CORRELATION BETWEEN EUROPEAN SMART CITIES AND REGIONAL COMPETITIVENESS

Nick G.A.
Doctoral School of Regional Economics and Business Administration Széchenyi István University - Győr, Hungary
nick.gabor@sze.hu

Abstract: *The Hannover Fair of 2011 opened a new era in the German industry: this is when Industrie 4.0, was first published. The series of innovations and developments in information and communication technology, which in turn affects the economic players, thus influencing regional competitiveness. Industrie 4.0 is an imagined future, which in my opinion if a direct or indirect was will have a fundamental influence on smart cities and their environments and regions, given that their primary goal is improving the competitiveness of a country. In the thesis I will provide an overview of the Global Competitiveness Index of the World Economic Forum and the Technisches Universität Wien's criteria for smart towns. I will establish a statistical correlation between the towns and their countries listed in the two rankings. I will point out how dominant the innovations affecting competitiveness are in these countries and how these may facilitate the implementability of Industrie 4.0. Finally, using cluster analysis I will take a look at the factors that contribute to the cities relative competitiveness.*

Keywords: SMART CITY, INDUSTRY 4.0, COMPETITIVENESS, RANKING

1. Introduction

The industry of 21st century Europe faces significant challenges. The ever-decreasing raw material supply, the rising energy prices and the demographic changes necessitate the modification of the existing model. The intensifying competition, which is mostly driven by the increasing productivity of the Asian industry and innovation makes it clear that the production industry needs solutions with which they can efficiently respond to challenges[1]. The following factors in my opinion post a challenge to the industry of the 21st century[2]:

- Global competition
- Market volatility
- Customized products
- Time-to-market and delivery performance (speed)
- The sustainability of the full life cycle of products
- Productivity (resource-efficiency, value orientation)
- Shortage of skilled labour

The manufacturing and production systems have been gradually complemented with information technology support tools in recent decades, as increasingly complex technological solutions, production in often multiple locations and the coordination of supporting logistics processes started to pose a more and more complex challenge. Accordingly, 90% of all production processes are now supported by IT tools. The increasingly dominant and pivotal role of IT in companies have changed lifestyles and working environments, the significance of which is unquestionable.

Miniaturization and the development of communication technologies enables the blending of the physical and virtual world and gives way to the so-called CPS – Cyber-Physical System. Industrial production becomes integratable into an intelligent environment that is referred to in reference literature as smart factory. Based on this technological evolution, Germany announced the arrival of Industrie 4.0, also called the fourth industrial revolution.

The year 2000 meant a paradigm shift insofar as half the world's population was living in cities by then. In our global world, cities have an intense role in shaping the economy, culture and society. Cities are structured into network systems and share functional roles[3]. The previously hierarchical relationship structure is replaced by horizontal integration. Earlier, urban concentration would have been justified by the codependent relationship between corporations and technologies, which by now have been replaced by economic benefits derived from a common milieu and common interest in innovation and the exploitation of shared knowledge. Sustainability and enhanced competitiveness has become a dominant priority of cities. They must, therefore, develop long-term strategies that provide for liveable, environmentally conscious spaces for regional economic players and local residents alike[1].

Smart city ranking

A leading scientific center in the research into smart cities is the technical University of Vienna (Technisches Universität Wien, TUW)[4] where the Smart City Ranking (SCR, TUW SCR), a kind of competitiveness, "smartness" index of European cities derived from a system of indicators chosen by the researchers is regularly published. Six basic characteristics are identified in their research (figure 1)[5]

- smart economy
- smart governance
- smart people
- smart mobility
- smart environment
- smart living,

which are weighted and represent the current and relative ranking among the cities involved, taking into account the criteria of smart cities.

