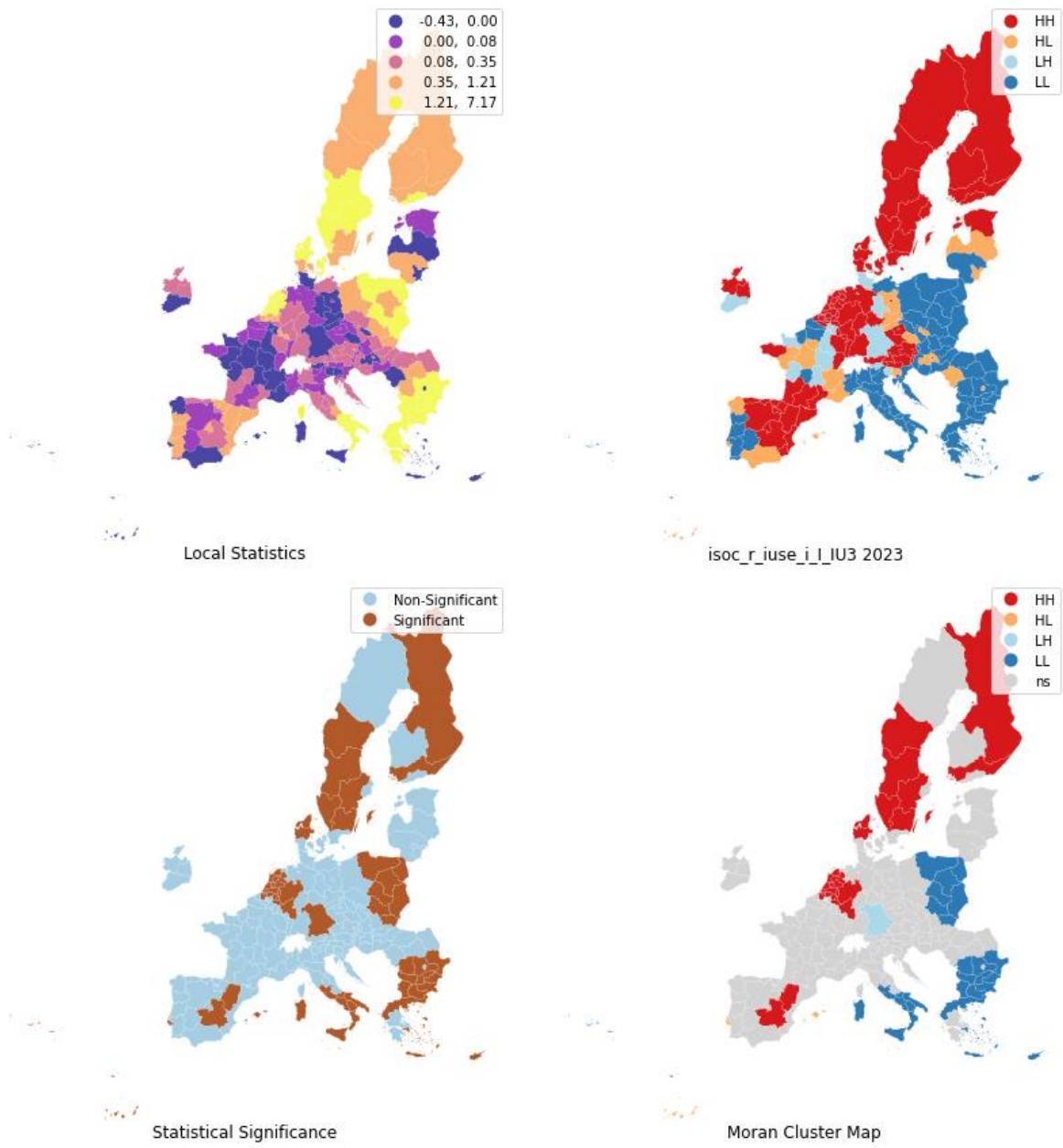


Figure 13 isoc_r_iuse_ILT12 Moran map, 2023

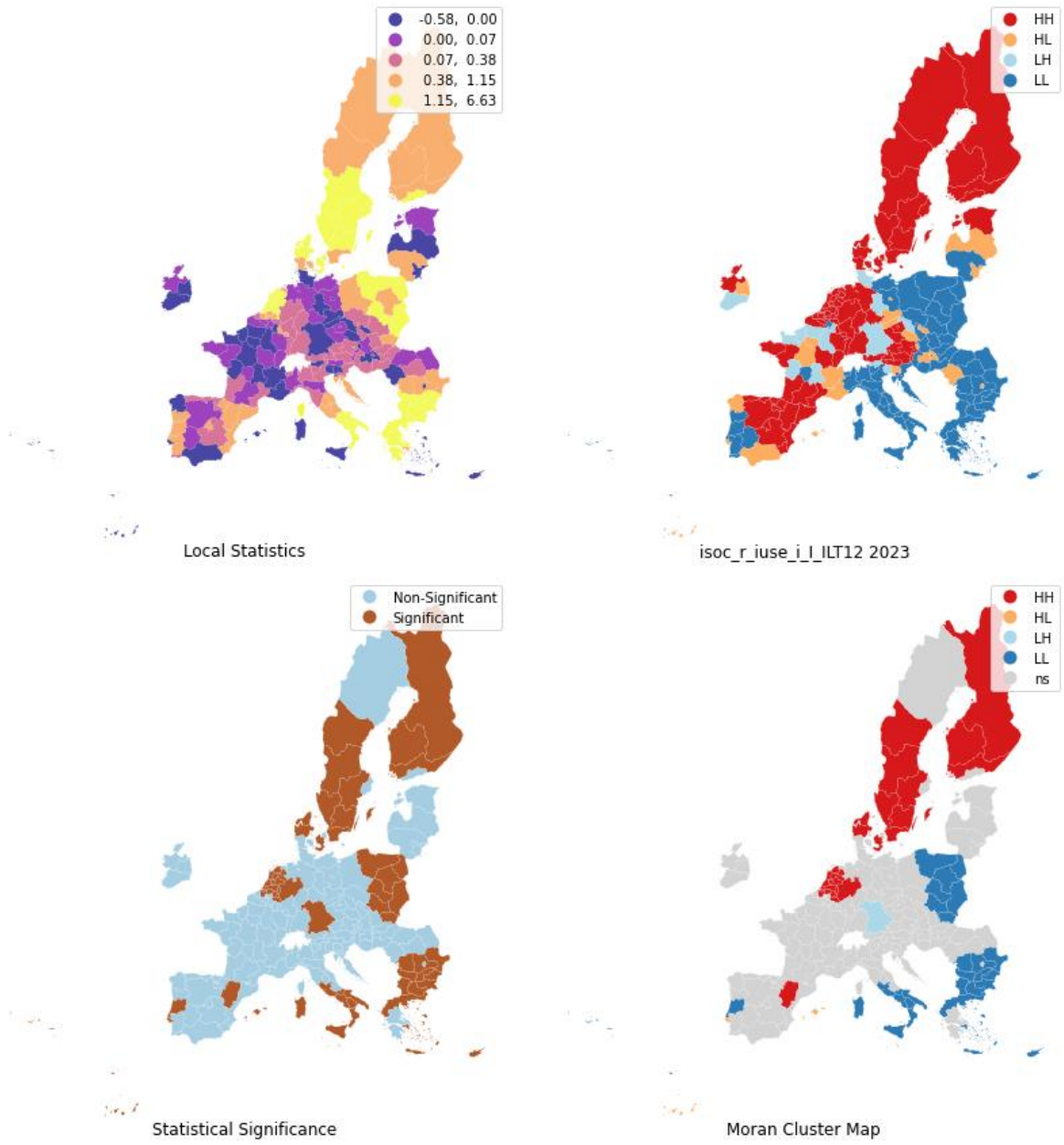


Figure 14 isoc_r_iuse_IUX Moran map, 2023