Varying numbers of towns are chosen from different European countries, but they basically have to meet the following criteria in order to be considered for the annual assessment:

- The city's population must be between 100 and 500 thousand
- 80% of the data pertaining to the indicators must be available
- The city must be included in the Eurostat Urban Audit database

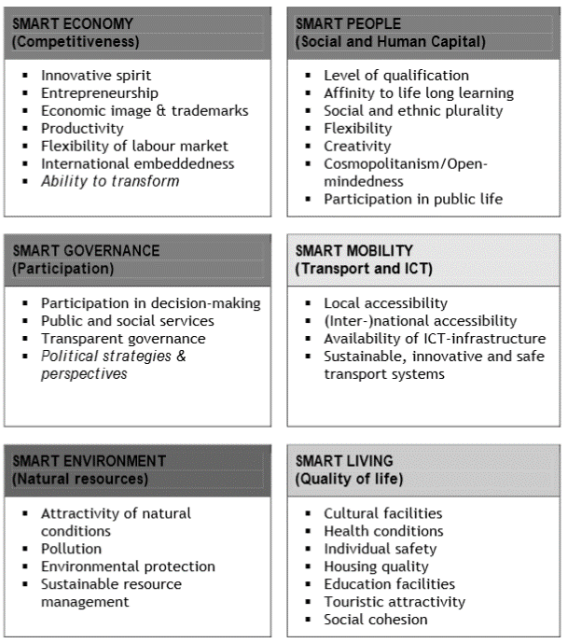

Figure 1: *The characteristics of the smart city index*[5]

Factors are assigned to the characteristics, data for which is derived from indicators. For example, within the Smart economy characteristic (competitiveness), which is of interest to this paper, we can find the Innovative will factor, which comes from three NUTS2 indicators:

- R&D expenditure in % of GDP
- Employment rate in knowledge-intensive sectors
- Patent applications per inhabitant

1.2. Global competitiveness index

The relevant annual publication of the World Economic Forum (WEF), The Global Competitiveness Report[6] is a macro level competitiveness index of great significance.

The document provides a detailed description of the structure, the calculation method, the input data and the resulting competitiveness ranking of the Global Competitiveness Index (WEF GCI). The competitiveness index defines 15 so-called pillars (figure 2)[7], which provide the final ranking of the countries derived from 300 indicators.

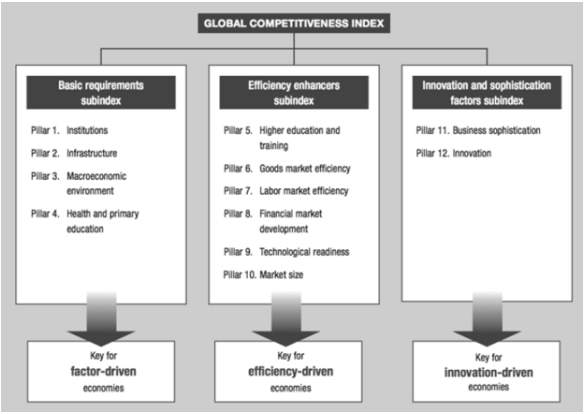

Figure 2: *The pillars of the Global Competitiveness Index*[6]

2. Hypotheses

Although the series of innovations, the developments in Information and Communication Technology (ICT) and Cyber-physical systems (CPS), i.e. Industrie 4.0 primary concern the industry, its effects can be felt, similarly to previous industrial revolutions, on cities, regions and their competitiveness, i.e. their competition. In order to measure competitiveness in a comparable way, it is important to use indicators. Given the numerous criteria, indicators and their weighted values, several existing best practices may be applied in the evaluation of a given territory. In my opinion, Pearson's correlation coefficient known from statistics can provide relevant information with respect to certain competitiveness ratings both in the comparison of factors influencing competitiveness ranking and the comparison of certain rankings, which is why I will apply it for proving the following hypothesis.

- Competitive countries and cities are the most conducive to introducing innovative solutions.
- There is a positive correlation between the rankings of smart cities and competitive countries.
- Innovative indicators have a fundamental influence on the rankings of smart cities and competitive countries. There is a high and positive correlation between ranking and innovation.

3. Analysing and interpreting findings

My calculations were conducted with the help of IBM SPSS, the data for which were based on:

- the EUStat database
- the Smart City Ranking model of the Technical University of Vienna
- the Global Competitiveness Index of the World Economic Forum
- my own derivations.

My research was conducted on the basis of the 2013 World Economic Forum Report on cities and towns included in the Smart Cities ranking of the Technisches Universität Wien of the same year, i.e. 71 cities from 24 countries[5].

The most countries, 7 respectively, are from Germany and Italy, each country thus representing 9.9% of the total. Other dominant countries with 6-4 cities in the ranking include Poland, France, Austria, the Netherlands and the UK. Ireland, Latvia, Lithuania, Luxembourg and Portugal are each represented by 1 city.