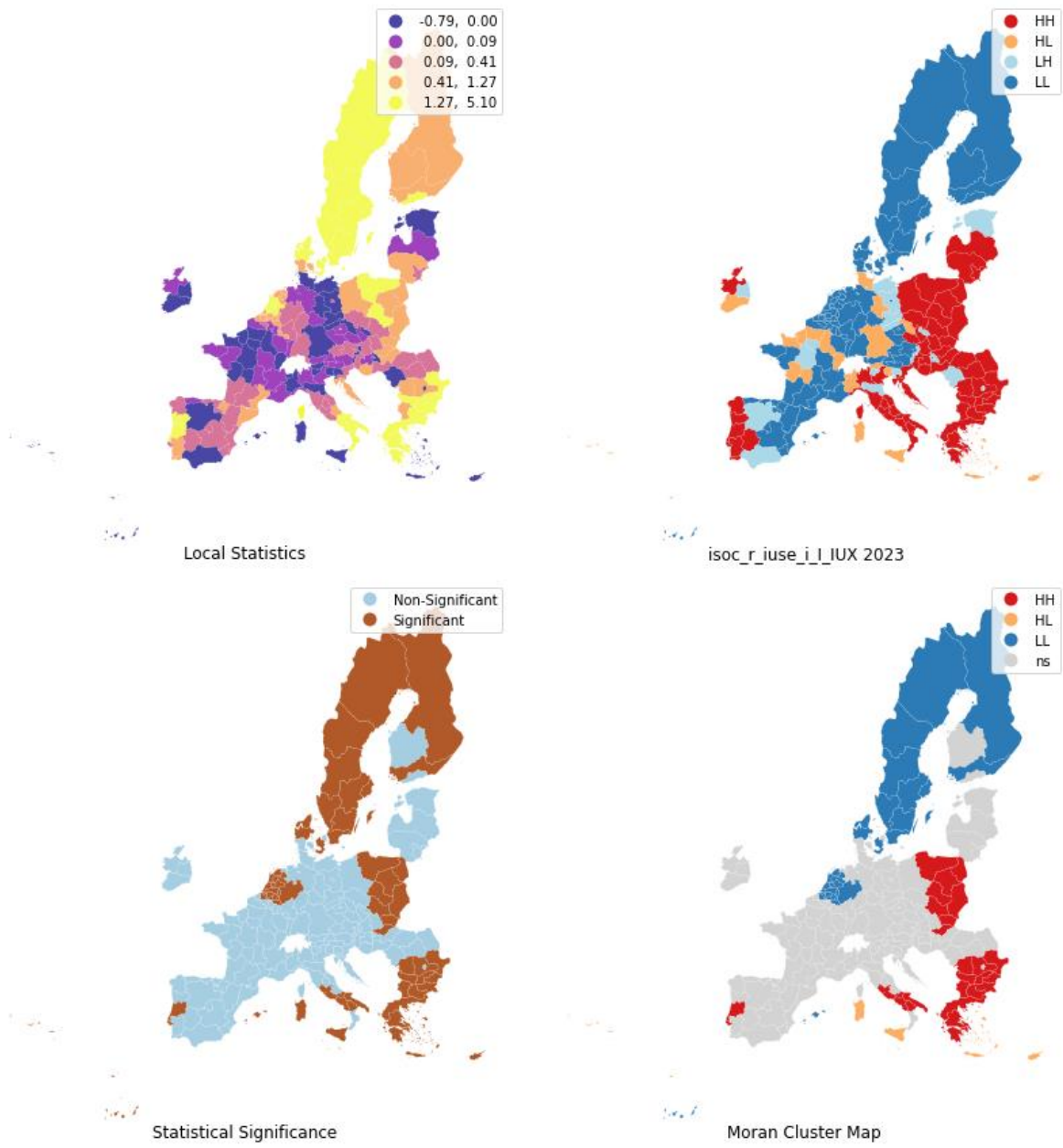


Figure 15 isoc_r_gov_IUGOV12 Moran map, 2021

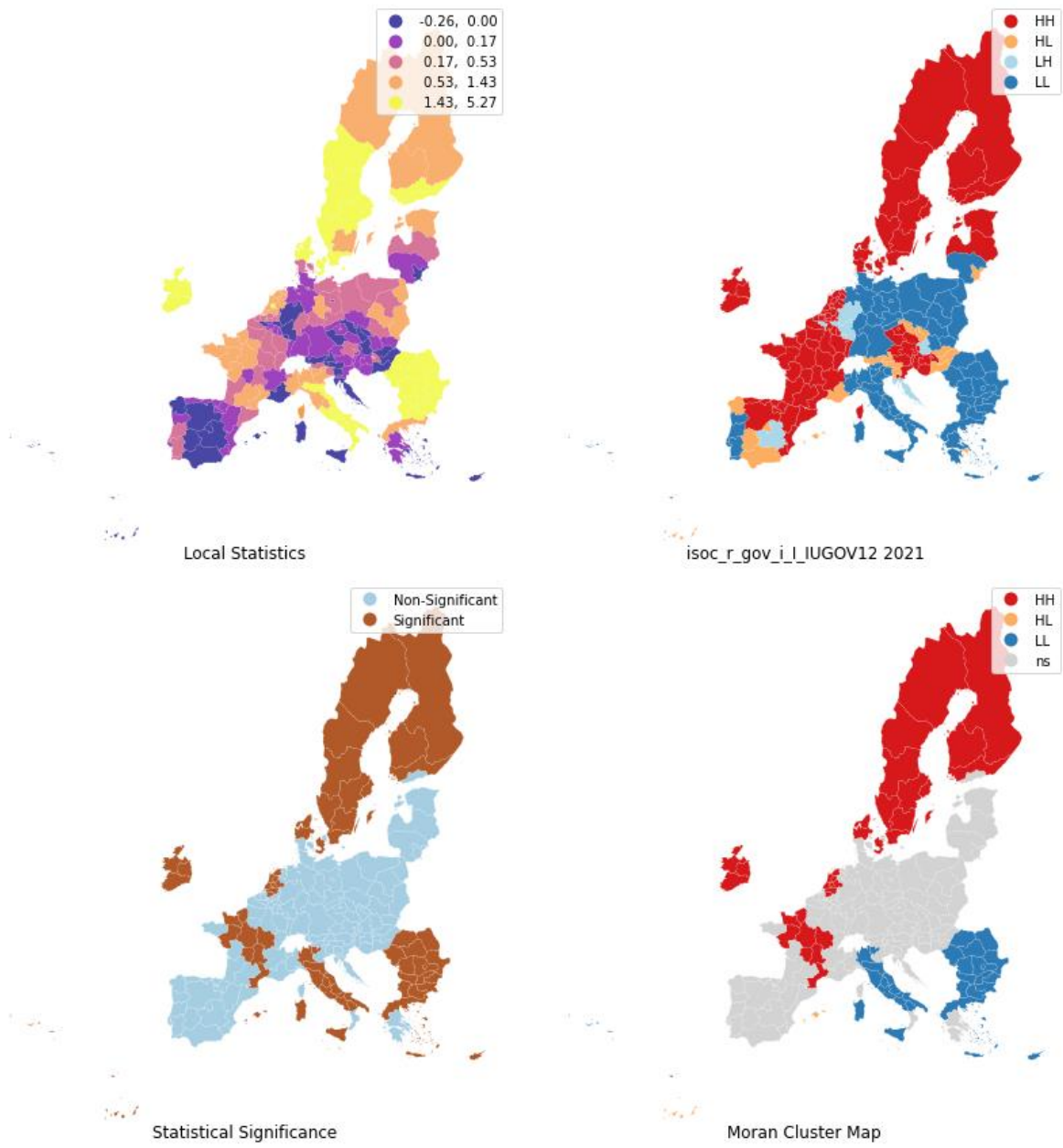


Figure 16 *isoc_r_gov_IUGOV12RT* Moran map, 2021