The World Economic Forum established the following ranking among the countries included in my research. Based on the 2013 index, Finland is ranked third, Germany fourth and Sweden sixth (table 1).

Table 1: *WEF GCI 2013*[6]

Country	The ranking	Value
Finland	3	5,54
Germany	4	5,51
Sweden	6	5,48
Netherlands	8	5,42
United Kingdom	10	5,37
Denmark	15	5,18
Austria	16	5,15
Belgium	17	5,13
Luxembourg	22	5,09
France	23	5,05
Ireland	28	4,92
Spain	35	4,57
Poland	42	4,46
Czech Republic	46	4,43
Lithuania	48	4,41
Italy	49	4,41
Portugal	51	4,40
Latvia	52	4,40
Bulgaria	57	4,31
Slovenia	62	4,25
Hungary	63	4,25
Romania	76	4,13
Slovakia	78	4,10
Greece	91	3,93

It can be established based on the competitiveness values of the individual countries (table 2) that the highest value is 5.538 (Finland), while the lowest is 3.928 (Greece), accounting for a median value of 4.515. Given the low value range of 1,61, the standard deviation of 0.518 and the 0.268 variance, the values are very close together.

Table 2: *WEG GCI statistical analysis, own compilation*

Mean		4,7
Std. Error of Mean		0,1
Median		4,5
Std. Deviation		0,5
Variance		0,2
Range		1,6
Minimum		3,9
Maximum		5,5
Percentiles	25	4,3
	50	4,5
	75	5,1

The competitiveness ranking is a cumulative value, which is derived from several pillars. Since the innovative value is the most of interest to this paper, I will look at what kind of correlation can be established from the model between the competitiveness ranking of the individual countries and the raking within the pillar 12, *Innovation*.

Competitiveness and Innovation ranking of countries: innovation ranking, global competitiveness ranking

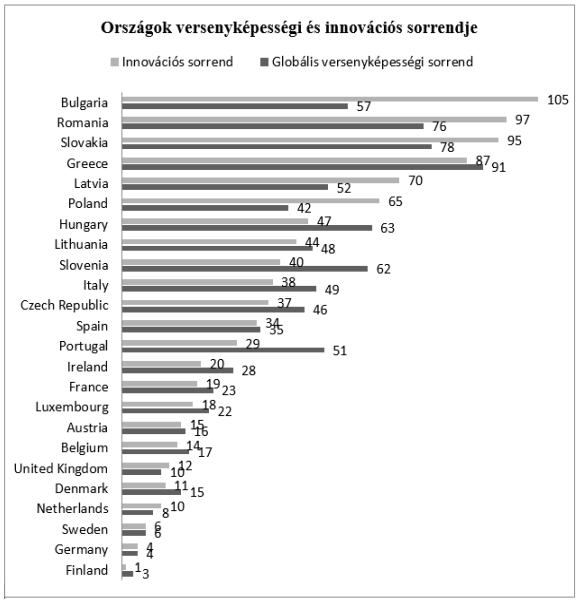

Figure 3: *WEF GCI and Innovation 2013*[6]

As we can see from the graph (figure 3), *Innovation rankings* and total *Competitiveness rankings* (WEF GCI) correlate with each other and a high ranking in innovation is associated with a high ranking in competitiveness. Statistical analysis of the two rankings (table 3) establish a significant correlation. Their Pearson's coefficient is 0.894, which is high (given that it is between 0.7 and 1.0). They show a positive correlation, which means that if a country ranks among the top in innovation, its competitiveness is also high. For example, while Finland ranks first in the *Innovation pillar*, they come third in the total *Competitiveness index*. Hungary ranks 47th in innovation and 63rd in competitiveness. I.e., based on the innovation pillar of the competitiveness index, it can be established that Hungary shows stronger competitiveness traits in innovation than in total.

In order to further look into the influential role of innovation in the present model, let us take a look at how the ranking of different countries in the other pillars correlate with their total ranking.

In an effort to test my hypothesis, I explored the correlation between the total competitiveness ranking of each country and their ranking within the different pillars associated with the index, i.e. the connection, for example, between a country's ranking 10th in the WEF GCI and same country ranking 20th in the *Infrastructure* pillar.