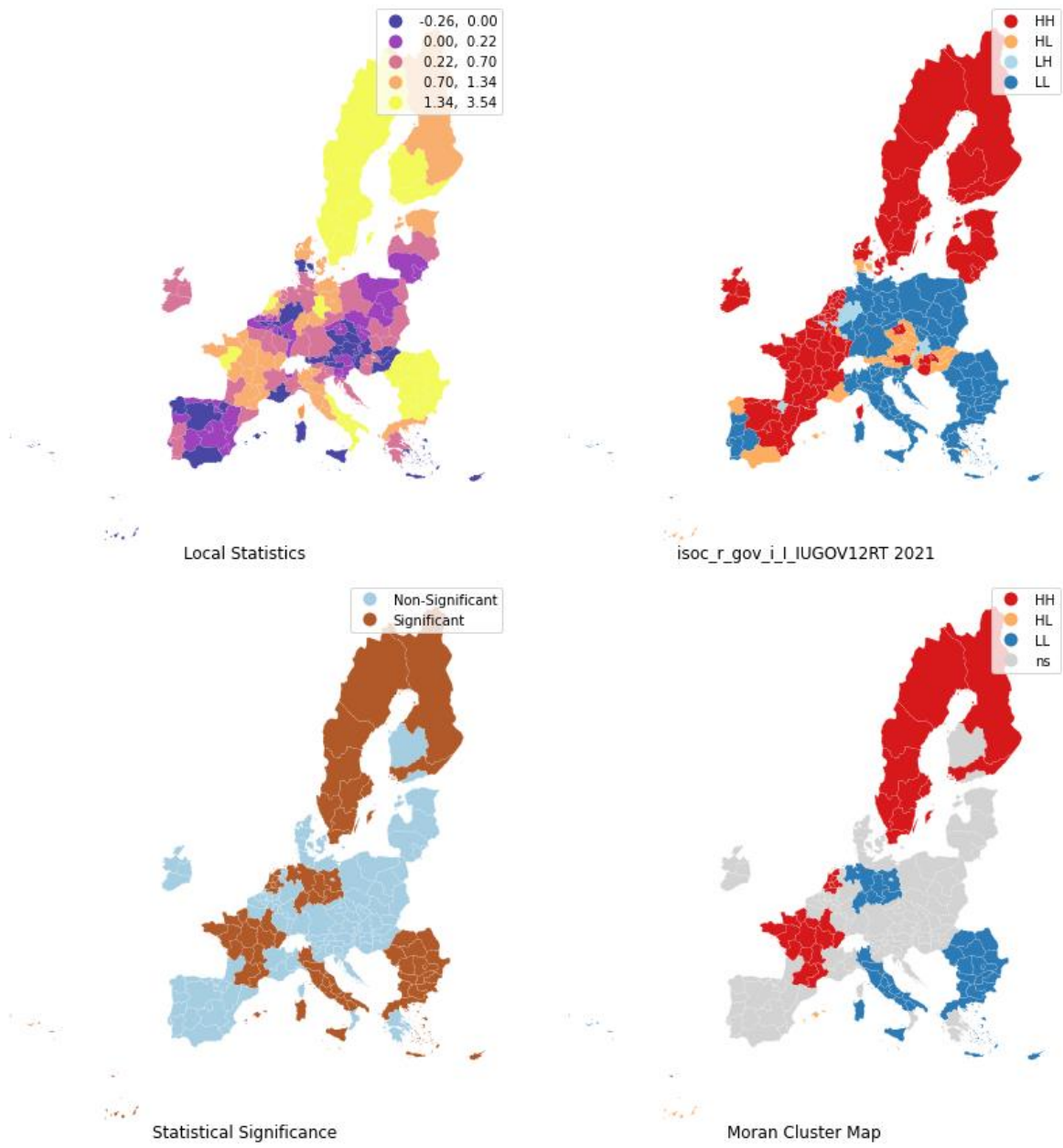


Figure 17: *isoc_r_blt12_IBUY3* Moran map, 2023

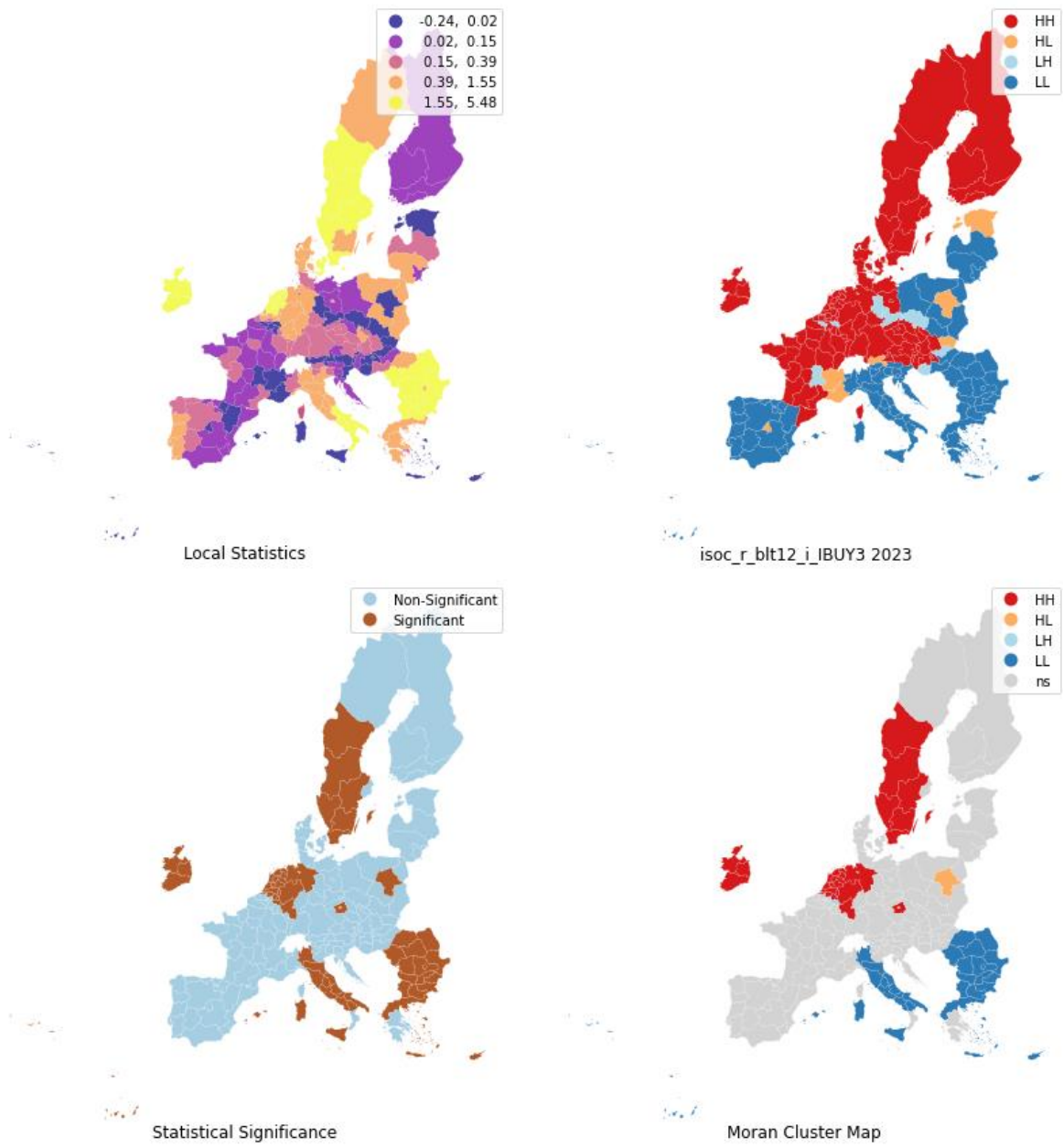


Figure 18 *isoc_r_blt12_IB3_12* Moran map, 2023

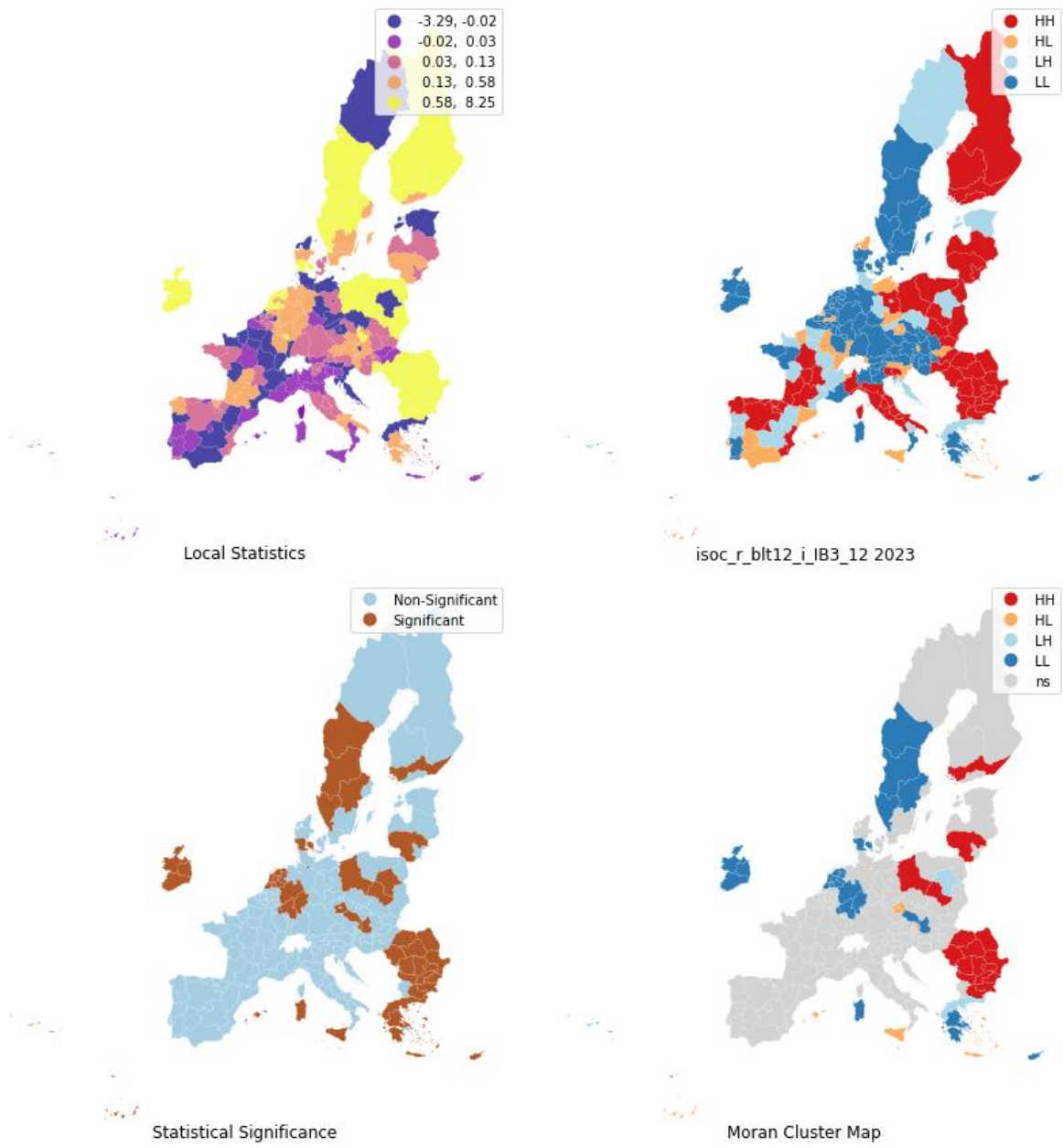


Figure 19 isoc_r_blt12_IBLT12 Moran map, 2023

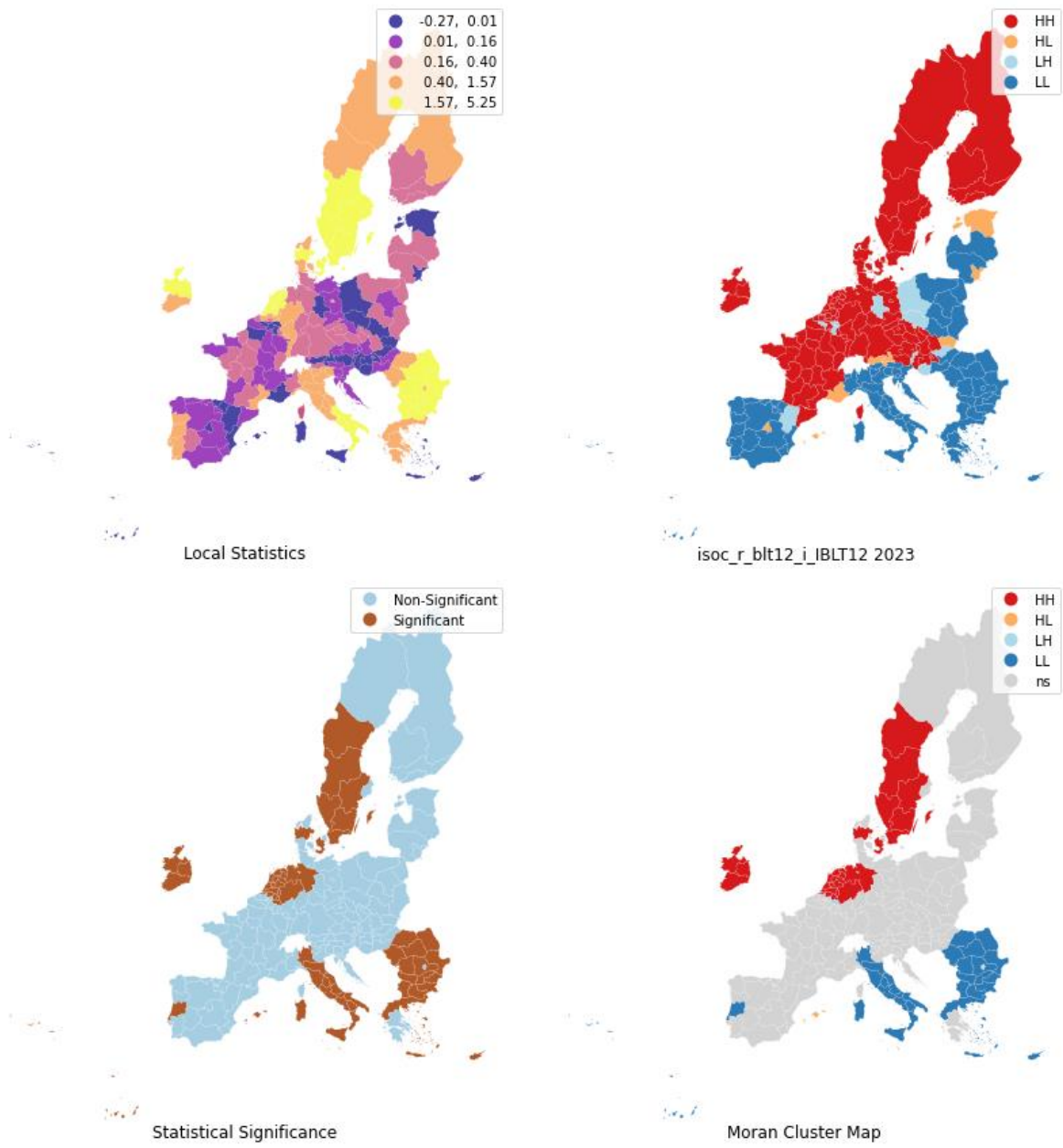


Figure 20 *isoc_r_blt12_IBUMT12* Moran map, 2023