Table 3 indicates that the most dominant element is *Institutions* (0.930), accounting for the highest correlation between the total WEC ranking and an individual indicator, while on the other end of the spectrum, *Macroeconomic environment* (0.381) and *Market size* (0.441) show a weak correlation**,** playing a less significant role in the index. The correlation coefficient for the pillar I wished to investigate and presented above, *Innovation*, is 0.894, which indicates a strong connection, meaning that the model also confirms the significant influence of innovation on a country's competitiveness.

Table 3: *Pearson correlations between WEF GCI pillars and WEF GCI — own compilation*

Competitiveness Pillars		Global Competitiveness Index
Institution	Pearson correlation	,930**
Infrastructure	Pearson correlation	,740**
Macroeconomic env.	Pearson correlation	,381**
Health and prim. edu.	Pearson correlation	,696**
Higher edu and training	Pearson correlation	,889**
Goods and market efficiency	Pearson correlation	,907**
Labor market efficiency	Pearson correlation	,733**
Financial market dev.	Pearson correlation	,683**
Technological readiness	Pearson correlation	,896**
Market size	Pearson correlation	,441**
Business sophistication	Pearson correlation	,886**
Innovation	Pearson correlation	,894**

**. Correlation is significant at the 0.01 level

If we illustrate the standardized values of the countries' competitiveness rankings (WEF GCI) and smart cities rankings (TUW SCR) in a coordinate system (figure 4), the correlation between the two values become visible. Statistically speaking, the significance of the correlation between the standardized rankings is 000., i.e. detectable, while the Pearson coefficient is 0.808, which indicates a positive relationship. The correlation is positive, i.e. the higher the competitiveness of a country, the better the chances that its cities will also rank higher among smart cities. The very smart cities of the highly competitive countries, such as Finland (FI), Germany (DE), Sweden (SE), can be found in the upper right quadrant of the figure. A striking finding is that the less competitive country of Slovenia (SI) also has a city listed among the very smart cities.

Standardized smart city ranking, standardized global competitiveness ranking

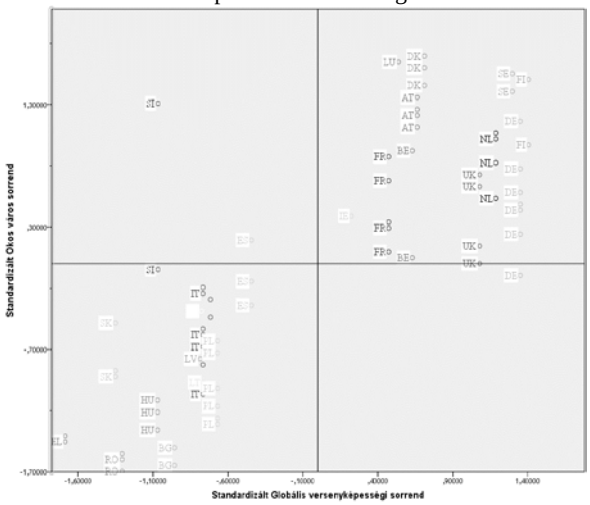

Figure 4: *Standardized country-city rankings — own compilation*

Although the Global Competitiveness Index, the Smart City ranking and regional rankings assess competitiveness on different levels, it is important to investigate the connection among these rankings in order to confirm or refute my hypotheses.

A strong positive correlation can be established (table 4) both the Global Competitiveness Index and the Smart City ranking (0.794), the Global Competitiveness Index and the NUTS2 competitiveness ranking (0.842) as well as NUTS2 competitiveness and the Smart City rankings (0.829), which confirms my hypothesis that Smart Cities are located in a regional (mezzo) and a national (macro) competitive space.

Table 4: *Correlations between Competitiveness rankings — own compilation*

		Global Competitiveness Index	Smart City ranking	NUTS2 Competitiveness Index
Global Competitiveness Index	Pearson correlation	1	,794**	,842**
Smart City ranking	Pearson correlation	,794**	1	,829**
NUTS2 Competitiveness Index	Pearson correlation	,842**	,829**	1

**. Correlation is significant at the 0.01 level

My mezzo level research established a positive, strong correlation between the NUTS2 level regional competitiveness ranking (NUTS2 RCI) and certain factors of smart cities (table 5).