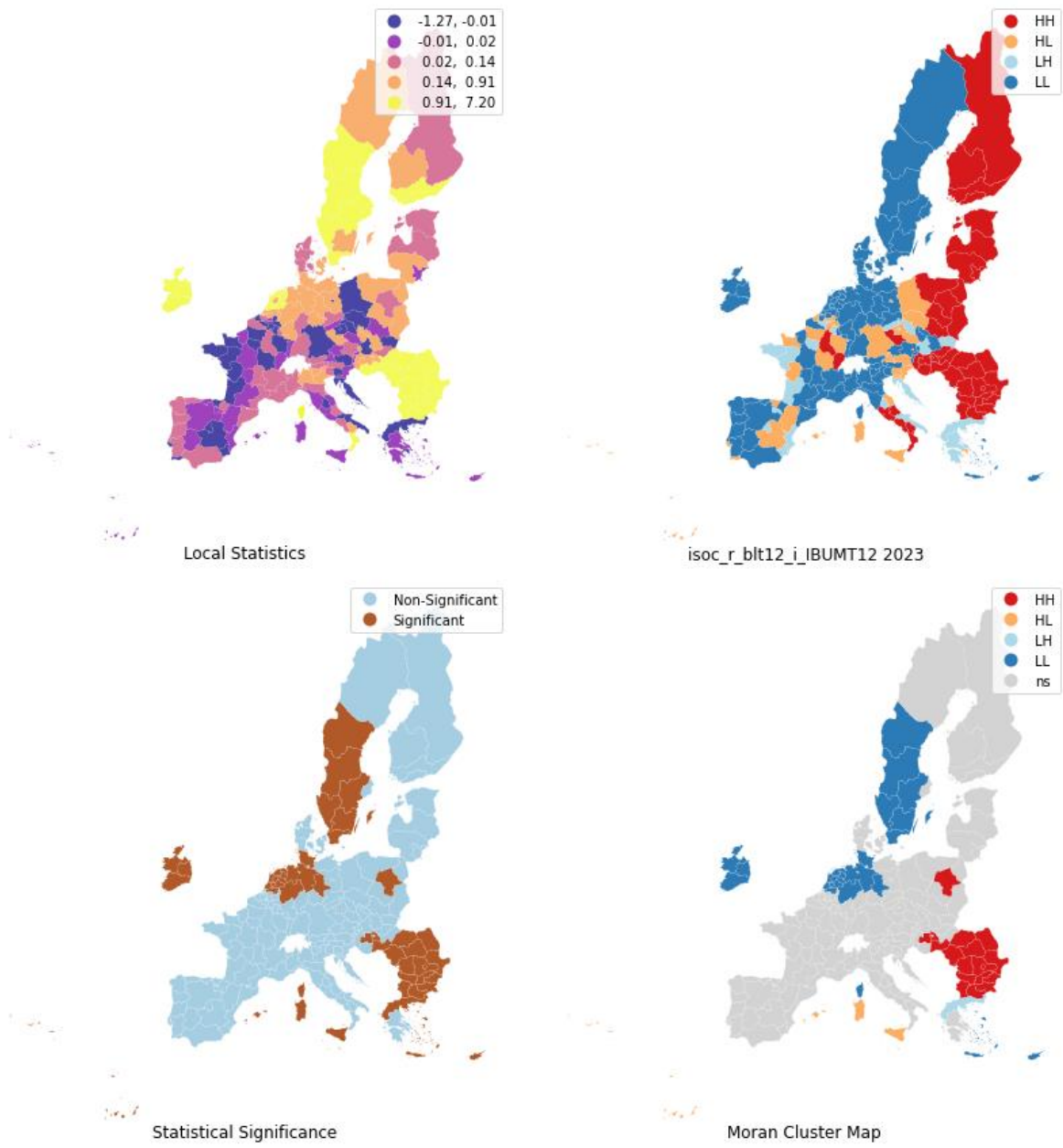


Figure 21: *Isoc_r_blt12_IBUMT12X* Moran map, 2023

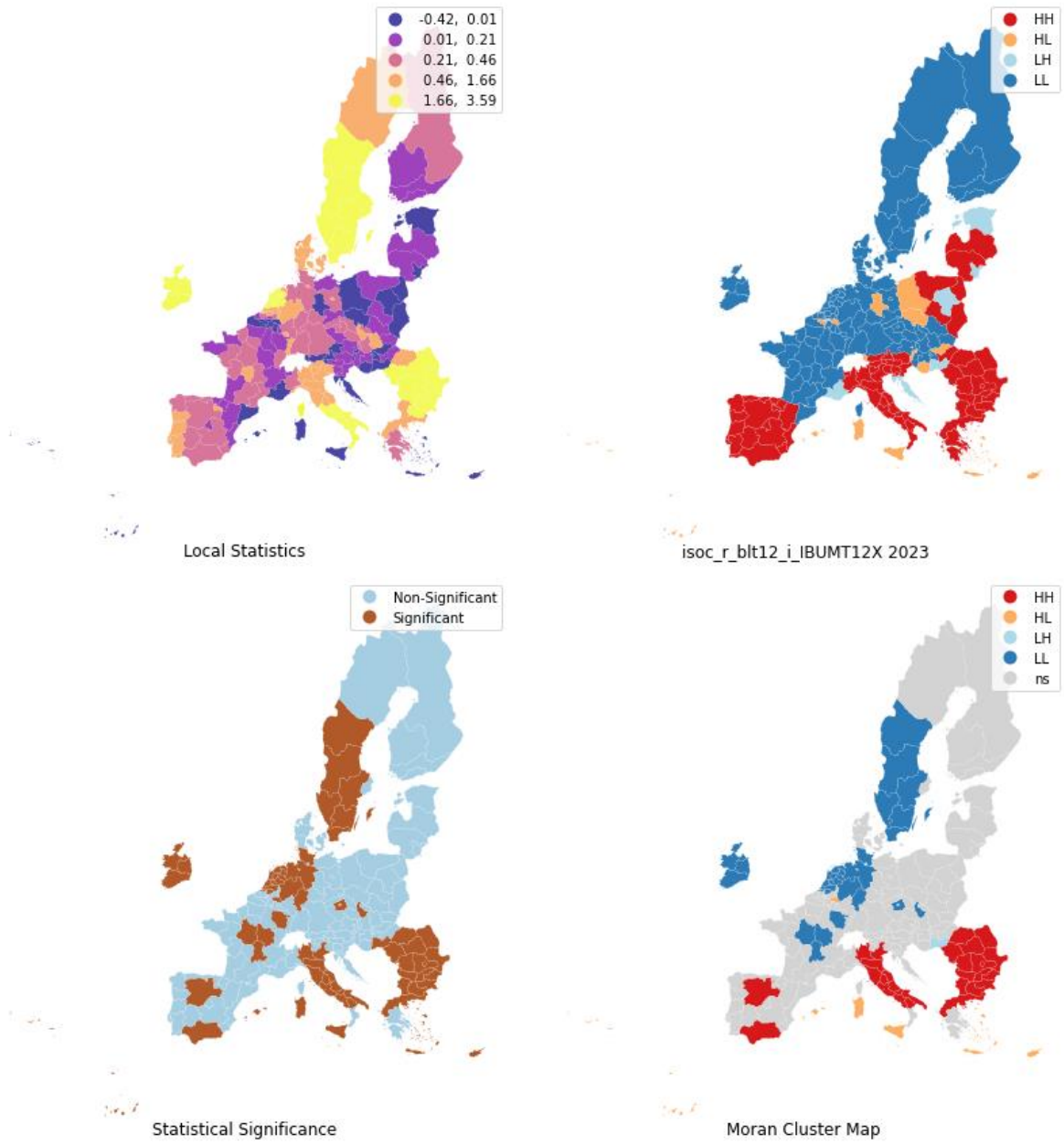
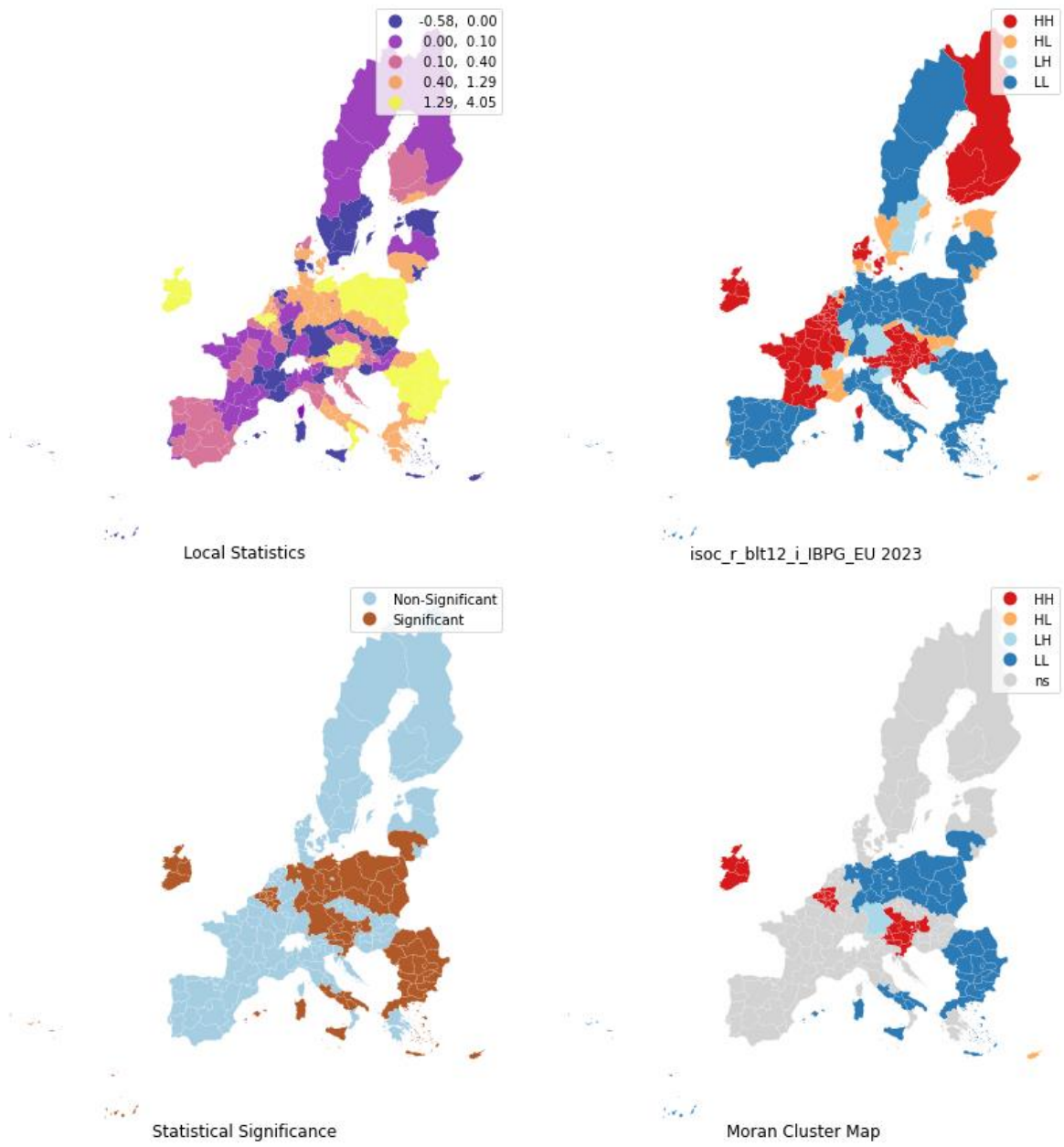


Figure 22: *isos_r_blt12_IBPG_EU* Moran map, 2023



Annex 3: Correlation tables between digitalization variables and RCI variables

In the following annex we can find the Pearson correlation tables between the digitalization variables and the RCI variables

Table 7: Pearson correlation between digitalization variables and RCI variables

	Corruption	Quality and accountability	Impartiality	Individuals who used the internet for interaction with public authorities	Presence of corruption in the national public institutions in the country	Presence of corruption in the local or regional public institutions in the country	Ease of doing business	Property rights	Intellectual property protection	Efficiency of legal framework in settling disputes	Efficiency of legal framework in challenging regulations	Organised crime	Reliability of police services	Judicial independence
isoc_r_iacc_h	0.418	0.474	0.479	0.490	-0.359	-0.362	0.330	0.463	0.435	0.443	0.345	0.459	0.524	0.397
isoc_r_broad_h	0.278	0.411	0.379	0.413	-0.202	-0.182	0.207	0.372	0.294	0.284	0.179	0.551	0.659	0.347
isoc_r_iuse_i_j_IUSE	0.654	0.666	0.729	0.667	-0.503	-0.454	0.514	0.681	0.652	0.686	0.613	0.504	0.638	0.656
isoc_r_iuse_i_j_IDAY	0.511	0.554	0.553	0.539	-0.448	-0.386	0.374	0.558	0.511	0.488	0.458	0.368	0.542	0.589
isoc_r_iuse_i_j_IUSNET	-0.018	-0.002	0.064	0.198	-0.203	-0.181	0.120	0.174	0.036	0.151	-0.009	0.451	0.184	0.167
isoc_r_iuse_i_j_IUBK	0.673	0.750	0.724	0.883	-0.518	-0.506	0.556	0.673	0.670	0.569	0.564	0.589	0.549	0.628
isoc_r_iuse_i_j_IUSELL	0.603	0.587	0.620	0.706	-0.598	-0.603	0.324	0.631	0.645	0.594	0.567	0.244	0.353	0.583
isoc_r_iuse_i_j_IU3	0.669	0.683	0.753	0.654	-0.520	-0.466	0.539	0.719	0.679	0.701	0.622	0.527	0.674	0.684
isoc_r_iuse_i_j_ILT12	0.662	0.660	0.744	0.626	-0.531	-0.484	0.538	0.711	0.668	0.722	0.635	0.507	0.640	0.671
isoc_r_iuse_i_j_IUX	-0.669	-0.658	-0.733	-0.606	0.543	0.498	-0.531	-0.707	-0.684	-0.712	-0.648	-0.416	-0.606	-0.685
isoc_r_gov_i_j_IUGOV12	0.567	0.612	0.704	0.990	-0.446	-0.474	0.498	0.656	0.669	0.703	0.555	0.706	0.607	0.601
isoc_r_gov_i_j_IUGOV12RT	0.444	0.491	0.582	0.963	-0.349	-0.391	0.383	0.538	0.600	0.620	0.457	0.617	0.535	0.488
isoc_r_blt12_i_IBUY3	0.751	0.736	0.774	0.815	-0.641	-0.628	0.566	0.681	0.670	0.679	0.671	0.410	0.371	0.631
isoc_r_blt12_i_IB3_12	-0.392	-0.438	-0.399	-0.486	0.197	0.154	-0.207	-0.348	-0.357	-0.207	-0.281	-0.180	-0.246	-0.377
isoc_r_blt12_i_IBLT12	0.754	0.725	0.779	0.800	-0.679	-0.675	0.589	0.683	0.669	0.719	0.690	0.420	0.357	0.619
isoc_r_blt12_i_IBUMT12	-0.514	-0.628	-0.542	-0.522	0.316	0.274	-0.367	-0.459	-0.471	-0.306	-0.412	-0.166	-0.293	-0.475
isoc_r_blt12_i_IBUMT12X	-0.697	-0.659	-0.692	-0.765	0.655	0.667	-0.539	-0.569	-0.569	-0.614	-0.613	-0.313	-0.167	-0.507
isoc_r_blt12_i_IBPG_EU	0.479	0.528	0.579	0.651	-0.342	-0.291	0.224	0.671	0.664	0.443	0.465	0.395	0.467	0.619

	General government deficit/surplus	National savings	Government bond yields	Government debt	Net international investment position	Road transport performance	Rail transport performance	Accessibility to passenger flights	Road fatalities	Healthy life expectancy	Child mortality	Cancer disease death rate (x1000)	Heart disease death rate (x1000)	Suicide death rate
isoc_r_iacc_h	0.087	0.273	-0.207	-0.169	0.239	0.415	0.319	0.364	-0.430	0.396	-0.274	-0.280	-0.390	0.013
isoc_r_broad_h	0.081	0.258	-0.139	-0.114	0.108	0.495	0.298	0.401	-0.459	0.387	-0.240	-0.242	-0.369	-0.111
isoc_r_iuse_i_IUSE	0.195	0.431	-0.414	-0.179	0.343	0.529	0.347	0.422	-0.596	0.502	-0.291	-0.367	-0.488	0.074
isoc_r_iuse_i_IDAY	0.271	0.424	-0.342	-0.126	0.360	0.517	0.313	0.435	-0.599	0.517	-0.307	-0.400	-0.430	-0.073
isoc_r_iuse_i_IUSNET	0.388	-0.019	0.217	-0.393	-0.010	-0.035	0.014	0.048	0.019	-0.158	0.087	0.142	0.247	0.058
isoc_r_iuse_i_IJUBK	0.323	0.693	-0.572	-0.106	0.285	0.505	0.231	0.368	-0.503	0.420	-0.489	-0.438	-0.574	0.293
isoc_r_iuse_i_IJUSELL	0.231	0.622	-0.503	-0.171	0.531	0.348	0.149	0.436	-0.395	0.367	-0.219	-0.210	-0.391	0.316
isoc_r_iuse_i_IJU3	0.197	0.446	-0.420	-0.177	0.369	0.515	0.348	0.402	-0.598	0.505	-0.328	-0.395	-0.507	0.071
isoc_r_iuse_i_ILT12	0.198	0.400	-0.405	-0.228	0.379	0.496	0.345	0.405	-0.587	0.476	-0.275	-0.364	-0.459	0.071
isoc_r_iuse_i_IJUX	-0.183	-0.427	0.444	0.210	-0.449	-0.501	-0.360	-0.415	0.588	-0.525	0.291	0.422	0.482	-0.062
isoc_r_gov_i_IJUGOV12	0.168	0.380	-0.382	-0.297	0.011	0.336	0.152	0.276	-0.305	0.117	-0.070	0.052	-0.334	0.411
isoc_r_gov_i_IJUGOV12RT	0.030	0.262	-0.279	-0.221	-0.030	0.289	0.135	0.261	-0.225	0.086	-0.058	0.146	-0.277	0.443
isoc_r_blt12_i_IBUY3	0.434	0.705	-0.573	-0.294	0.394	0.430	0.238	0.445	-0.542	0.365	-0.316	-0.335	-0.484	0.248
isoc_r_blt12_i_IB3_12	-0.214	-0.509	0.406	-0.099	-0.159	-0.361	-0.076	-0.261	0.352	-0.326	0.277	0.329	0.449	-0.002
isoc_r_blt12_i_IBLT12	0.438	0.659	-0.545	-0.362	0.407	0.394	0.251	0.438	-0.524	0.328	-0.286	-0.294	-0.431	0.282
isoc_r_blt12_i_IBUMT12	-0.273	-0.571	0.559	-0.094	-0.252	-0.426	-0.222	-0.333	0.505	-0.517	0.498	0.545	0.630	0.042
isoc_r_blt12_i_IBUMT12X	-0.498	-0.671	0.528	0.379	-0.361	-0.279	-0.171	-0.377	0.420	-0.217	0.256	0.231	0.355	-0.337
isoc_r_blt12_i_IBPG_EU	0.115	0.466	-0.513	-0.005	0.206	0.387	0.156	0.351	-0.357	0.364	-0.325	-0.366	-0.451	0.201