Table 5: *Pearson correlation coefficients between TUW SCR and NUTS2 RCI rankings — own compilation*

		NUTS2 Competitiveness Index
Economy	Pearson correlation	,860**
People	Pearson correlation	,805**
Governance	Pearson correlation	,566**
Mobility	Pearson correlation	,774**
Environment	Pearson correlation	,398**
Living	Pearson correlation	,688**

**. Correlation is significant at the 0.01 level

There is a significant, positive and strong correlation between the Smart City ranking (TUW SCR) and its internal factors (table 6). This connection is the strongest in the case of the *People* variable (0.938), while the weakest correlation (0.664) is accounted for by the *Environment* and *Life* variable. The *Economy* variable, which is important for my hypothesis, showed a strong correlation (0.845); it can thus be established that in the case of smart cities model, the indicator that also includes innovation has a strong influence on the ranking of the given town or city.

Table 6: *Pearson correlation coefficients between TWU SCR and its factors — own compilation*

		Smart City ranking
Economy	Pearson correlation	,845**
People	Pearson correlation	,938**
Governance	Pearson correlation	,735**
Mobility	Pearson correlation	,808**
Environment	Pearson correlation	,664**
Living	Pearson correlation	,664**

**. Correlation is significant at the 0.01 level

When investigating the correlation among the six factors determining the final smart cities ranking (TUW SCR) (table 7), I noticed that the *People* and the *Economy* variables show a very strong connection (0.822), compared to a lower than average correlation between *Mobility and the Environment* (0,380).

If we take a look at the indicator components behind the factors presented earlier (figure 1), we can see that while *Training, Education and Creativity* as human capital show a strong correlation to competitiveness factors, such as *Innovation, Entrepreneurial spirit and Productivity*, the same cannot be said for *ICT development, International access and Attractive natural environment*.

The correlation between the other variable pairs is relatively strong, ranging between 0.749 and 0.437. Overall, all correlations are positive and significant.

Table 7: *Pearson correlation coefficients between TUW SCR factors — own compilation*

		Economy	People	Governance	Mobility	Environment	Living
Economy	Pearson correlation	1	,822**	,462**	,749**	,437**	,665
People	Pearson correlation	,822**	1	,703**	,738**	,665**	,643**
Governance	Pearson correlation	,462**	,703**	1	,485**	,511**	,549**
Mobility	Pearson correlation	,749**	,738**	,485**	1	,380**	,622**
Environment	Pearson correlation	,437**	,665**	,511**	,380**	1	,486
Living	Pearson correlation	,665**	,643**	,549**	,622**	,486	1

**. Correlation is significant at the 0.01 level

Using the characteristics ranking of smart cities and the Two-step clustering method, I created clusters from the cities that were part of my research. The advantage of the applied method is that it standardizes the entered — in this case 6 — variables (*Economy, People, Government, Mobility, Environment, Living*) and automatically offers an optimal cluster number. The cluster analysis resulted in 5 separate groups of cities based on the ranking among city characteristics. My goal was to understand as deeply as possible the correlations between the variables determining the rankings of cities and identify possible trends.

The different variables can be prioritized and they have varying degrees of significance in the establishment of clusters. The investigated variables in the order of significance in the cluster creation are the following: *People* and *Economy* are the two variables that play the most dominant role in cluster creation. These two are followed by *Governance, Mobility and Environment,* while *Living* played the least significant role in cluster creation.

The first and largest cluster in terms of multiplicity accounts for 39.4% of the total item number, the second 15,5%, the third 8.5%, the fourth 19.7% and the fifth 16.9%. Each cluster can be viewed (figure 5) in terms of where the individual variables are compared to the averages of all items. This way we can distinguish variable with above average, average and below average values within the cluster.

I named the clusters after their typical characteristics so I can assess, taken all variables into account, where the values of a given cluster are and which clusters have a higher or lower position compared to the other groups. For future reference I named the clusters after their typical characteristics.

The first, *Leading* includes cities that also ranked the highest in total in the TUW SCR ranking. The *Economy*, *People* and *Mobility* variables are dominant and above average. Due to the high standard deviation of the values, the cluster center of the *Governance* variable is close to the average, but never goes below. The values of the *Environment* and *Living* variables show a wide range.