	Low achievement in reading (15-year-olds)	Low achievement in maths (15-year-olds)	Low achievement in science (15-year-olds)	Higher educational attainment	Lifelong learning	Early school leavers	University accessibility	Lower-secondary completion only	Employment rate (excluding agriculture)	Long-term unemployment	Unemployment rate	Labour productivity	Gender balance unemployment	Gender balance employment	NEET rate	Labour market slack	Temporary employment
isoc_r_iacc_h	-0.286	-0.361	-0.330	0.532	0.532	-0.133	0.284	-0.069	0.428	-0.208	-0.073	0.456	-0.158	-0.275	-0.417	-0.038	0.063
isoc_r_broad_h	-0.215	-0.316	-0.323	0.472	0.536	-0.025	0.332	0.162	0.323	-0.090	0.015	0.336	-0.071	-0.133	-0.345	0.017	0.214
isoc_r_iuse_i_IUSE	-0.286	-0.348	-0.336	0.635	0.698	-0.175	0.307	-0.122	0.580	-0.250	-0.058	0.636	-0.166	-0.487	-0.565	-0.024	-0.102
isoc_r_iuse_i_IDAY	-0.202	-0.275	-0.231	0.548	0.679	-0.117	0.342	0.011	0.524	-0.149	-0.002	0.570	-0.102	-0.371	-0.428	0.074	-0.036
isoc_r_iuse_i_IUSNET	0.113	0.090	0.092	0.194	0.234	0.008	-0.079	-0.067	0.204	-0.150	-0.099	-0.115	-0.052	-0.043	-0.125	-0.166	-0.111
isoc_r_iuse_i_IJUBK	-0.605	-0.694	-0.670	0.651	0.713	-0.414	0.247	-0.195	0.597	-0.289	-0.110	0.548	-0.218	-0.549	-0.565	-0.048	-0.005
isoc_r_iuse_i_IJUSELL	-0.292	-0.540	-0.362	0.412	0.615	-0.286	0.244	-0.193	0.551	-0.369	-0.241	0.496	-0.317	-0.458	-0.418	-0.095	-0.213
isoc_r_iuse_i_IJU3	-0.305	-0.365	-0.354	0.596	0.694	-0.171	0.313	-0.125	0.579	-0.245	-0.061	0.639	-0.167	-0.471	-0.576	-0.028	-0.112
isoc_r_iuse_i_ILT12	-0.250	-0.325	-0.304	0.602	0.676	-0.165	0.312	-0.167	0.590	-0.280	-0.090	0.632	-0.187	-0.479	-0.584	-0.069	-0.155
isoc_r_iuse_i_IJUX	0.249	0.347	0.294	-0.581	-0.689	0.152	-0.331	0.166	-0.574	0.263	0.083	-0.669	0.204	0.481	0.546	0.030	0.154
isoc_r_gov_i_IJUGOV12	-0.492	-0.582	-0.620	0.648	0.716	-0.346	-0.063	-0.308	0.451	-0.343	-0.158	0.444	-0.240	-0.518	-0.491	-0.213	-0.138
isoc_r_gov_i_IJUGOV12RT	-0.416	-0.529	-0.552	0.600	0.708	-0.320	-0.096	-0.251	0.374	-0.312	-0.117	0.361	-0.222	-0.486	-0.378	-0.145	-0.066
isoc_r_blt12_i_IBUY3	-0.468	-0.602	-0.531	0.603	0.653	-0.430	0.244	-0.381	0.728	-0.433	-0.277	0.624	-0.329	-0.562	-0.685	-0.221	-0.281
isoc_r_blt12_i_IB3_12	0.321	0.364	0.334	-0.241	-0.333	0.137	-0.215	-0.048	-0.314	0.003	-0.020	-0.381	0.058	0.197	0.264	-0.090	-0.017
isoc_r_blt12_i_IBLT12	-0.451	-0.590	-0.516	0.623	0.655	-0.454	0.221	-0.447	0.746	-0.493	-0.322	0.610	-0.359	-0.588	-0.712	-0.276	-0.324
isoc_r_blt12_i_IBUMT12	0.400	0.466	0.412	-0.411	-0.480	0.345	-0.320	0.029	-0.456	0.158	0.049	-0.538	0.062	0.338	0.432	-0.068	0.026
isoc_r_blt12_i_IBUMT12X	0.494	0.621	0.536	-0.544	-0.574	0.519	-0.135	0.511	-0.708	0.516	0.373	-0.505	0.385	0.554	0.665	0.319	0.351
isoc_r_blt12_i_IBPG_EU	-0.195	-0.335	-0.240	0.497	0.446	-0.336	0.317	-0.121	0.462	-0.262	-0.157	0.613	-0.260	-0.437	-0.348	-0.074	-0.236

	Disposable income per capita	Potential market size expressed in GDP	Potential market size expressed in population	Households with broadband access (%)	Individuals buying over internet the last year	Enterprises having received orders online (at least 1 %)	Enterprises with fixed broadband access.	Access to high-speed broadband	Individuals with above-basic overall digital skills	Employment (K-N sectors)	Gross value added (GVA) (K-N sectors)	Innovative SMEs collaborating with others	Marketing or organisational innovators
isoc_r_iacc_h	0.481	0.357	0.317	0.797	0.519	0.371	0.458	0.475	0.509	0.488	0.276	0.198	0.054
isoc_r_broad_h	0.374	0.389	0.370	0.916	0.404	0.419	0.476	0.474	0.525	0.417	0.189	0.062	-0.066
isoc_r_iuse_i_j_IUSE	0.625	0.387	0.312	0.659	0.737	0.589	0.516	0.551	0.734	0.600	0.358	0.412	0.260
isoc_r_iuse_i_j_IDAY	0.575	0.409	0.342	0.636	0.603	0.560	0.445	0.505	0.670	0.588	0.391	0.287	0.228
isoc_r_iuse_i_j_IUSNET	-0.094	0.024	-0.003	0.418	0.136	0.482	-0.079	0.241	0.233	-0.091	-0.166	0.058	-0.202
isoc_r_iuse_i_j_IUBK	0.531	0.284	0.218	0.561	0.828	0.645	0.815	0.327	0.783	0.551	0.263	0.585	0.433
isoc_r_iuse_i_j_IUSELL	0.479	0.349	0.311	0.372	0.712	0.372	0.579	0.282	0.697	0.581	0.273	0.445	0.301
isoc_r_iuse_i_j_IU3	0.647	0.370	0.296	0.651	0.714	0.605	0.539	0.504	0.746	0.580	0.351	0.452	0.290
isoc_r_iuse_i_j_ILT12	0.641	0.376	0.304	0.641	0.713	0.582	0.482	0.529	0.724	0.578	0.348	0.432	0.243
isoc_r_iuse_i_j_IUX	-0.668	-0.387	-0.318	-0.587	-0.701	-0.546	-0.500	-0.499	-0.700	-0.608	-0.394	-0.428	-0.262
isoc_r_gov_i_j_IUGOV12	0.269	0.207	0.147	0.555	0.841	0.531	0.629	0.550	0.685	0.387	0.065	0.448	0.201
isoc_r_gov_i_j_IUGOV12RT	0.171	0.188	0.135	0.497	0.740	0.361	0.593	0.547	0.570	0.376	0.066	0.391	0.158
isoc_r_blt12_i_IBUY3	0.597	0.399	0.328	0.457	0.942	0.608	0.620	0.364	0.807	0.586	0.258	0.540	0.365
isoc_r_blt12_i_IB3_12	-0.357	-0.221	-0.178	-0.146	-0.460	-0.410	-0.478	-0.096	-0.468	-0.331	-0.187	-0.291	-0.404
isoc_r_blt12_i_IBLT12	0.585	0.397	0.327	0.482	0.951	0.584	0.579	0.390	0.795	0.579	0.244	0.538	0.308
isoc_r_blt12_i_IBUMT12	-0.542	-0.316	-0.271	-0.204	-0.603	-0.438	-0.591	-0.168	-0.576	-0.520	-0.340	-0.412	-0.505
isoc_r_blt12_i_IBUMT12X	-0.468	-0.334	-0.273	-0.329	-0.922	-0.514	-0.534	-0.273	-0.718	-0.484	-0.150	-0.506	-0.287
isoc_r_blt12_i_IBPG_EU	0.536	0.301	0.220	0.317	0.539	0.484	0.540	0.126	0.518	0.564	0.439	0.654	0.541