After the overview of the list of cities (AARHUS, LUXEMBOURG, AALBORG, UMEAA, TAMPERE, ODENSE, JOENKOEPING SALZBURG, LJUBLJANA, LINZ, INNSBRUCK, REGENSBURG, GRAZ, EINDHOVEN, GRONINGEN, OULU, GENT, NIJMEGEN, GOETTINGEN, CARDIFF, ERFURT, ENSCHEDE, TRIER, KIEL, CORK, PORTSMOUTH, LEICESTER) it can be clearly seen that, with the exception of Ljubljana in Slovenia, this list consists of Western European and Scandinavian cities. Ljubljana ranks very high in *Economy* (4) and *Living* (3). The NUTS2 regions of the cluster have a high GDP the and employment rate of over 75%.

The cities in the second, *Pathfinder* cluster rank below average in every variable in terms of their cluster center. This is especially true for the collectively low *Governance* variable value, which means non-transparent governance, a lack of political strategy and future vision, as well as low quality social and public services. Looking at the *Environment* variable I can conclude that is also not in the center of focus. The cities in this cluster are: VENEZIA, VERONA, PLZEN, OVIEDO, USTI NAD LABEM, TRENTO, TRIESTE, PERUGIA, LIEPAJA, PADOVA, KAUNAS.

The third, *Natural* cluster typically includes Greek and Slovakian cities. This is the group with the fewest items, 6: BANSKA BYSTRICA, KOSICE, NITRA, ANCONA, LARISA, PATRAI. These cities rank very high in terms of the *Environment* variable, while the values of all other variables are below average. Employment rate in the region is 63%, accompanied by modest GDP production. Research and development spending is less than 60% of GDP.

The fourth, *Lagging* cluster includes all Hungarian cities of the survey and most of the towns of the Eastern-European region: RZESZOW, SZCZECIN, BYDGOSZCZ, GYOR, BIALYSTOK, PECS, KIELCE, SUWALKI, MISKOLC, RUSE, SIBIU, TIMISOARA, PLEVEN, CRAIOVA. All values are below average. It is interesting to note that the *Governance* variable produced that highest during the study. These cities are characterized by low GDP and about 60% employment rate.

The fifth, *Conservative* cluster includes Western cities that did not quality for the *Leading* cluster: MONTPELLIER, NANCY, CLERMONT-FERRAND, POITIERS, ROSTOCK, PAMPLONA, DIJON, BRUGGE, MARIBOR, MAGDEBURG, VALLADOLID, COIMBRA. This cluster also includes a Slovenian city, Maribor, which ranks in the prestigious 16th position in both *Environment* and People. A typical characteristic of the cluster is the high number of patent submissions.

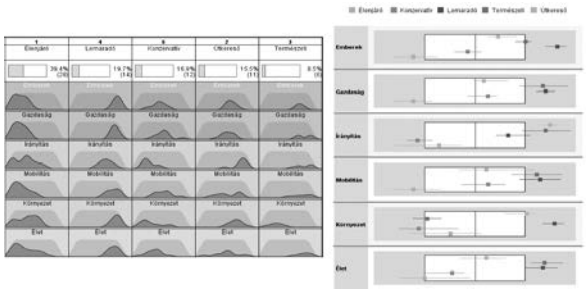

Figure 5*: City clusters — own compilation*

The cluster analysis resulted in 5 separate clusters, but if we merge the *Leading* and the *Conservative* cluster on the one side and the *Pathfinder, Natural and Lagging clusters*, we can see a clearly divided Western and Eastern Europe.

Based on the competitiveness index illustrated on a map (figure 6) – in both cases a darker colour means a higher ranking – the thesis statement of the hypothesis is confirmed by the correlation analysis, i.e. smarter cities can be found in more competitive countries.

Figure 6: *WEF GCI and TUW SCR EU on map* [5, 6]

4. Conclusion

The conducted correlation calculations proved my hypothesis that there is a positive correlation between the smart cities and competitive countries rankings.

I was also abele to establish innovation indicators have a fundamental influence on the rankings of smart cities and competitive countries. In addition, the correlation between ranking and innovation is positive and strong.

The cluster analysis made it possible to identify the criteria, such as economic performance, innovation, education level and flexibility of the inhabitants, which contribute to the competition between cities. It was interesting and surprising to see that the boundaries between the West and the East are still significant decades after the fall of communism. The investigation of the reasons behind this boundary might be the continuation of the research started with the present paper.

In the future I wish to interpret the relevance of the NUTS2 and NUTS3 statistical data in the ranking of smart cities.

In addition, it might be a good idea to include the competitiveness rankings of larger cities (with 500.000-1.000.000 inhabitants) in further research.

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