	Total patent applications	Core creative class employment	Knowledge workers	Scientific publications	Total intramural research and development expenditure	Human Resources in Science and Technology	Employment in technology and knowledge-intensive sectors	Trademark applications	Design applications	Sales of new-to-market and new-to-firms innovation
isoc_r_iacc_h	0.338	0.510	0.474	0.371	0.309	0.532	0.370	0.406	0.270	0.115
isoc_r_broad_h	0.290	0.414	0.290	0.314	0.132	0.430	0.317	0.413	0.188	0.150
isoc_r_iuse_i_j_IUSE	0.423	0.648	0.602	0.436	0.472	0.660	0.434	0.398	0.137	0.177
isoc_r_iuse_i_j_IDAY	0.425	0.636	0.556	0.502	0.402	0.565	0.485	0.450	0.149	0.233
isoc_r_iuse_i_j_IUSNET	0.139	0.261	0.118	0.246	-0.026	0.067	0.241	0.191	-0.021	-0.191
isoc_r_iuse_i_j_IUBK	0.371	0.597	0.620	0.359	0.459	0.685	0.342	0.377	0.208	0.322
isoc_r_iuse_i_j_IUSELL	0.357	0.494	0.553	0.263	0.437	0.510	0.266	0.242	0.146	0.303
isoc_r_iuse_i_j_IU3	0.438	0.631	0.593	0.432	0.500	0.637	0.415	0.435	0.180	0.187
isoc_r_iuse_i_j_ILT12	0.434	0.640	0.604	0.433	0.491	0.643	0.423	0.423	0.194	0.150
isoc_r_iuse_i_j_IUX	-0.443	-0.640	-0.623	-0.427	-0.503	-0.643	-0.416	-0.412	-0.228	-0.209
isoc_r_gov_i_j_IUGOV12	0.220	0.490	0.474	0.152	0.247	0.629	0.309	0.058	-0.042	-0.123
isoc_r_gov_i_j_IUGOV12RT	0.144	0.422	0.413	0.103	0.184	0.563	0.258	-0.015	-0.106	-0.101
isoc_r_blt12_i_IBUY3	0.438	0.652	0.719	0.367	0.538	0.696	0.414	0.263	0.190	0.177
isoc_r_blt12_i_IB3_12	-0.207	-0.239	-0.288	-0.144	-0.213	-0.301	-0.168	-0.138	-0.046	-0.294
isoc_r_blt12_i_IBLT12	0.444	0.682	0.746	0.379	0.557	0.713	0.430	0.263	0.204	0.124
isoc_r_blt12_i_IBUMT12	-0.302	-0.409	-0.476	-0.354	-0.420	-0.503	-0.251	-0.311	-0.170	-0.346
isoc_r_blt12_i_IBUMT12X	-0.389	-0.608	-0.707	-0.302	-0.508	-0.641	-0.369	-0.153	-0.179	-0.087
isoc_r_blt12_i_IBPG_EU	0.386	0.426	0.466	0.269	0.391	0.558	0.423	0.407	0.165	0.394

Annex 4: Contagion index competitiveness variables

In the following annex we can find Moran's I and Geary's C for the variables comprising the Regional Competitiveness Index

Table 8: Contagion competitiveness variables

	Moran's I*	Geary's C*
Corruption	0.838	0.146
Quality and accountability	0.854	0.158
Impartiality	0.825	0.162
Individuals who used the internet for interaction with public authorities	0.835	0.192
Presence of corruption in the national public institutions in the country	0.876	0.113
Presence of corruption in the local or regional public institutions in the country	0.860	0.119
Ease of doing business	0.828	0.118
Property rights	0.855	0.178
Intellectual property protection	0.880	0.150
Efficiency of legal framework in settling disputes	0.802	0.193
Efficiency of legal framework in challenging regulations	0.894	0.138
Organised crime	0.781	0.194
Reliability of police services	0.752	0.232
Judicial independence	0.876	0.168
General government deficit/surplus	0.842	0.162
National savings	0.899	0.111
Government bond yields	0.832	0.222
Government debt	0.812	0.142
Net international investment position	0.860	0.092
Road transport performance	0.676	0.348
Rail transport performance	0.315	0.670
Accessibility to passenger flights	0.735	0.311
Road fatalities	0.459	0.530
Healthy life expectancy	0.863	0.136
Child mortality	0.676	0.284
Cancer disease death rate (x1000)	0.843	0.174
Heart disease death rate (x1000)	0.952	0.117
Suicide death rate	0.648	0.376
Low achievement in reading (15-year-olds)	0.860	0.115
Low achievement in math (15-year-olds)	0.913	0.096
Low achievement in science (15-year-olds)	0.902	0.111
Higher educational attainment	0.541	0.416
Lifelong learning	0.900	0.134
Early school leavers	0.411	0.378
University accessibility	0.348	0.561
Lower-secondary completion only	0.676	0.144
Employment rate (excluding agriculture)	0.633	0.259
Long-term unemployment	0.400	0.264

Unemployment rate	0.442	0.284
Labor productivity	0.696	0.317
Gender balance unemployment	0.458	0.410
Gender balance employment	0.663	0.338
NEET rate	0.619	0.277
Labor market slack	0.597	0.214
Temporary employment	0.701	0.153
Disposable income per capita	0.733	0.290
Potential market size expressed in GDP	0.635	0.359
Potential market size expressed in population	0.658	0.331
Households with broadband access (%)	0.542	0.328
Individuals buying over internet the last year	0.860	0.129
Enterprises having received orders online (at least 1\%a0%)	0.824	0.198
Enterprises with fixed broadband access.	0.955	0.072
Access to high-speed broadband	0.598	0.359
Individuals with above-basic overall digital skills	0.902	0.119
Employment (K-N sectors)	0.570	0.428
Gross value added (GVA) (K-N sectors)	0.407	0.598
Innovative SMEs collaborating with others	0.597	0.358
Marketing or organizational innovators	0.698	0.295
Total patent applications	0.248**	0.696**
Core creative class employment	0.483	0.470
Knowledge workers	0.579	0.363
Scientific publications	0.151***	0.797
Total intramural research and development expenditure	0.414	0.594
Human Resources in Science and Technology	0.519	0.438
Employment in technology and knowledge-intensive sectors	0.218	0.710
Trademark applications	0.398	0.518
Design applications	0.389	0.573
Sales of new-to-market and new-to-firms innovation	0.675	0.323

*p < 0.001; **p<0.002; ***p<0.003